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Opening Remarks

53rd Gulf and Caribbean Fisheries Meeting
November 6 - 10, 2000
Biloxi, Mississippi USA

Bob Glazer, Chairman

These are exciting times for the GCFI! Look around and you will see representatives of new countries and regions, new faces, new organizations. It is by design that we now have this wider membership - in fact, this is the first time GCFI has ventured into the northern Gulf of Mexico for an annual meeting. And with the wider membership comes more widely diverse interests. Ultimately, we all benefit because the wise management and conservation of our marine resources requires the exchange of ideas and information from widely diverse interests. Recently for example, the GCFI has targeted for greater participation the non-profit conservation community; we now have several representatives of that sector on the Board of Directors.

Much has changed over the last year. GCFI has as its core mission facilitating the dissemination of information among those who use and manage the marine resources in the region. It is with this in mind that we focused our efforts. First, we implemented the GCFINET listserver through the generous support of Dr. Bob Ditton at Texas A&M University. This initiative has brought real and obvious benefits to the membership - we now have a way of dispensing information in real time. Not only can we exchange information and ask questions about our own interests, we can now also quickly relay information about important environmental events that need the timely response of experts. You will also see information about upcoming meetings and symposia on the listserver.

Secondly, we implemented the gcfi.org website. At this site, there is information about upcoming meetings, regional news, abstracts from the recent meetings, a bulletin board where individuals can exchange ideas, and much more.

But the electronic medium is not the only way we have chosen to enhance our services. We have also expanded the scope of the annual meeting. We now have a dedicated poster sessions special awards are offered for the best presentation by a student, and special topical sessions are now an integral part of the program. In fact, next year in the Turks and Caicos, we will be hosting a special symposium on Marine Protected Areas emphasizing socio-economic and scientific issues. We will invite participants who are the very best in the field to present case studies from throughout the region and who will present the results of their research. We will also publish a special publication on the technical papers from the symposium that will be distributed at no additional cost to the GCFI members.

We are committed to continue to expand the membership, offer even more services, and develop strategic partnerships with regional organizations. However, we can not do this alone. GCFI has no paid staff; we are all volunteers. Therefore, we ask each member to help in whatever way you can. Tell us what you like. Just as importantly, tell us what we need to improve. Let us know of opportunities that may help further our mission. Help develop partnerships. Many of us remember

when we were much smaller and the intimacy that was fostered then. It is undeniable that we've grown in the last several years; however, I would like to think we have not lost that sense of community. That is still what makes GCFI unique. It is through this sense of GCFI community that we will continue to further our mission and move forward into the next century.

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Sources, Distribution, and Conveyance of Opportunistic Pathogens in Estuaries and the Oceans

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ABSTRACT

In 1981, water samples collected from 14 stations distributed along a track-line from Barbados to Bermuda revealed a preponderance of bacteria belonging to the genus *Vibrio* (Grimes et al. 1984a). Ten years earlier, using the same experimental design along the same approximate track-line, Sieburth (1971) had reported that nearly 100% of the culturable bacterial isolates belonged to the genus *Pseudomonas*. Explanations offered for this apparent shift in the dominance of culturable bacteria included chronic pollution of the ocean with anthropogenic hydrocarbons, resulting in the selection of hydrocarbon-degrading vibrios (Grimes et al. 1984a). It is well known that some species *Vibrio* cause a variety of diseases in marine fishes, marine invertebrates, and humans. *Vibrio* species are also autochthonous inhabitants of estuaries and the oceans, and they possess an array of degradative enzymes that allow them to metabolize compounds ranging from chitin and squalene to short chain fatty acids and polyaromatic hydrocarbons. Clearly, the vibrios possess an impressive set of habitat-adaptive enzymes, and this general adaptation was recently confirmed for one species by the completion of the genomic sequence of *V. cholerae* (Heidelberg et al. 2000). In 1997 and 1998, the largest outbreaks of human disease ever caused by *V. parahaemolyticus* in North America occurred from the consumption of contaminated oysters. Interestingly, these years were also years of increased sea surface temperature associated with the El Niño Southern Oscillation, and *V. parahaemolyticus* grows best under mesophilic conditions. The focus of this paper will be the niches that are filled by members of the bacterial genus *Vibrio* that are capable of degrading anthropogenic compounds, responding to global climate change, and infecting and causing disease in vertebrate and invertebrate hosts.

KEY WORDS: Autochthonous, allochthonous, anthropogenic chemicals, nutrients, pathogens, opportunistic, *Vibrio*, ENSO, currents, degradation

INTRODUCTION

Recent literature abounds with reports of marine diseases affecting marine organisms and humans (Grimes 1991, Harvell et al. 1999, DePaola et al. 2000). After a thorough review of the literature on this matter, Harvell et al. (1999) concluded that reports of diseases in the oceans are on the rise. They noted that there have been many epidemics affecting economically and ecologically important species, and that unknown species may be disappearing without notice. They went

on to note that most "new" diseases occur by host shifts and not by the emergence of "new" microorganisms. Clearly, pathogens have always existed in estuaries and the oceans and they continue to plague humans and the living resources available to humans for sustainable use.

SOURCES AND DISTRIBUTION

Opportunistic pathogens are organisms that do not normally cause disease in a host unless that host has been in some way compromised. There are many such pathogens living in oceans (Grimes et al. 1986) and estuaries (Grimes 1991), some of which normally reside in those habitats and some of which are transients. The indigenous pathogens are referred to as autochthonous by ecologists and their physiology is ideally suited to survival and life in estuaries and the oceans. Unfortunately, there are also mechanisms of attachment and growth that allow these microorganisms to infect susceptible hosts and therein cause disease. Some of the better known examples of autochthonous opportunistic pathogens are listed in Table 1. The non-indigenous pathogens are transients that gain entrance to oceans and estuaries through some point or non-point source of pollution, and they do not usually survive well in these saline aquatic environments. Ecologists refer to non-indigenous microorganisms as allochthonous, and the better known examples of allochthonous opportunists are listed in Table 2.

Table 1. Genera containing opportunistic pathogens autochthonous to estuaries and oceans*

Known autochthonous bacteria	Possibly allochthonous
*Vibrio**	*Staphylococcus*
*Aeromonas**	*Clostridium*
Renibacterium	*Pseudomonas**
*Mycobacterium**	*Flavobacterium*
Plesiomonas	*Klebsiella**
	Acinetobacter
	*Legionella**

*Some members of the genus have demonstrated ability to become nonculturable in response to stress

An important survival mechanism that allows both autochthonous and allochthonous microorganisms to exist in spite of environmental stress was first described by Xu et al. (1982) for *Vibrio cholerae* and *Escherichia coli* - good examples of an autochthonous opportunist and an allochthonous opportunist, respectively. Since that initial description, many laboratories throughout the world have observed the viable but nonculturable phenomenon for numerous pathogens and non-pathogens alike. The essence of this mechanism is illustrated in the survival

curves shown in Figure 1. Briefly, when stressed by a physical or chemical factor (e.g., loss of nutrients, adverse temperature, chlorine), microbes examined thus far respond to the stress by undergoing a series of structural and physiological changes that result in a dormant or "nonculturable" stage of growth. They tend to become smaller, less permeable, refractory to cultivation on culture media normally supportive of their vegetative growth, and some lose their flagella. Little is known about the mechanism or mechanisms that return normal vegetative growth, but it is clear that a susceptible host will suffice for many of the opportunistic pathogens when they are in a nonculturable state. Recently, Colwell and Grimes (2000) collected and published several reviews of this survival strategy that appears to play an important role in the conveyance of opportunistic pathogens in estuaries and oceans. The microorganisms listed in Tables 1 and 2 that have been shown to be capable of this survival strategy are so denoted.

Table 2. Genera containing opportunistic pathogens allochthonous to estuaries and oceans*

Known allochthonous bacteria	Possibly autochthonous
*Salmonella**	*Staphylococcus*
*Shigella**	*Clostridium*
Leptospira	*Pseudomonas**
*Escherichia**	*Flavobacterium*
*Campylobacter**	*Klebsiella**
*Enterococcus**	*Acinetobacter*
Morganella	*Legionella**
*Enterobacter**	
Listeria	

*Some members of the genus have demonstrated ability to become nonculturable in response to stress

Of all the known opportunistic pathogens in estuaries and oceans throughout the world, the *Vibrio* species generally predominate the culturable microbial community (Grimes et al. 1984a). This was an unexpected finding by Grimes et al. (1984a), because since the mid-1900s it was almost axiomatic that *Pseudomonas* species dominated the culturable bacterial communities of the world oceans (ZoBell and Upham 1944, Sieburth 1971). In 1981, water samples collected along a track-line from Barbados east into the Caribbean Sea and north through the Mona Passage to Bermuda demonstrated that vibrios had replaced pseudomonads (Grimes et al. 1984a). *Vibrio* species comprised up to 100% of the culturable community, followed by acinetobacters (Figure 2, Grimes et al. 1984a). Now, it is known that *Vibrio* species are ubiquitous in oceans and estuaries – throughout the water column, in bottom sediments, attached on marine plants and animals, and within marine animals. Their distribution and density are, ultimately, dependant upon known environmental limiting factors, including salinity (vibrios preferentially generate

energy by means of a Na-dependant ATP pump), temperature (vibrios are mesophiles), organic and inorganic nutrients (all vibrios are chemoheterotrophs, some can fix N, and most can use nitrate in anaerobic respiration), currents (bacteria are colloids that are easily conveyed by tides, currents, upwellings, and rings), and possibly light.

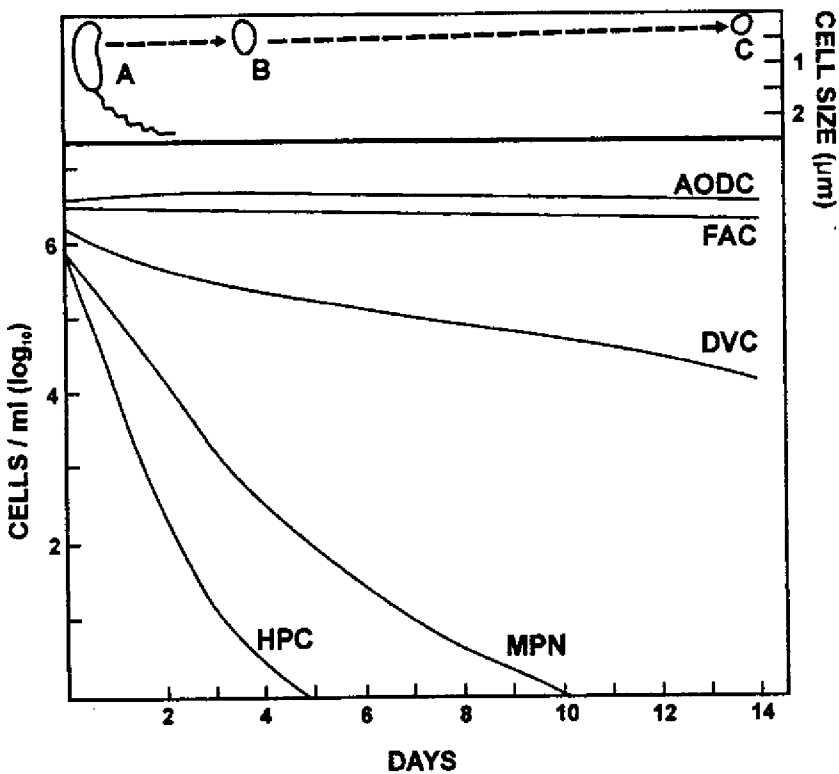


Figure 1. Survival curves and morphological changes typical of vibrios as they transition from vegetative growth into the viable but nonculturable stage of growth

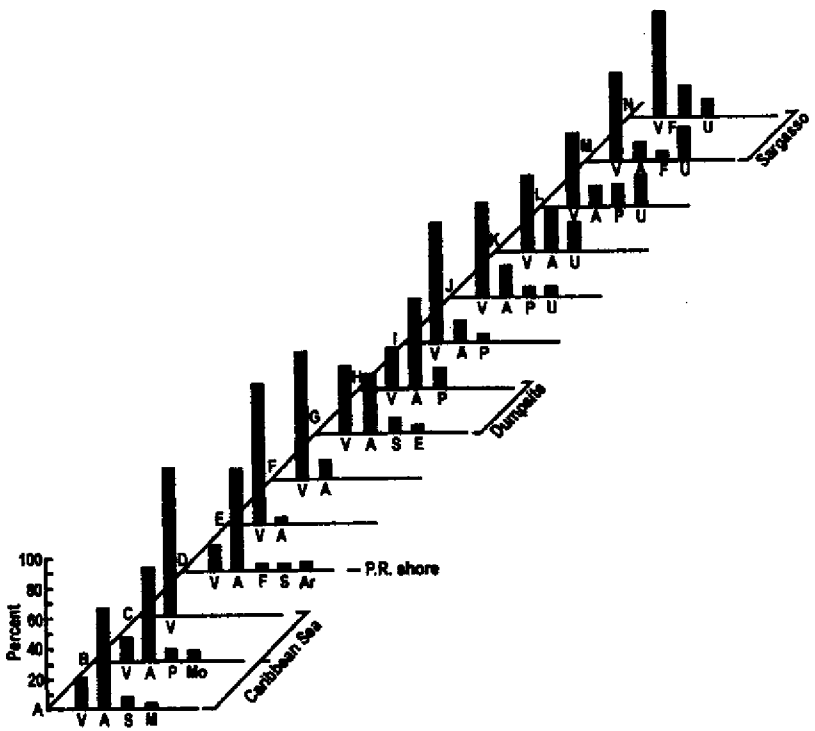


Figure 2. Distribution of culturable, heterotrophic bacteria in water samples collected at 14 stations along a track-line from Barbados, into the Caribbean Sea, and through Mona Passage into the Atlantic Ocean to Bermuda

Consistent with their ubiquitous distribution in oceans and estuaries, vibrios and acinetobacters are capable of metabolizing a wide variety of hydrocarbons. Short chain volatile fatty acids, alcohols, toluene, benzene, dimethylaniline, and polyaromatic hydrocarbons (PAHs) are all subject to biodegradation by vibrios and acinetobacters (Okpokwasili et al. 1986), and these hydrocarbons were characteristic of wastes being disposed of at the Puerto Rico dumpsite and of petroleum being transported from South America (Grimes et al. 1984a). Clearly, the vibrios are capable of metabolizing a wide variety of anthropogenic chemicals.

Vibrios are also capable of metabolizing a wide variety of biopolymers. Most can hydrolyze and utilize monomers from proteins, complex carbohydrates, and lipids. This ability not only confers metabolic versatility on the vibrios, but it also allows them to colonize and grow in a variety of animal hosts. They can hydrolyze the building blocks of connective and soft tissues; in other words, they can easily exploit the habitat provided by chance hosts and act as opportunistic pathogens. Table 3 illustrates the metabolic versatility of the vibrios, by listing some of the compounds that can be used by the shark pathogen *V. carchariae* (Grimes et al. 1984c, Grimes et al. 1989).

Table 3. Compounds metabolized by *Vibrio charchariae*, an opportunistic pathogen of sharks (Grimes et al. 1984c and 1989)

Lysine, ornithine, tryptophan, glycine	Starch, algin
Chitin, chondroitin, hyaluronic acid	Xanthine, salicin
Casein, gelatin, collagen	γ-aminobutyrate
Lecithin, squalene	α-ketoglutarate
Tweens 20, 40, 60, 80	Glucose, sucrose, mannose
Urea	Trehalose, arabinose, mannitol
Nitrate	Ethanol, 1-propanol

Clearly, the vibrios are elegantly equipped to quickly exploit a wide variety of potential nutrient sources - inputs and fluxes - in estuaries and oceans. The full extent of this capability was recently demonstrated for the type species of the genus, *V. chloerae*, by Heidelberg et al. (2000). The vibrios closely follow primary producer as well as primary consumer population increases, as they grow in response to fluxes in dissolved organic material and on living and dead zooplankton (Harvell et al. 1999, Kaneko and Colwell 1973). They respond to anthropogenic inputs (Grimes et al. 1984a) and to climate change (Lobitz et al. 2000). In every sense, they are "r-strategists" or copiotrophs, living off the "fat of the land" (Grimes 1991). Vibrios grow quickly in response to new sources of nutrients in natural aquatic habitats, they rapidly disseminate in compromised hosts, and they become dormant or nonculturable (Colwell and Grimes 2000) during famine or otherwise adverse environmental conditions.

CONVEYANCE

There is ample evidence that vibrios, like most marine bacteria, are conveyed throughout estuaries and oceans of the world by both natural and anthropogenic influences. Currents, tides, waves, gyres, and other natural water movements convey bacteria as they would any comparable sized particle. In 1984, it was hypothesized that pharmaceutical wastes released at a dumpsite north of Puerto Rico meandered throughout the Atlantic Ocean and, eventually, into the Caribbean Sea (Grimes et al. 1984a). In turn, it was further hypothesized that these wastes stimulated the growth of a community of vibrio bacteria in the affected waters. In a related study, it was shown that pharmaceutical wastes introduced into the ocean by means of a long sewage outfall also had an influence that was related to prevailing currents (Grimes et al. 1984b).

In 1997, consumption of raw oysters from the Pacific Northwest resulted in a major disease outbreak of *V. parahaemolyticus* that caused 210 cases, including one death from septicemia (CDCP 1998). The *V. parahaemolyticus* strains involved (O1, O4, and O5) were serogroups commonly found in the U.S., and there was reason to believe that their increased prevalence in oysters harvested from Pacific NW waters may have been associated with increased water temperatures caused by the El Niño Southern Oscillation. The following year, *V. parahaemolyticus* appeared again, this time predominantly in oysters harvested from Galveston Bay, Texas, and it exclusively involved an Asian serogroup (O3:K6) not reported from the U.S. since 1972 (DePaola et al. 2000). The 1998 "*Vp*"outbreak was the largest ever recorded in the U.S., involving over 500 individuals but no deaths. This time, there was reason to believe that the exotic "*Vp*" may have been introduced through ship ballast water.

CONCLUSIONS

It has been documented that a shift in the culturable community of heterotrophic bacteria in the Atlantic Ocean occurred sometime in the late 1970s. A variety of influences may have caused this shift, including anthropogenic nutrients – both organic and inorganic. The resulting "climax" bacterial community is characterized by a predominance of *Vibrio* species, including autochthonous vibrios pathogenic for humans and fishes. Global climate change may have also influenced, either directly or indirectly, this bacterial community-shift. It is hypothesized that the chemicals which cause bacterial community-shift also stress potential animal hosts (e.g., fishes), thereby allowing the increased densities of opportunistic pathogens to easily invade, colonize, and cause disease in their hosts. With regard to human hosts, demographics (e.g., most people live close to the coastal ocean) and food preferences (e.g., seafood is becoming increasingly popular) are also contributing to risk. Overall, it would appear that anthropogenic influences – inorganic nutrients, toxic chemicals, organic chemicals, greenhouse gases, global transportation – are influencing the sources, distribution, and conveyance of opportunistic pathogens in estuaries and the oceans.

LITERATURE CITED

Centers for Disease Control and Prevention (CDCP). 1998. Outbreak of *Vibrio parahaemolyticus* infections associated with eating raw oysters – Pacific Northwest, 1997. *Morbidity and Mortality Weekly Report* **47**:457-462.

Colwell, R.R. and D.J. Grimes (eds.). 2000. *Nonculturable Microorganisms in the Environment*. ASM Press. Washington, D.C. USA. 354 pp.

DePaola, A., C.A. Kaysner, J. Bowers, and D.W. Cook. 2000. Environmental investigations of *Vibrio parahaemolyticus* in oysters after outbreaks in Washington, Texas, and New York (1997 and 1998). *Applied Environmental Microbiology* **66**:4649-4654.

Grimes, D.J. 1991. Ecology of estuarine bacteria capable of causing human disease: a review. *Estuaries* **14**:345-360.

Grimes, D.J., F.L. Singleton, and R.R. Colwell. 1984a. Allogenic succession of marine bacterial communities in response to pharmaceutical waste. *Journal of Applied Bacteriology* **57**:247-261.

Grimes, D.J., F.L. Singleton, J. Stemmler, L.M. Palmer, P. Brayton, and R.R. Colwell. 1984b. Microbiological effects of wastewater effluent discharge into coastal waters of Puerto Rico. *Water Research* **18**:613-619.

Grimes, D.J., J. Stemmler, H. Hada, E.B. May, D. Maneval, F.M. Hetrick, R.T. Jones, M. Stoskopf, and R.R. Colwell. 1984c. *Vibrio* species associated with mortality of sharks held in captivity. *Microbial Ecology* **10**:271-282.

Grimes, D.J., R.W. Attwell, P.R. Brayton, L.M. Palmer, D.M. Rollins, D.B. Roszak, F.L. Singleton, M.L. Tamplin, and R.R. Colwell. 1986. Fate of enteric pathogenic bacteria in estuarine and marine environments. *Microbiological Sciences* **3**:324-329.

Grimes, D.J., J. Burgess, J.A. Crunkleton, Jr., P.R. Brayton, and R.R. Colwell. 1989. Potential invasive factors associated with *Vibrio carchariae*, an opportunistic pathogen for sharks. *Journal of Fish Diseases* **12**:69-72.

Harvell, C.D., K. Kim, J.M. Burkholder, R.R.Colwell, P.R. Epstein, D.J. Grimes, E.E. Hoffmann, E.K. Lipp, A.D.M.E. Osterhaus, R.M. Overstreet, J.W. Porter, G.W. Smith, and G.R. Vasta. 1999. Emerging marine diseases - climate links and anthropogenic factors. *Science* **285**:1505-1510.

Heidelberg, J.F. et al. 2000. DNA sequence of both chromosomes of the cholera pathogen *Vibrio cholerae*. *Nature* **406**:477-483.

Kaneko, T. and R.R. Colwell. 1973. Ecology of *Vibrio parahaemolyticus* in Chesapeake Bay. *Journal of Bacteriology* **113**:24-32.

Lobitz, B., L. Beck, A. Huq, B. Wood, G. Fuchs, A.S.G. Faruque, and R.R. Colwell. 2000. Climate and infectious disease: Use of remote sensing for detection of *Vibrio cholerae* by indirect measurement. *PNAS* **97**:1438-1443.

Okpokwasili, G.C., C.C. Somerville, M. Sullivan, D.J. Grimes, and R.R. Colwell. 1986. Plasmid mediated degradation of hydrocarbons in estuarine bacteria. *Oil and Chemical Pollution* **3**:117-129.

Sieburth, J.McN. 1971. Distribution and activity of oceanic bacteria. *Deep Sea Research* **18**:1111-1121.

Xu, H.-S., N. Roberts, F.L. Singleton, R.W. Attwell, D.J. Grimes, and R.R. Colwell. 1982. Survival and viability of nonculturable *Escherichia coli* and *Vibrio cholerae* in the estuarine and marine environment. *Microbial Ecology* 8:313-323.

ZoBell, C.E. and H.C. Upham. 1944. A list of marine bacteria including descriptions of sixty new species. *Bulletin of the Scripps Institute of Oceanog.raphy. University of California Technical Series* 5:239-292.

Potential Pathological Effects of Blood Flukes (Digenea: Sanguinicolidae) on Pen-reared Marine Fishes

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ABSTRACT

Sanguinicolids, or fish blood flukes, infect the vascular system of both marine and freshwater fishes, and some act as serious pathogens of hosts in aquaculture. Blood flukes typically possess a relatively benign relationship with wild fishes; however, cultured hosts near appropriate intermediate hosts (i.e., snail, bivalve, or polychaete) may accumulate heavy infections of the worms and their eggs. The resulting disease, sanguinicoliasis, has caused mass mortalities of fish reared in ponds and cages in North America, Europe, and Asia. In the life cycle, the cercaria emerges from the intermediate invertebrate host and penetrates into and matures in the definitive fish host, and the resulting adult releases eggs into the fish's vascular system. These eggs may be sequestered in gill, heart, kidney, liver, spleen, pancreas, or other organs, where they cause inflammation and decrease the physiological and mechanical efficiency of these organs. In some cases, they kill the host. Treatment of debilitated fishes is difficult, and the combination of stock destruction and facility disinfection is a realistic option for managing cases in freshwater systems. However, because this is usually not possible in marine systems, early detection and identification of the parasite, careful site selection and construction of culture facilities, and elimination of infected hosts (definitive or intermediate) are important. Much information needs to be acquired about each parasite's biology and geographic range, and imported fishes and fish products should be quarantined or examined fresh for infections prior to potential contamination of culture systems.

KEY WORDS: Aquaculture, disease, parasite

INTRODUCTION

Blood flukes of fishes, sanguinicolids, represent an unusual group of digeneans because their life cycles lack a second intermediate host and an encysted or encapsulated metacercaria. In addition, unlike all other families of flukes, members of which have a molluscan first intermediate host, some blood flukes utilize a polychaete rather than a snail or bivalve (e.g., Køie 1982, Smith 1997). Not having to eat a second intermediate host means that to complete a life cycle depends on the proximity of definitive and intermediate hosts to the free-swimming infective stages of the parasite. Manipulating the location of the fish host to its fluke's intermediate host, such as occurs in some aquaculture activities, can easily dictate infections, which in turn produces sickness or death of the fish host. Understanding the life cycles, seasonality of the cycles, specificity of the flukes, immunological responses of the fishes, and environmental interactions with the infections allows a biologist and manager to assess better the potential for infections and the resulting associated

disease sanguinicoliasis. Dwindling wild stocks of marine fishes and increased demand for fish products has catalyzed aquaculture production, but sanguinicoliasis could threaten the economic growth and sustainability of the industry. In the present paper, we summarize the biology and host-parasite associations, discuss some physical and biological factors that affect blood fluke infections in confined fishes, and describe some pathological alterations to host tissue caused by blood flukes in both wild and captive fishes.

Fish Blood Flukes

Sanguinicolids comprise a morphologically and ecologically diverse family of flukes (Platyhelminthes: Digenea) that infects both marine and freshwater fishes and is usually reported from large blood vessels such as the heart, branchial vessels, or mesenteric vessels. They are roughly 2 - 11 mm in total length, thin-bodied, dorsoventrally flat, narrow and elongate or oval in shape, and opaque or nearly transparent in life. Adults of some species are concave and capable of using the ventral surface of the body as a suction cup that allows them to adhere to smooth surfaces such as the walls of arteries, veins, or even a petri dish. Adults of many species possess tread-like rows of lateral tegumental spines that facilitates both attachment and rapid motion. Adults of other species possess minute spines and partially embed themselves in the wall of the heart. Some blood flukes are extremely active, and, if removed from heart and placed in a dish with physiologic saline solution, they rapidly crawl or swim about and make quick, repeated, flapping body movements. Live specimens are therefore relatively easy to notice and collect because the movements signal their location in a dissection tray or petri dish. They differ from mammalian blood flukes because they are usually wider and are hermaphroditic rather than having separate males and females. The tegument of many fish blood flukes is delicate and deteriorates rapidly after host death. This, along with the transparent appearance of many sanguinicolids and the atypical sites they infect, results in many being overlooked during parasitological examinations.

In the Gulf of Mexico, just as in most regions around the world, there presently exists little information on blood fluke diversity, host ranges, life cycles, intermediate hosts, geographic ranges, and pathogenicity. Only four adult sanguinicolids belonging in three genera are known from six Gulf of Mexico fishes, an adult blood fluke has not been described from a Gulf fish in 46 years, none has been described from the northern Gulf west of Mobile Bay, a study on the distribution or seasonality of any blood fluke in a Gulf fish population has not been conducted, and few details of wild host-parasite relationships have been described (e.g., Overstreet and Thulin 1989).

Life Cycle

Life cycles for most blood flukes are cryptic, making eradication or control of the parasites in aquaculture difficult. The life cycles may be challenging to study because a definitive host's diet does not necessarily indicate the probable intermediate host; however, comparisons of molecular sequences from various cercariae and adult flukes could elucidate the cycles. Of the roughly 60 known marine species, the life cycle of only one has been demonstrated experimentally (Køie 1982). The blood fluke *Aporocotyle simplex* develops in the terebellid

polychaete intermediate host (*Artacama proboscidea*) before infecting the flatfishes *Limanda limanda*, *Pleuronectes platessa*, or *Platichthyes flesus*. Life cycles of several freshwater blood flukes are known, and each of these also lacks a second intermediate host (Schell 1974, Hoffman et al. 1985, Kirk and Lewis, 1992, 1993). The following serves as a generalized life cycle based on those studies (Fig. 1). Adult flukes deposit thin-shelled, pliable eggs in the vascular system of the definitive host. Some eggs travel to and lodge in the fish's gill, where the embryo develops in and hatches from the egg. After hatching, the first free-swimming form of the fluke, the miracidium, emigrates through the gill epithelium and searches for an appropriate snail, bivalve, or polychaete intermediate host. After penetration of the intermediate host, the parasite undergoes asexual reproduction. A sporocyst or redial stage may produce the second free-swimming infective stage, the cercaria, which is shed from the intermediate host and either infects an appropriate fish host or dies. The cercaria penetrates the fish host through its gill, skin, eye, fin, or alimentary tract and develops through the juvenile stage as a schistosomule before ending up in a specific site in the circulatory system of the host. Often in the heart or branchial vessels, the fluke ultimately matures, copulates, and releases eggs. We suspect that these sites are advantageous for egg deposition because eggs released there immediately are carried to the gill; however, adults of other fish blood flukes occur in vessels involving the mesentery, intestine, kidney, and brain (e.g., Smith, 1972, 1997), and perhaps eggs of these flukes exit the fish host from different sites. Further investigations are needed to determine other pathways for eggs. For example, they may pass through the intestine, as shown by schistosomes and spirorchiids, blood flukes that infect mammalian and reptilian hosts, respectively. On the other hand, *Cruoricola lates* infects the vessels of the mesentery and other visceral organs but miracidia seem to develop in the gills and heart only.

Dynamics of Life Histories

Some blood fluke life cycles exhibit seasonal development, and monthly data on the prevalence and intensity of these infections could elucidate details about the life history of sanguinicolids and dictate schedules for both stocking and harvest of cultured fishes. Some blood flukes migrate to branchial vessels and lay eggs during a specific season, creating peak periods of intense infections and subsequent fish kills (e.g., Ogawa et al. 1989). On the other hand, Ewens et al. (1994) showed that the adult of *Sanguinicola inermis* overwintered in wild common carp and released eggs in the spring. Hine (1978) readily observed adult specimens of *Paracardicoloides yamagutii* in the gills of eels (*Anguilla australis* and *Anguilla dieffenbachii*) only when the flukes migrated there to lay eggs in spring and autumn. Maillard and Ktari (1978) found that the uterus of adult specimens of *Hyperandrotrema cetorhini* collected from a basking shark (*Cetorhinus maximus*) either lacked eggs or possessed only a few deformed eggs, suggesting that viable eggs were produced during a specific period other than when collected. Of course, that host could have been an abnormal host. Concurrent infections of the blood flukes *Paradeontacylix grandispinus* and *Paradeontacylix kampachi* caused mass mortalities of cage-cultured greater amberjack from December 1983 to 1984 (Ogawa et al. 1989). Later study of that relationship showed that the number of blood fluke eggs in the gill entered the gills in November and increased until March, when it decreased

toward July (Ogawa et al.1993). An interacting set of abiotic factors probably drives this apparent seasonality, but knowledge on how each of those factors affects the miracidium, schistosomule, and adult for any species is scant, if known at all. Abiotic factors such as water temperature and salinity probably significantly influence the behavior and physiology of blood fluke miracidia and cercariae as well as the complex of hosts (e.g., Overstreet 1982). Because these factors are site- or season- dependent, information on how they affect the free swimming infective stages of blood flukes could be invaluable in selecting culture sites and in predicting seasons in which epizootics are likely to occur. Ewens et al. (1994) reported that under laboratory conditions the life cycle of *S. inermis* was dependent on temperature, and Smith (1997) stated that discrepancies in the times for penetration and migration of *S. inermis* as reported by several workers were possibly a result of different temperatures for host maintenance. Temperature also appears to dictate developmental time of the schistosomule. It and other features such as site in the host probably affect how this stage can influence health of the host. Examples expressing different sites for this preadult stage developing between the cercaria and adult, taking the place of the metacercaria of other digeneans, include the dermis for *S. inermis* in the carp. The schistosomule remains in the dermis much longer at low compared to higher temperatures. Adults occur in branchial arteries, bulbus arteriosus, and aortas (Kirk and Lewis 1993). The juvenile of *S. klamathensis* occurs throughout the circulatory system of *O. clarki* but is restricted to the efferent renal vein as an adult (Meade 1967), and that of *A. simplex* occurs in the lymphatic system, under the skin, and between muscles containing light yellow gut contents whereas adults in blood has yellow-brown contents. In its flatfish hosts, the adult of *A. simplex* infects the heart, ventral aorta, and gill arteries (Køie 1982). Seasonal assessments of the effect of salinity on different blood flukes infecting cultured hosts are necessary. For example, at the time of this manuscript's preparation, salinities in the northern Gulf of Mexico (e.g., Gulf-proper, Mississippi Sound, Back Bay) were higher than they had been for many years, and seemingly there was a greater prevalence of adult blood flukes in the heart of 1- to 3-year-old red drum and black drum from those waters as well as a few infections in other hosts not seen previously.

Host specificity

Knowing which host or hosts a blood fluke can infect helps identify aquaculture candidates that might be vulnerable to developing sanguinicoliasis and those that are not. Some parasites infect a wide range of fish hosts, while others apparently infect only a single fish species. Parasites that infect one or relatively few hosts are more "host specific" than those that infect several hosts. A list compiled by Smith (1997) shows that of the roughly 76 described sanguinicolids (20 freshwater, 56 marine), 53 (70%) have been reported from a single host, 11 (14%) from two hosts, 5 (7%) from three hosts, and 7 (9%) from four or more hosts. Those flukes from more than one host infect hosts in the same genus or family. However, exceptions, including experimental infections, occur. For example, *Sanguinicola fontinalis* probably is restricted to the cyprinid *Rhinicthys cataractae* (longnose dace) in nature, but it can infect the brook trout, *Salvelinus fontinalis*. Because it killed so many brook trout in culture and was refractive to a variety of other salmonids, the contaminated

Pennsylvania fish hatchery discontinued producing brook trout. This example illustrates the implications of "host specificity" for aquaculture where infective cercariae could infect an abnormal host. Further collections of blood flukes from different-aged fishes and during different seasons are needed to accurately assess identifications and host range; susceptible hosts may not be infected throughout the year. The true host range of a blood fluke could be underestimated if hosts were sampled only once or during a season of low prevalence of infection.

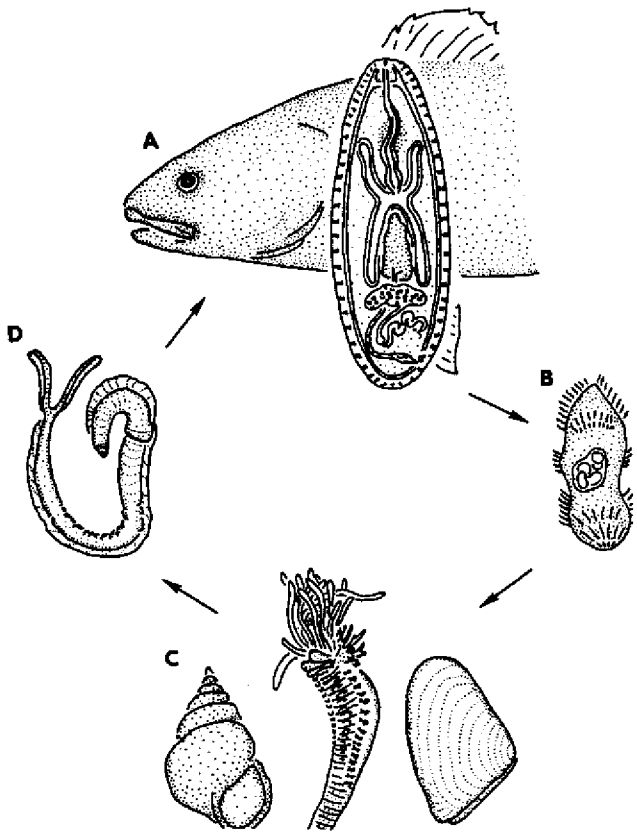


Figure 1. Generalized sanguinicolid life cycle. **A.** The adult fluke in the vascular system of the definitive host, a fish, releases eggs into the blood. **B.** The first free-swimming stage of the fluke, the miracidium, hatches from the egg in the gill, emigrates through the gill epithelium, and seeks and penetrates the appropriate intermediate host. **C.** In the intermediate host (snail, polychaete, or bivalve), asexual reproduction (mother and daughter sporocyst or redial stage) ultimately produces the second free-swimming stage, the cercaria. **D.** The tailed cercaria is shed from the intermediate host and penetrates a definitive host. In the fish, it loses its tail, develops to an adult as a schistosomule, and finally migrates to the specific site in the circulatory system of the host where it copulates and produces eggs.

Immunity

At least some fish have a documented immune response to sanguinicolids. Presumably, all hosts have significant immune responses, but the responses probably differ according to a number of factors. A series of papers by Richards et al. (e.g., 1994, 1996a) has provided considerable information on the response of the carp to *Sanguinicola inermis*. The fish clearly elicits a cellular response against the adult, egg, and cercaria, involving eosinophils, neutrophils, and macrophages (Richards et al. 1994, 1996a). Lymphocyte production was experimentally enhanced in response to both cercarial and adult extracts at 20°C. At 10°C, the adult extract produced a greater response. Perhaps the reduced ability of the lymphocytes to proliferate in carp at lower temperatures in response to the fluke extracts suggests an impairment of the immune system. This can serve the parasite in a number of ways. It would allow the adult worm to overwinter, since at the higher temperature the adult may survive a couple of months only (Kirk and Lewis 1993). Periods of cool weather also correspond to periods of cercarial shedding, enhancing cercarial penetration into host and survival of the young worm. The proliferation of lymphocytes in carp is even more complicated because at 10°C, it occurs in the pronephric (kidney) and splenic lymphocytes. But at 20°C, most proliferation occurs in the pronephric cells. Perhaps during warmer months, specific humoral immune responses mediated by kidney lymphocytes influence infections, but during cool months, more non-specific responses, probably mediated by T-cells in the spleen, predominate (Richards et al. 1996b). The ability of leucocytes to adhere to cercariae and encapsulate and degrade eggs appears to be inhibited by live adult worms (Richards et al. 1996a). Other immune responses also play a role in the relationship between carp and blood fluke as well as those of other fish and their parasites. As a marine example, Ogawa et al. (1989) presented data on prevalence and intensity of sanguinicolids infecting young and old samples of greater amberjack in a net pen. Individuals less than 1-year-old had a relatively high number of eggs in cardiac muscle and gill, suggesting that the older fish acquired some level of immunity to infections after receiving an initial exposure to the flukes a year earlier. Further studies are needed; however, individual hosts may respond to infections differently, and infection intensity and abiotic factors probably have an interacting effect on the host's immune response. In summary, little is known about specifics of the immune responses directed at sanguinicolids, but the responses differ among species, differ between other digeneans, and presumably play an important role in infections in both wild and cultured fishes.

Wild host-parasite relationships

Relatively few digeneans reportedly cause significant disease of fishes in the wild, and blood flukes are no different. Based on what is known on sanguinicolid life cycles, the strategy of debilitating or killing the definitive host should not increase transmission within a host population. For most species, a few pliable eggs are released on a seasonal basis. Most of the eggs become entrapped in gill tissue. For those species investigated, the miracidium develops in that location. For *S. inermis*, the miracidium develops and is released, leaving the fish within 7 days (Kirk and Lewis 1993). Eggs that do not accumulate in the gills typically become lodged in viscera or connective tissue where the host's inflammatory granulomatous

response encapsulates them and degrades the miracidium. Overstreet and Thulin (1989) investigated the heart and tissues of a large number of marine teleosts and found that most serranids contained an abundance of macrophage aggregates (MA's) in the ventriculus, and they and a few other fishes contained free macrophages among ventricular trabeculae. This unusual abundance of macrophages in these locations appeared to have developed as a means to contend with blood flukes. One sanguinicolid, *Pearsonellum corventum*, in its serranid host *Plectropomus leopardus* causes minimal harm to the wild host (Overstreet and Thulin 1989). In the heart, the macrophages along with neutrophils and lymphocytes surrounded the eggs as well as the adult worm, but no fibrotic encapsulation was evident. Eggs that ended up in the ventricular epicardium, pericardium, aortic serosa, mesentery, liver, spleen, and kidney were mostly encapsulated and being degraded in small granulomas, some associated with ceroid or MA's. Moreover, the substantial cellular response of most serranids and a few other fishes also serves to sequester a variety of parasites, prey spines, entire eels, and other foreign bodies within heavily pigmented fibro-encapsulations (Overstreet and Thulin 1989).

We observed sanguinicolid eggs in cardiac muscle, gill epithelium, and liver of several wild-caught fish, including the red snapper (*Lutjanus campechanus*) from the northern Gulf of Mexico (Figures 2-6), and they were like most cases in the literature. Eggs in cardiac muscle, which contained no MA's, and liver were not abundant and typically present in various stages of degeneration (Figures 2-4). Recently deposited eggs in early stages of degeneration were encapsulated by a thin epitheliod or fibroid layer (Figure 2). More degenerated eggs exhibited some yellowish ceroid pigment (Figure 3). Some eggs in a later phase of degeneration exhibited more conspicuous light to dark brown ceroid pigment (Figure 4). Cardiac muscle surrounding the degenerated eggs appeared normal except for invading leucocytes. Based on these observations, we doubt these eggs caused any significant decrease in the mechanical efficiency of the heart. Eggs in the liver primarily occurred in pancreatic nodules and were surrounded by a granulomatous response. (Figure 5). Sequestered eggs in the gill mostly contained living miracidia and were readily apparent by their refractive excretory products in fresh wet-mounted preparations (Figure 6). We estimated that fewer than ten of these thin-shelled, elongated eggs in the afferent vessels infected each filament of the wild-caught red snapper. For comparison, eggs in wild-caught red drum (Figure 7) differed by being more spherical, but neither elicited a severe host response.

Not all mature blood flukes occur in the heart and vessels leading to the gills. *Plethorchis acanthus* from the intestine and mesenteric pancreas of wild-caught mullet (*Mugil cephalus*) from Queensland, Australia, provide a good example. In some geographic areas, most of the mullet exhibited infections with a grossly apparent host response. Histologically, the adult expanded the vessels and accommodated large numbers of surrounding leucocytes (Figure 8). Large clusters of eggs with the associated host inflammatory response occluded both large and small vessels (Figures 9-13). A given fish typically demonstrated both recently deposited eggs containing miracidia and a slight granulomatous response (Figure 10) and more advanced cases with eggs in various phases of degeneration (Figures 11-13). The more advanced cases, especially when heavily infected, typically exhibited

an extensive inflammatory response involving ceroid pigmentation. Perhaps some eggs with infective miracidia of this species are voided through the intestine.

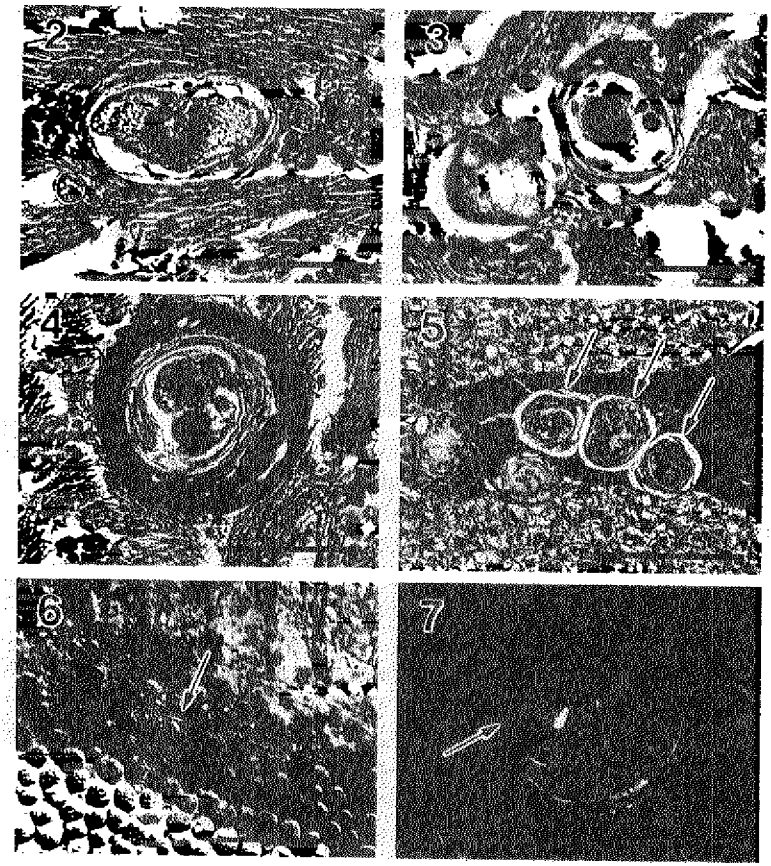
The host response to fish blood flukes varies according to host species, site in the host, intensity of infection, season, and environmental conditions. Little information exists regarding the effect of these flukes on wild host populations, but some flukes may weaken their hosts, making them vulnerable prey and reducing their populations, especially during certain seasons. However, probably few wild host-parasite associations significantly influence population-structure.

Cultured host-parasite relationships

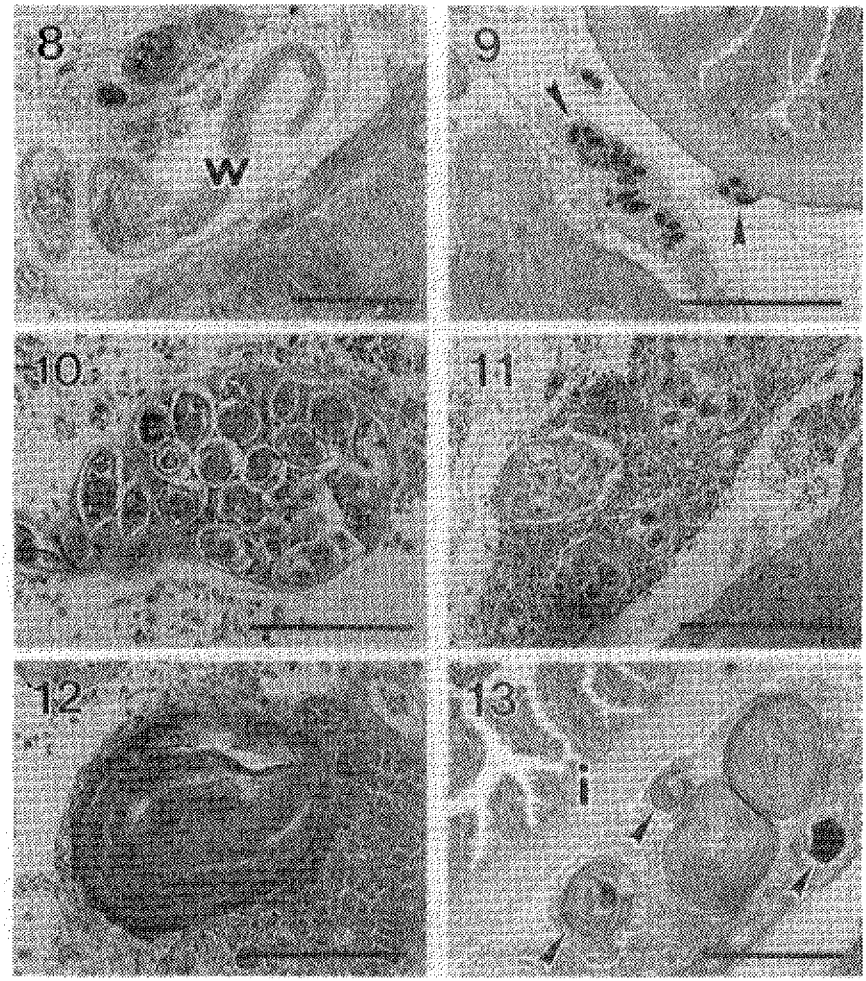
Confined fishes are either more or less prone to sanguinicoliasis than wild fishes. The infection, whether the parasite is present, and the disease, whether the parasite is present in high enough density to harm the host, depend on the closeness of the intermediate host to the fish host. As indicated above, wild fish get infected, but disease rarely occurs. Freshwater pond conditions that promote the presence of an intermediate host to be present therefore promote infections and disease. Marine net pens can be positioned such that the two hosts remain distant, preventing infections. On the other hand, marine fishes in ponds could easily get infected, if the intermediate host was one that could live in the pond habitat.

When confined fish come in contact with the cercaria, they probably will come in contact with large numbers. The more cercariae that penetrate a fish, the more likely it is to be detrimentally affected or die. Death can result from acute or chronic conditions. Acute cases can involve large numbers of either cercariae or miracidia. As an example, when 2,500 cercariae of *S. inermis* are exposed to carp, they produce in the fish severe edema, epidermal hemorrhage, and death within a few hours (Kirk and Lewis 1992). When lower numbers are exposed, the effects are reduced, and fish do not die. When large numbers of miracidia exit a host simultaneously, there can be severe hemorrhaging of the secondary lamella or elsewhere in the gills, with resulting mortalities. In contrast to the acute conditions, chronic conditions kill or debilitate hosts over a longer period. This disease usually results from the effects of a large number of eggs and associated host response occluding blood vessels. Consequently, various vital organs and tissues lose their blood supply, and the fish can die from a variety of specific causes.

As with the lodging of fluke eggs in wild fish, those in confined fish may be more numerous, accumulate faster, trigger a stronger immune response, form a more effective blockage, and result in greater infarctions and more reduced blood flow and hypoxia. Moreover, in some cases, the host can have severe reactions to the adults or juveniles, which can then cause blockage. We also see a greater need to investigate the effect of temperature on the health of the fish. One should consider the possibility of various scenarios. Assume that large number of eggs are lodged in vessels during a period of low temperatures. The fish might be sluggish from the temperature, but adequate blood flow would exist for most purposes. Now when the temperature increases, the host's immune response becomes active, and its cellular response produces masses of leucocytes, fibroblasts, and other components that quickly seal the vessels. The fish then dies as a compounded result of the increased temperature.



Figures 2-7. Sanguinicolid eggs in wild fish from Mississippi. **Figs. 2-6.** In red snapper. **2.** Egg surrounded by few inflammatory cells in cardiac muscle. Scale bar = 30 µm. **3.** Early granuloma involving two degenerating eggs in cardiac muscle. Scale bar = 30 µm. **4.** More developed response with ceroid pigment surrounding egg in cardiac muscle. Scale bar = 30 µm. **5.** Degenerating eggs in pancreatic nodule in liver, showing slight ceroid response surrounding eggs (arrows). Scale bar = 75 µm. **6.** Elongated egg (arrow) in fresh preparation of gill tissue with live well-formed miracidium. Scale bar = 75 µm. **7.** Spheroidal fresh egg in gill of different species in red drum. Note well-developed miracidium (arrow). Scale bar = 30 µm.



Figures 8-13. *Plethorchis acanthus* and its eggs in mesentery of wild striped mullet from Queensland, Australia. Sections are stained with hematoxylin and eosin except Fig. 9, which is stained in PAS. **8.** Adult worm (w) and clusters of eggs surrounded by inflammatory cells in dilated mesenteric vein. Scale bar = 115 μm. **9.** Eggs occluding wide and narrow mesenteric veins (arrowheads). Scale bar = 345 μm. **10.** Early granuloma involving large cluster of eggs. Scale bar = 75 μm. **11.** Granulomas containing clusters of eggs and surrounded by intensive leucocytic response. Scale bar = 115 μm. **12.** Ceroid involvement in epithelioid granuloma. Scale bar = 115 μm. **13.** Late fibroid granulomas surrounded by packed leucocytes and earlier granulomas (arrowheads) still containing egg fragments and ceroid response in completely occluded vein abutting intestine (i). Scale bar = 345 μm.

Pen and cage culture offer an excellent potential for development of sanguinicoliasis. If the intermediate host can develop within its cercaria's range of the confined fish, and this might be enhanced by the feed and waste products from the system, then fish can get infected. The intermediate host could obtain the initial infection from a wild fish. There is also the possibility that a blood fluke not normally infective to the reared organism could infect it under specific conditions.

Sanguinicoliasis was reported in a cage-cultured marine fish (greater amberjack, *Seriola dumerili*) by Ogawa and Egusa (1986). Mass mortalities of this amberjack maintained in shallow-water floating net cages off the coast of Shikoku Island, Japan, occurred between December and March. Gill filaments of heavily-infected dead fish contained more than 1,000 eggs of *Paradeontacylix grandispinus* and/or *P. kampachi* per filament, causing gill hyperplasia and extensive papillae formed from proliferation of endothelium in the afferent branchial arteries (Ogawa et al, 1989). Nodules of encapsulated eggs in the gill obstructed blood flow through afferent arteries, and those in the ventricle wall were surrounded by atrophied muscle. Heavily-infected fish gasped at the water surface and died soon after being fed, suggesting that the increased oxygen demand during feeding could not be met. A subsequent mass mortality occurred in May 10 years later off Kyushu, Japan, with fish exhibiting similar signs (Ogawa and Fukudome 1994). Crespo et al. (1992) reported mass mortalities of 0- and 1-year-old cultured greater amberjack from the Spanish Mediterranean Sea off Majorca, Catalonia, and Murcia. They attributed the primary cause of death in the 0-year-class fish to epitheliocystis, but one of the same or a related blood fluke was present, and some of the older infected fish without epitheliocystis also died. Other blood flukes infect marine and estuarine fishes in culture. For example, *Cruoricola lates* in the centropomid *Lates calcarifer* in Malaysia (Herbert et al. 1995) occurs commonly in vessels of the mesentery, kidney, pericardium.

Cases of sanguinicoliasis in freshwater ponds from North America, Europe, and Asia also provide good examples because 1) they show what could happen in saltwater ponds where confined fish have a continual exposure of the larvae from an extraordinarily high infection of the abundant intermediate host and 2) they demonstrate the variation in disease signs in different fishes and from different flukes.

For example, Hoffman et al. (1985) reported a mass mortality of many of the 400,000 infected brook trout (*Salvelinus fontinalis*) caused by *Sanguinicola fontinalis*. Severely infected fishes exhibited affected gills, but also damaged the kidneys. The latter demonstrated generalized nephrosis and moderate edema, with accumulation of basophilic material in both Bowman's capsule and tubule lumina. For lack of an effective treatment, all heavily infected fish had to be destroyed. That blood fluke was just one of the five known to infect North American salmonids: *Sanguinicola davisi*, *Sanguinicola klamathensis*, *Sanguinicola alseae*, and *Sanguinicola idahoensis*. Davis et al. (1961) reported mortalities of fingerlings of *Oncohrhynchus clarki* and *Oncohrhynchus mykiss* infected by *S. davisi*; they were anemic, and their gills were damaged by fluke eggs and exiting miracidia. Evans (1974a, 1974b) showed that eggs of *S. klamathensis* in *O. clarki*, when deposited over a period of time, produced progressive alterations in gills and kidney, resulting

in poor weight gain and mortality. Schell (1974) reported that the eye of *O. mykiss* heavily infected with *S. idahoensis* exhibited a bulging retina, thickened iris, and disrupted vascular stroma in addition to affected gills.

Commercially valuable fishes such as the red drum (*Sciaenops ocellatus*), red snapper (*Lutjanus campechanus*), cobia (*Rachycentron canadum*), Florida pompano (*Trachinotus carolinus*), and greater amberjack are all likely candidates for net pen culture in the Gulf of Mexico. These plus other fishes host a blood fluke (unpublished data), and awareness and understanding of these and the corresponding diseases are needed so that these potential fish resources can be managed in an economically and environmentally sound manner.

Control and Management

Control of infections of blood flukes in culture systems can be easier than controlling most parasites with direct life cycles, those without intermediate hosts. Nevertheless, a good management strategy involves keeping intermediate and definitive hosts separate. Early detection and identification of a blood fluke could be essential for elimination of susceptible intermediate hosts from the vicinity of fishes in pens, ponds, or raceways. We advocate regular monitoring of several fish from each group to assess all parasites and diseases, including blood fluke infections. Infected fishes such as brood stock or fingerlings should not be transported to other facilities, and inspection for blood fluke infections in each facility could help reduce or halt the spread of disease from facility to facility by movements of fish.

Elimination of susceptible intermediate hosts could protect enclosed fishes against sanguinicoliasis, and molluscicide application has been suggested for ponds (Smith 1972, 1997). However, such application would probably be impractical and cost-prohibitive for marine pens or cages. Moreover, biodiversity of endemic fauna inhabiting sites below and near containments should be preserved and protected.

As demonstrated in other culture systems, biosecurity is needed in aquaculture with regard to blood flukes, and quarantine protocols should be defined, implemented, and enforced to protect cultured and wild fishes. Introduced parasites can become pathogens of local, endemic fishes (Overstreet, 1990). Because of this threat, imported fingerlings, brood stock, and fish products including frozen fish should be quarantined until a subsample can be examined carefully for the presence of either blood fluke eggs or adults or other parasites. For example, Ogawa and Fukudome (1994) suggested that infected greater amberjack imported from China eventually caused mass mortalities of that fish in Japanese culture systems. Anderson and Shaharom-Harrison (1986) believed that *Sanguinicola armata* was brought into Malaysia by importation of fingerling bighead carp (*Aristichthys nobilis*) and grass carp (*Ctenopharyngodon idella*). Kirk and Lewis (1994) reported that *S. inermis* was introduced to Britain when infected fishes were imported from continental Europe in the 1950s and 1960s, and that the fluke has since spread to various British rivers by movements of fishes that were caught for display or recreation and subsequently released. Infections of *S. inermis* have been sustained in British rivers and hatcheries because the intermediate hosts occur abundantly there. Inadequate pre-transfer protocols were blamed for subsequent mass mortalities in hatcheries. Studies on sanguinicoliasis among net-penned fishes in the Gulf of Mexico are currently not possible because there are few, if any, pens or

cages. Nevertheless, now is the time to develop adequate protocols for preventing the spread of sanguinicoliasis based on studies of local wild parasite-host interactions combined with those investigating sanguinicoliasis in hatcheries and culture systems elsewhere.

Capture Fisheries and Aquaculture

Marine fishes traditionally have been overexploited. Some assessments are controversial, but 30-year trends show that stocks of most capture fisheries are eventually overfished. Presently, 44% of the major marine fish stocks are fully exploited and producing catches at their maximum limit; 16% are overfished with no room for increased production; 6% are depleted with declining production; and 3% are recovering slowly (FAO 1999). Capture fisheries reached their maximum production levels 10 - 20 years ago, and catches of some of those same stocks have now declined (FAO 1999). The need for alternate sources of fish products is becoming increasingly more evident.

The marine aquaculture industry expects to supplement the demand for fish products and relieve some pressure from wild stocks, as already demonstrated by the freshwater aquaculture industry. This would allow some wild stocks to begin recovery and increase above threshold levels. Humans consume predominantly wild-caught marine fishes; however, this may soon change. The aquaculture industry now includes greater than 220 species of finfish and shellfish, global fish and shellfish production more than doubled to 28 million metric tons between 1987 and 1997, with 40% from marine sources, (FAO 1999, Naylor et al. 2000), and aquaculture provided 22-29% of all fish consumed by humans in 1996 (New, 1997; FAO 1999). Growth of the industry will continue; however, with expansion comes disease, and sanguinicoliasis is an important one.

CONCLUSIONS

Blood flukes may debilitate or kill cultured fishes, and studies on sanguinicolid diversity, geographic range, host specificity, life histories, and host-parasite relationships all should be incorporated in cost- effective, environmentally-sound management practices for the emerging aquaculture industry in the northern Gulf of Mexico. The strategy for control of sanguinicoliasis in the Gulf or any marine habitat should include rigorous biosecurity measures consisting of quarantine and subsequent necropsies of subsamples of imported fishes and fish products, monitoring of local cultured stocks for the presence of blood flukes, specific identification of blood flukes from these stocks, and implementation and enforcement of quarantine protocols.

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LITERATURE CITED

Anderson, I.G. and F.M. Shaharom-Harrison. 1986. *Sanguinicola armata* infection in bighead carp (*Aristichthys nobilis*) and grass carp (*Ctenopharyngodon idella*) imported in Malaysia. Pages 247-250 in: J. L. Maclean, L. B. Dizon, and L. V. Hosillos (eds.). *The First Asian Fisheries Forum,* Asian Fisheries Society, Manilla, Philippines.

Crespo, S., A. Grau, and F. Padros. 1992. Sanguinicoliasis in the cultured amberjack *Seriola dumerili* Risso, from the Spanish Mediterranean area. *Bulletin of the European Association of Fish Pathology* **12:**157-159.

Davis, H.S., G.L. Hoffman, and E.W. Surber. 1961. Notes on *Sanguinicola davisi* (Trematoda: Sanguinicolidae) in the gills of trout. *Journal of Parasitology* **47:**512-514.

Evans, W.A. 1974a. The histopathology of cutthroat trout experimentally infected with the blood fluke *Sanguinicola klamathensis*. *Journal of Wildlife Diseases* **10:**243-248.

Evans, W.A. 1974b. Growth, mortality, and hematology of cutthroat trout experimentally infected with the blood fluke *Sanguinicola klamathensis*. *Journal of Wildlife Diseases* **10:**341-346.

Ewens, E., J.W. Lewis, D.T. Richards, D. Hoole, and C. Arme. 1994. Epidemiological studies on the blood fluke: *Sanguinicola inermis* Plehn, 1905, in the common carp (*Cyprinus carpio* L.). Page 50 in: *International Symposium on Aquatic Animal Health, Program and Abstracts*, Davis, California USA.

FAO. 1999. *The State of the World Fisheries and Aquaculture 1998.* Food and Agriculture Organization, Rome, Italy. 127 pp.

Herbert, B.W., F.M. Shaharom, and I.G. Anderson. 1995. Histopathology of cultured sea bass (*Lates calcarifer*) (Centropomidae) infected with *Cruoricola lates* (Trematoda: Sanguinicolidae) from Pulau Ketam, Malaysia. *International Journal of Parasitolology* **25:**3-13.

Hine, P.M. 1978. Distribution of some parasites of freshwater eels in New Zealand. *New Zealand Journal of Marine and Freshwater Research* **12:**179-187.

Hoffman, G L., B. Fried, and J.E. Harvey. 1985. *Sanguinicola fontinalis* sp. nov. (Digenea: Sanguinicolidae): a blood parasite of brook trout, *Salvelinus fontinalis* (Mitchill), and longnose dace, *Rhinichthys cataractae* (Valenciennes). *Journal of Fish Diseases* **8:**529-538.

Kirk, R.S. and J.W. Lewis. 1992. The laboratory maintenance of *Sanguinicola inermis* Plehn, 1905 (Digenea: Sanguinicolidae). *Parasitology* **104:** 121-127.

Kirk, R.S. and J.W. Lewis. 1993. The life-cycle and morphology of *Sanguinicola inermis* Plehn, 1905 (Digenea: Sanguinicolidae). *Systemic Parasitology* **25:**125-133.

Kirk, R.S. and J.W. Lewis. 1994. The distribution and host range of species of the blood fluke *Sanguinicola* in British freshwater fish. *Journal of Helminthology* **68:**315-318.

Køie, M. 1982. The redia, cercaria and early stages of *Aporocotyle simplex* Odhner, 1900 (Sanguinicolidae)- a digenetic trematode which has a polychaete annelid as the only intermediate host. *Ophelia* **21**:115-145.

Maillard, C. and M.H. Ktari 1978. *Hyperandrotrema cetorhini* n. g., n. sp. (Trematoda, Sanguinicolidae) parasite du système circulatoire de *Cetorhinus maximus* (Selacii). *Ann. Parasitol. Hum. Comp.* **53**:359-365.

Meade, T.G 1967. Life history studies on *Cardicola klamathensis* (Wales, 1958) Meade and Pratt, 1965 (Trematoda: Sanguinicolidae). *Proceedings of the Helminthology Society of Washington* **34**:210-212.

Naylor, R.L., R.J. Goldburg, J.H. Primavera, N. Kautsky, M.C.M. Beveridge, J. Clay, C. Folke, J. Lubchenco, H. Mooney, M. Troell. 2000. Effect of aquaculture on world fish supplies. *Nature* **405**:1017-1024.

New, M.B. 1997. Aquaculture and capture fisheries - balancing the scales. *World Aquaculture* June: 11-30.

Ogawa, K. and S. Egusa. 1986. Two new species of *Paradeontacylix* McIntosh, 1934 (Trematoda: Sanguinicolidae) from the vascular system of a cultured marine fish, *Seriola purpurascens*. Fish Pathol. **21**:15-19.

Ogawa, K., K. Hattori, K. Hatai, and S. Kubota. 1989. Histopathology of cultured marine fish, *Seriola purpurascens* (Carangidae) infected with *Paradeontacylix* spp. (Trematoda: Sanguinicolidae) in its vascular system. *Fish Pathology* **24**:75-81.

Ogawa, K., H. Andoh, and M. Yamaguchi. 1993. Some biological aspects of *Paradeontacylix* (Trematoda: Sanguinicolidae) infection in cultured marine fish *Seriola dumerili*. *Fish Pathology* **28**:177-180.

Ogawa, K. and M. Fukudome. 1994. Mass mortality caused by blood fluke (*Paradeontacylix*) among amberjack (*Seriola dumerili*) imported to Japan. *Fish Pathology* **29**:265-269.

Overstreet, R M. 1982. Abiotic factors affecting marine parasitism. Pages 7-14 in: D. F. Mettrick and S. S. Desser (eds.) *Parasites - Their World and Ours. Fifth International Congress of Parasitology Proceedings and Abstracts Volume* 2, Toronto, Canada.

Overstreet, R.M. 1990. Antipodean aquaculture agents. *International Journal of Parasitology* **20**:551-564.

Overstreet, R.M. and J. Thulin. 1989. Response by *Plectropomus leopardus* and other serranid fishes to *Pearsonellum corventum* (Digenea: Sanguinicolidae), including melanomarcrophage centers in the heart. *Australian Journal of Zoology* **37**:129-142.

Richards, D.T., D. Hoole, J.W. Lewis, E. Ewens, and C. Arme. 1994. Changes in the cellular composition of the spleen and pronephros of carp *Cyprinus carpio* infected with the blood fluke *Sanguinicola inermis* (Trematoda: Sanguinicolidae). *Diseases of Aquatic Organisms* **19**:173-179.

Richards, D.T., D. Hoole, J.W. Lewis, E. Ewens, and C. Arme. 1996a. Adherence of carp leucocytes to adults and cercariae of the blood fluke *Sanguinicola inermis*. *Journal of Helminthology* **70**:63-67.

Richards, D.T., D. Hoole, J.W. Lewis, E. Ewens, and C. Arme. 1996b. Stimulation of carp *Cyprinus carpio* lymphocytes *in vitro* by the blood fluke *Sanguinicola*

inermis (Trematoda: Sanguinicolidae). *Diseases of Aquatic Organisms* **25**:87-93.

Schell, S.C. 1974. The life history of *Sanguinicola idahoensis* sp. n. (Trematoda: Sanguinicolidae), a blood parasite of steelhead trout, *Salmo gairdneri* Richardson. *Journal of Parasitology* **60**:561-566.

Smith, J.W. 1972. The blood flukes (Digenea: Sanguinicolidae and Spirorchidae) of cold-blooded vertebrates and some comparison with the schistosomes. [Review article] *Helminthology Abstract Series A* **41**:161-204.

Smith, J.W. 1997. The blood flukes (Digenea: Sanguinicolidae and Spirorchidae) of cold-blooded vertebrates: Part 1. A review of the published literature since 1971, and bibliography. *Helminthology Abstracts* **66**:255-294.

Factors Contributing to the 1999 Mass Mortality of Reef-Associated Fish in Barbados

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ABSTRACT

During the period August to November 1999, mass mortalities of several species of reef-associated fish were reported at a number of islands in the southern Caribbean, including Tobago, Grenada, Barbados, St. Vincent and the Grenadines. Histopathological and bacteriological studies conducted in Barbados revealed that the fish died from severe disseminated bacteraemic disease caused by the pathogen *Streptococcus iniae* which had not previously been reported in the marine environment in the southern Caribbean. Analysis of satellite imagery indicated that a plume of water originating in the region of the Orinoco River, and characterised by high chlorophyll concentrations and low nocturnal oxygen levels, impacted on Barbados and the neighbouring islands at the time of the fish kill. It is suggested here that several atypical environmental conditions, including elevated sea water temperature, high phytoplankton concentration and reduced oxygen levels worked in concert to stress the fish and increase their susceptibility to *S. iniae*.

KEY WORDS: Pathogen, Oxygen Depletion, *Streptococcus iniae*

INTRODUCTION

Barbados is the most easterly of the Caribbean islands. It is located at approximately 13°N and 59°W (Figure 1). During the period mid-September to mid-October 1999, large numbers of dead and moribund fish were deposited on the beaches in Barbados. In the early stages of the mass mortality, fish were deposited on the eastern and southeastern coast beaches, while towards the end of the event, dead fish also washed ashore along the northeast coast (Figure 2).



Figure 1. Map of the eastern Caribbean showing the location of the islands affected by the 1999 fish kill.

Several other islands in the southeastern Caribbean also verbally reported the beaching of thousands of dead and dying fish along their eastern and southeastern Atlantic coasts, from as early as August and continuing into November 1999. The islands reportedly affected were Grenada, St. Vincent, the Grenadine islands and Tobago, (Figure 2).

Local fish kills on the individual islands are common in the southeast Caribbean. Reports of these fish kills are not usually published, but the Fisheries Officials in Grenada, St. Vincent, Tobago and Barbados have confirmed the occurrence of such

events in their respective countries (pers. com. and Heileman Leo, and A. Siung-Chang 1990), while the 1994 mass mortality of reef-associated fish in Barbados was investigated and documented (Alleyne 1998).

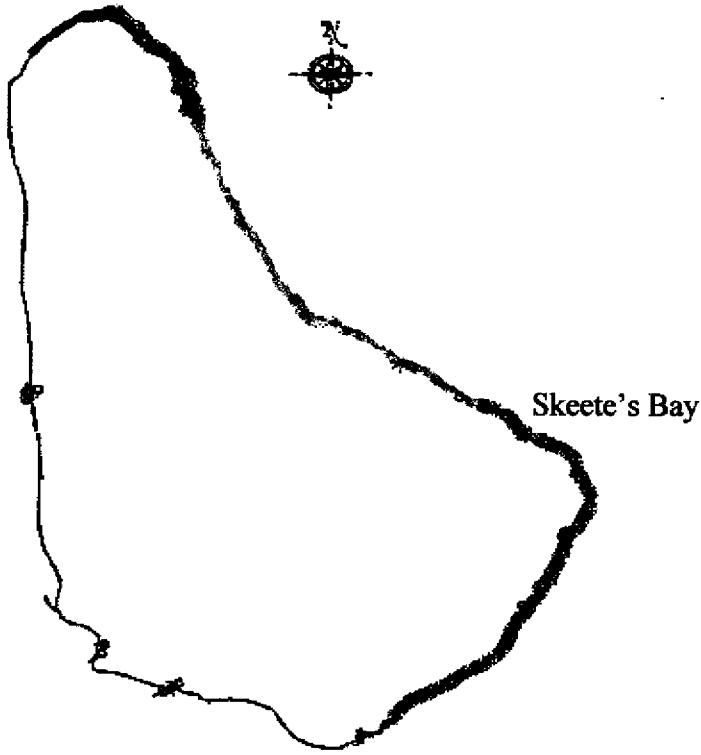


Figure 2. Areas of Barbados where fish were beached during the 1999 fish kill.

The 1999 fish kill in the southeastern Caribbean was unusual in that it was regional affecting several islands almost simultaneously. The only previous report of a regional mass mortality of a marine organism in the Caribbean was that of the black sea urchin *Diadema antillarum* in 1983 - 1984 (Lessios et al. 1984, Hunte et al. 1986). The mortality of *D. antillarum* started in Panama and was distributed throughout the Caribbean by water currents. It is believed to be caused by a species-specific water-borne pathogen.

Based on the results of the bacteriological and histo-pathological examinations of freshly dead and moribund fish collected in Barbados during the 1999 fish kill, Ferguson et al. (in press) concluded that the fish died from severe disseminated bacteraemic disease caused by the pathogenic bacterium, *Streptococcus iniae*. *S. iniae* was isolated in pure culture from inflamed tissues of the gills, epicardium, myocardium, and liver. However, Herman (1990) emphasised that outbreaks of bacterial diseases are seldom the result of a single factor. Consequently, although the bacterium *S. iniae* was the pathogen that ultimately caused the death of the fish, predisposing factors were probably also involved in the epizootic occurrence.

This paper reports the observations made of environmental conditions existing during the 1999 fish kill in Barbados and assesses their possible roles as predisposing factors of the mass mortality.

METHODS

Information about the 1999 fish kill in the southern Caribbean was obtained from several sources, including reports of local and international governmental and non-governmental agencies, observations of personnel of the Barbados Fisheries Division and interviews with local fishermen, divers and members of the public. The Internet was used extensively to access relevant information from individuals, institutions and international agencies, and to obtain information on regional water quality characteristics during the period of the fish kill. The species of fish deposited on the beaches in the affected areas were identified, counted, and necropsies performed on sick, freshly dead and moribund fish samples. A detailed report of the post-mortem investigations of the fish is presented by Ferguson et. al. (in press).

OBSERVATIONS

Beaching of Dead Fish

Available records kept by the Ministry of Health of the Government of Barbados, indicated that an estimated 40 - 45 tons of fish were deposited on the beaches and removed by the Ministry of Health, fishermen and residents, during the clean-up exercise. The fish deposited on the beaches are believed to be less than half of the total fish killed, since divers and fishermen reported that fish deposited on the reefs, and those being carried offshore by the currents and tides, were together more than those deposited on the beaches. Many more fish were observed on the beaches in the early mornings, before the beaches were cleaned, than were deposited during the rest of the day.

Size and Species Composition

Among the affected shallow water reef species, mortality was highest among larger individuals. Forty fish species from 20 families were among the fish beached during the fish kill. The majority of dead fish were surgeon fish (46%), followed by Bermuda chubs (22%), parrot fishes (7%), sea basses (5%) and triggerfishes (4%).

All others species together accounted for only 16% of the fish beached, with individual species in this group accounting for less than 3% of the fish beached. Deep reef fish, coastal and offshore pelagics, and shellfish were not among the organisms deposited on the beaches. Divers also confirmed that these groups were not among the dead fish seen on the seabed.

Gross Anatomical Observations

Examination of the freshly dead or dying fish from the affected area revealed:

i) There were few external lesions such as haemorrhages, ulcerations and/or lesions.
ii) Gills, gut and livers were pale in colour.
iii) The gastro-intestinal tract of most species sampled, except the Bermuda chub, were empty.
iv) The stomachs of the Bermuda chubs examined were filled with unidentified green algae.
v) In some fish, the gall-blabber was enlarged or ruptured; in others, there was an excess of bile in the stomach.
vi) The spleens were enlarged and congested.

Presence of Discoloured Water

Fishermen reported the presence of murky green coloured water prior to and during early stages of the fish kill in the areas along the southeast coast of Barbados first affected by the fish kill. According to fishermen, murky green water is seen on occasions along the southeast coast during late summer, but it usually disappears within a day or two. However, in September 1999, the murky green water lingered for an extended period. Pilots flying aircraft in the southeastern Caribbean during the fish kill episode reported seeing large masses of green water around the islands. The neighbouring islands of Grenada and St. Vincent, reported discoloured coastal waters during the fish kill episode (CARICOM 1999). Satellite imagery of the southern Caribbean taken during the fish kill - specifically September 14 - 21, 1999 (Figure 3), showed that Barbados and other islands affected by the fish kill were engulfed by a mass of water with chlorophyll concentrations an order of magnitude (10 X) higher than normal (seawifs.gsfs.nasa.gov). This water mass appeared to have originated in the area of the Orinoco river, Venezuela. Similar satellite imagery for the period immediately prior to the fish kill (August 29 to September 5, 1999; Figure 4) shows the water mass heading north towards Barbados from the Orinoco area, but Barbados still surrounded by typical oceanic water of low chlorophyll concentration. Satellite imagery for the period following the fish kill (October 8 –15, 1999; Figure 5), shows Barbados again surrounded by oceanic water, that is, no longer engulfed by the high chlorophyll water mass. In a typical September, the water mass originating from the Orinoco region tends to move south and west of Barbados and the Lesser Antilles chain, in to the Caribbean Sea (Figure 6).

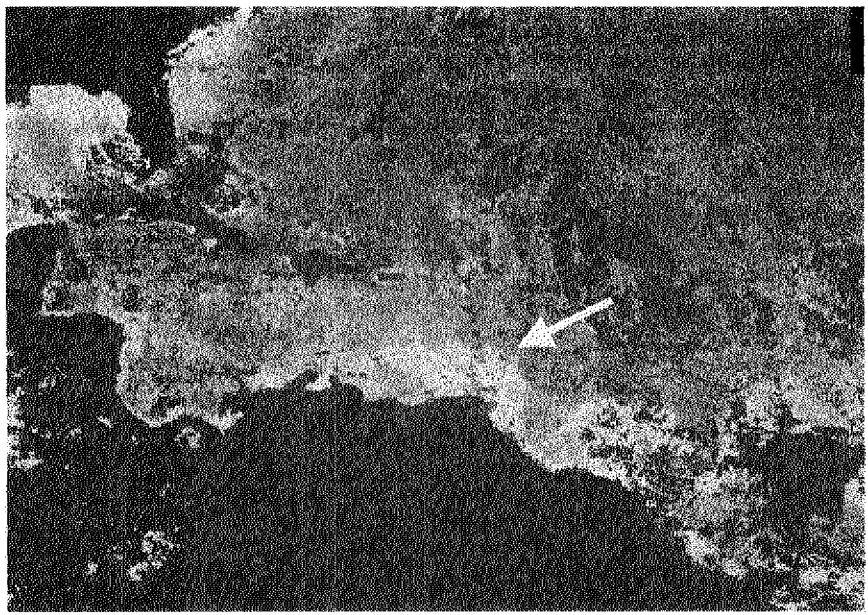


Figure 3. Satellite pictures for the period 14-21 September 1999, showing Barbados engulfed by water of chlorophyll concentration (shown as white) as much as 30 times normal seawater concentration. Arrow shows location of Barbados. **Source:** seawifs.nasa. gov.

Plant Material in the Discoloured Water

During the early stages of the fish kill, when fishermen were reporting the presence of the murky green water, the beaches were being littered with organic and plant material, including large numbers of seedlings from an unidentified legume. The seedlings were not from a local legume (Carrington, S pers.com.). This suggested that the plant and organic materials were brought in from outside of Barbados. Grenada also reported floating plant materials in the discoloured water observed along their coasts during the fish kill episode (CARICOM 1999).

No harmful algae were found in water samples taken from affected coastal areas in Barbados during the latter stages of the fish kill. Water samples were not taken in Barbados during the early and peak stages of the kill. However, water samples taken off Tobago and St. Vincent during the fish kill, and analysed by agencies within those territories, showed no evidence of harmful phytoplankton known to be associated with fish kills (CARICOM 1999).

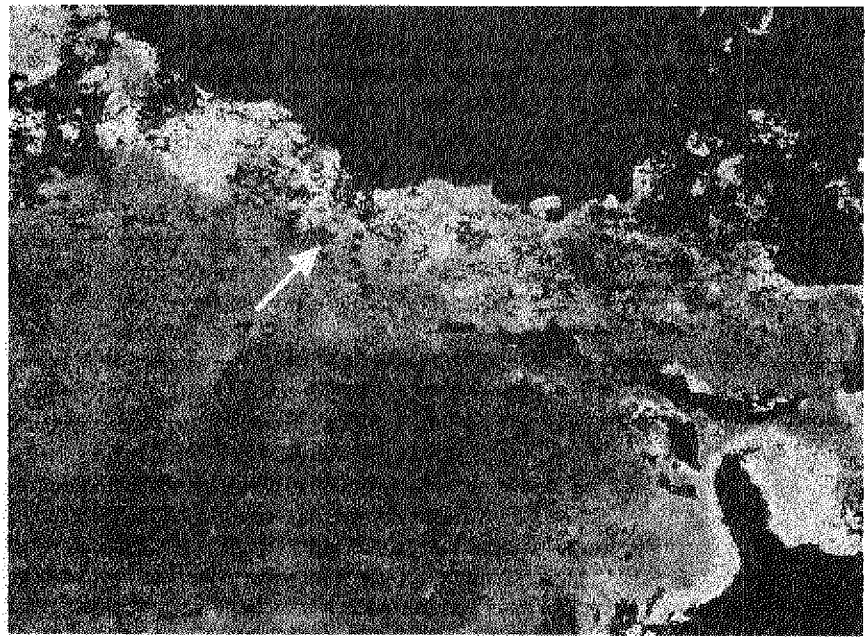


Figure 4. Satellite pictures for the period 29 August - 8 September 1999, showing a plume of water of high chlorophyll concentration (shown as green) to the southeast of Barbados. Arrow shows location of Barbados. **Source:** seawifs.nasa.gov.

Sea Surface Temperatures

Fishermen and swimmers in the near shore waters of Barbados reported that the seawater was noticeably warmer then usual. The Barbados Meteorological Office reported that unusually high sea surface temperatures (29^0 - 33^0 C) were recorded during September 1999, between longitudes 7^0 and 10^0 N and latitudes 55^0 and 60^0 W. These sea surface temperatures were reported to the Meteorological Office by ships in the area. Seawater temperatures near Barbados in August and September for 1993 – 95 varied between 28^0 and 29^0C (CARICOMP).

Oxygen Concentration

Oxygen readings taken in Grenada and to a lesser extent in Barbados, during the fish kill detected values significantly lower than normal, particularly in the early morning (Hunte, W. University of the West Indies; pers. com.)

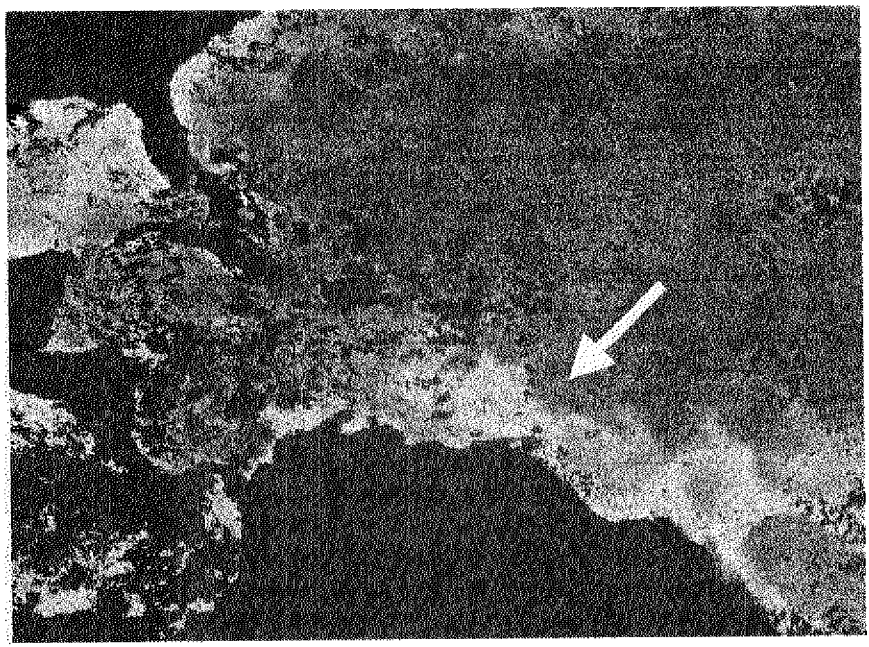


Figure 5. Satellite pictures for the period 8-15 October 1999, showing the plume of water of high chlorophyll concentration (shown as white) to the west of Barbados and extending into the Caribbean. Arrow shows location of Barbados. **Source:** seawifs.nasa.gov.

Unusual Currents

Just prior to the fish kill, tropical storm Gert passed through the southern Caribbean. In Barbados, it provided very high sea-swells and rough seas that pounded coastal areas, especially the east and southeast coasts. Prior to the first report of beaching of dead fish, divers and fishermen observed a change in current direction from the normal northwesterly pattern to a northeasterly flow. The observed change is believed to have been caused by the passage of tropical storm Gert and may have been responsible for the movement of the water mass from the Orinoco region north towards Barbados and the Lesser Antilles

.DISCUSSION

The pathogenic bacterium *Streptococcus iniae* ultimately caused the death of the fish in Barbados during the 1999 mass mortality of reef-associated fish, the fish dying from severe disseminated *Streptococcus* septicaemia, (Ferguson et al. in press). Pathogen-caused fish kills in natural systems usually involve - hosts that are

susceptible to the contagion by the specific pathogen and exposure to predisposing environmental conditions that increase susceptibility of the hosts to the pathogen (Hermen 1990). The observations presented in this report indicate that the reef-associated fish affected by the 1999 fish kill were exposed to several predisposing environmental factors that may have increased the fishes' susceptibility to *S. iniae*.

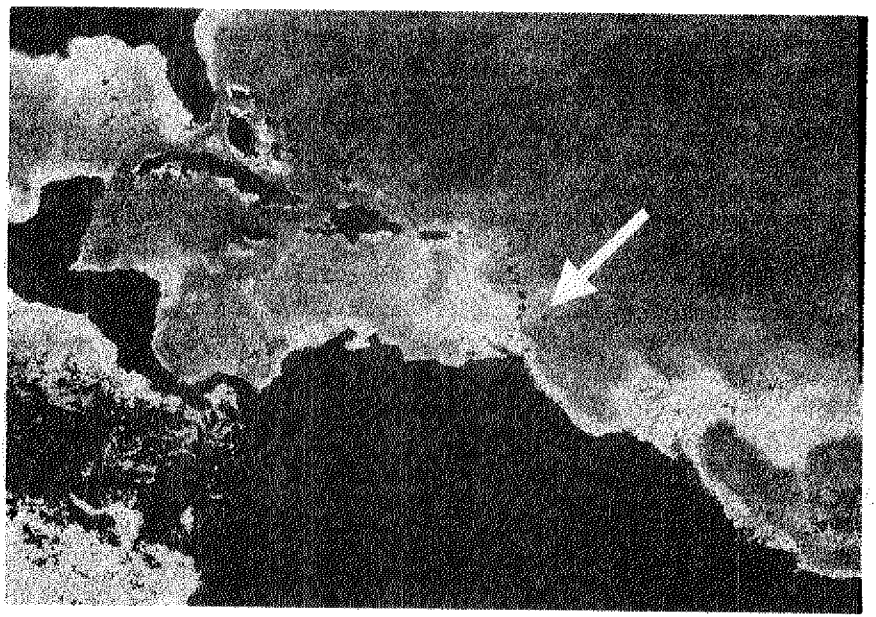


Figure 6. Satellite imagery for the period September 1998, showing the plume of water of high chlorophyll concentration (shown as green) to the south and west of Barbados and extending into the Caribbean. Arrow shows location of Barbados. **Source: seawifs.nasa.gov.**

In most fish kill investigations, information on the environmental conditions that contributed to the mortality are not accurately assessed, as the conditions often cease to exist before the mortality is noted and the investigation has begun. Snieszko (1964) listed temperature stress, decreased immunological response, pollution, unfavourable water chemistry, inadequate food supply and storms as some of the predisposing environmental conditions associated with fish kills. Herman and Meyer (1990) identified oxygen depletion, toxic algal blooms and sudden or excessive temperature changes as some of the agents that cause fish kills. Herman and Meyer (1990) also listed several observations that are evidence of a fish kill caused by oxygen depletion. Among these are that fish mortality occurs mainly at night and

subsides during the day, that mortality rate is highest among larger individuals and that there is discoloration of water. These conditions were observed during the 1999 mortality event, indicating that low oxygen levels were a contributing factor to fish death, either directly or through increasing susceptibility to the pathogen. Oxygen depletion occurs when the total demand for oxygen by aquatic organisms exceeds the dissolved oxygen available in the surrounding water, and it is typically associated with heavy algal growth or high concentrations of organic matter or plant material (Herman and Meyer 1990).

Satellite imagery for the period of the fish kill (September 1999) shows Barbados engulfed by a plume of water that is of higher chlorophyll concentration than that of normal seawater (<seawifs.nasa.gov> 1999). The high chlorophyll content indicates the presence of large quantities of photosynthetic (phytoplankton, floating plant) material in the water. The murky green water that lingered around Barbados during the early stages of the fish kill was directly observed to be carrying plant and organic material, including seedlings that were not from local plants. The respiratory needs of the dense assemblage of phytoplankton, and the oxidative decay of the dead plant material, would have sharply reduced the supply of dissolved oxygen in the water column, making less oxygen available for other marine organisms. During the daytime, oxygen levels would have been at least partially replenished through photosynthesis. However, at night in the absence of photosynthesis, oxygen levels would not have been maintained. It is therefore expected that oxygen levels would have been lowest during the nighttime.

Excessive temperature changes are one of the environmental factors often associated with fish kills (Herman and Meyer 1990). Above normal sea surface temperatures were reported around Barbados, and throughout the southern Caribbean, during the period of the fish kill. The solubility of oxygen in water is inversely related to temperature. The above normal sea-water temperatures observed would therefore, have resulted in even lower concentrations of dissolved oxygen in the seawater, that is the creation of hypoxic conditions in the water column. Such environmental changes can stress fish to the extent that a weakening of the immune response may predispose the fish to infectious diseases (Herman and Meyer 1990). Larger fish have higher oxygen demands than smaller individuals and may therefore be expected to be more acutely affected by lowered dissolved oxygen levels. Once infected with *S. iniae*, hypoxia is especially critical in the toxaemic fish. Consequently, sick fish, especially the larger ones, would be more likely to die during the night when hypoxic conditions were most severe. This is consistent with the observation that many more fish were found on the beach in the early hours of the morning than later in the day.

The death of the fish in the 1999 fish kill was apparently not immediate, since the stomachs and guts of the freshly dead and dying fish were often empty. This suggests that the fish exposed to stressful environment conditions and to *S. iniae* were probably sick and not eating for several days before eventually succumbing to the effects of the pathogen.

The mass mortality of a wide variety of reef fish species along the east and southeast coasts, the complete absence of *S. iniae* in fish outside of the affected areas, suggests that the affected reef fish do not normally carry *S. iniae*, and were immunologically naïve. Once introduced, *S. iniae* would spread rapidly through the naïve population, already stressed by the deteriorated environmental conditions. These observations suggest that the virulent *S. iniae* may have been entrained in the same invading water mass as the predisposing environment conditions, and would therefore be available to infect fish that had not previously been exposed to the pathogen. However, it is uncertain how *S. iniae* was actually transported. It is unlikely that it was transported in the water outside the body of a host, since *S. iniae* does not survive very long in seawater. This suggests the involvement of a host, presently unknown, in carrying the pathogen in the water mass to Barbados. Once the pathogen was introduced to the area, it may have entered the fish either via the gills from the seawater or by the fish eating contaminated carriers.

In concluding, the satellite imagery and other observational data presented in this paper support the suggestion that there was a significant deterioration of water quality at the time of the 1999 Caribbean fish kill. High sea surface temperatures and the high oxygen demand resulting from the influx of large amounts of photosynthetic material into the area, depleted oxygen levels in surrounding near-shore waters. Although the oxygen levels may not have been low enough to kill healthy fish, they were low enough to critically stress fish, increase their susceptibility to S. *iniae* infection, and increase the morbidity of the disease.

LITERATURE CITED

Alleyne, S. 1998. Severity and Etiology of the 1994 mass mortality of coral reef fish in Barbados. M.Sc. Thesis, University of the West Indies, Cave Hill 72H, Barbados.

Berridge, B.R., J.D. Fullier, J. de Azavedo, D.E. Low, H. Bercovier, and P.F.. Frelier. 1998. Development of specific nested oligonucleotide PCR primers for the *Streptococcus iniae* 16S-23S ribosomal DNA intergenic spacer. *Journal of Clinical Microbiology* **36**:2778-2781.

Ferguson, H., S. St. John, C.J. Roach, S. Willoughby, C. Parker, and R. Ryan. *Caribbean Reef Fish Mortality Associated with Streptococcus iniae.* In press. *Veterinary Records.*

CARICOM. Draft Summary Proceeding of the CARICOM Regional Workshop on the Fish Kill Events, held on 16th October, 1999 in Barbados. In prep.

CARICOM. 1997. Studies on Caribbean coral bleaching, 1995 – 1996. *Proceedings of the 8th International Coral Reef Symposium* 1:673-678.

Herman R.L. 1990. The role of infectious agents in fish kills. Pages 43-54 in: F.P. Meyer and L.A. Barclay (eds.) *Field Manual for the Investigation of Fish Kills. United State Dept. of the Interior Fish and Wildlife Services/Resource Publication 177.*

Herman R.L and F. P. Meyer, 1990. Fish kills due to natural causes. Pages 41-44 in: F.P. Meyer and L.A. Barclay (eds.) *Field Manual for the Investigation of Fish Kills: United State Dept. of the Interior Fish and Wildlife Services/Resource Publication 177.*

Heilemam L.I. and A. Siung-Chang 1990. Analysis of fish kill in coastal and internal waters of Trinidad and Tobago, West Indies, 1976 – 1990. *Caribbean Marine Studies* **2**:126-136.

Hunte, W., I. Cote, and T. Tomascik.. 1989. On the dynamics of the mass mortality of *Diadema antillarum* in Barbados. *Coral Reef* **4**:135-139.

Lesions H.A., D.R. Robertson, and J.D. Cubit. 1984. Spread of *Diadema* mass mortality through the Caribbean. *Science* **226**:335-337.

Snieszko, S.F 1964. Remarks on some facets of epizootiology of bacterial fish diseases. *Developments in Industrial Microbiology* **5**:97-100.

Weinstein, M.R., M. Litt, D.A. Kertesz, P. Wyper, D. Rose, M. Coulter, A. McGeer, R. Facklam, C. Ostach, B.M. Willey, A. Borczyk, and D.E. Low. 1997. *New England Journal of Medicine* **337**:589-594.

Susceptibility of *Litopenaeus vannamei, Farfantepenaeus duorarum,* to White Spot Syndrome Virus (WSSV) and Infection of *Menippe adina* with WSSV

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ABSTRACT

White spot syndrome virus (WSSV) can cause 100 % cumulative mortality to farmed shrimp, and there is increasing concern over the possible introduction of this virus into wild shrimp and crab populations in the Gulf of Mexico. In this contribution, we compare the mortality rate of WSSV infected *Farfantepenaeus duorarum* to *Litopenaeus vannamei*. In addition, we demonstrate that the stone crab (*Menippe adina*) is susceptible to WSSV infection.

We used an experimental procedure that is based on a mathematical epidemiology model to compare the survival of *F. duorarum* to *L. vannamei* from exposures to WSSV. The experimental procedure involved exposing 12 uninfected susceptible shrimp to a single infected shrimp cadaver for a specified period of time and then isolating the exposed shrimp individually to determine the number of deaths. *Menippe adina* were challenged by injection of a homogenate containing WSSV and exposed *per os* to WSSV infected tissue. The *L. vannamei* used in the experiment were obtained from the United States Marine Shrimp Farming Program, and *F. duorarum* and *M. adina* were obtained from the wild.

The mean mortality rate from a WSSV exposure was 0.81 for *L. vannamei*, and 0.75 for *F. duorarum*. A statistical difference was not detected in final mean mortality rates between *L. vannamei* and *F. duorarum*. From the *M. adina* challenge, two of the four crabs injected with WSSV died, and both of those were found to be histologically positive for WSSV associated lesions. In addition to the WSSV inclusions, basophilic, intranuclear inclusions were found in hypertrophied nuclei of hepatopancreatic cells which may be caused by another pathogen. Our results suggest *F. duorarum* is as susceptible to mortality from WSSV as *L. vannamei*,, and that *M. adina* is susceptible to infections by WSSV.

KEY WORDS: Crustaceans, Gulf of Mexico, viruses

INTRODUCTION

White spot syndrome virus (WSSV) is a recently described shrimp pathogen that is devastating the shrimp farming industry. WSSV can cause 100 % cumulative mortality to farmed shrimp. Because WSSV is known to have a broad host range, there is concern over the possible introduction of this virus into economically

valuable shrimp and crab populations in the Gulf of Mexico.

Two of the known shrimp hosts of WSSV are *Litopenaeus vannamei*, white-legged shrimp and *Farfantepenaeus duorarum*, pink shrimp (Lightner 1998). *Litopenaeus vannamei* is the most commonly cultured species in the Americas and is one of the most commercially important species comprising the wild shrimp fishery along the Pacific coast of the Americas. *Farfantepenaeus duorarum* is one of three species of shrimp comprising the wild shrimp fishery in the Gulf of Mexico. *Litopenaeus vannamei* is known to be highly susceptible to WSSV, however there is some confusion as to the relative susceptibility of *F. duorarum* to WSSV. Results from two studies have demonstrated that larval *F. duorarum* are as susceptible to WSSV as larval *L. vannamei* and that juvenile *F. duorarum* are less susceptible to WSSV infections than juvenile *L. vannamei* (Lightner et al. 1998 and Wang et al. 1999). However, in the study by Wang et al. (1999) they mention that in a preliminary experiment, juvenile *F. duorarum* were found to be as susceptible to WSSV as juvenile *L. vannamei* (Wang et al. 1999). In addition, preliminary studies performed in our lab have found little difference in mortality rates between juvenile *F. duorarum* and *L. vannamei*.

Menippe adina is a commercially valuable species of stone crab in the Gulf of Mexico (Stuck and Perry 1992). Various crab species have been found to be susceptible to WSSV, but it is not known if *M. adina* is susceptible to WSSV.

In this contribution, we compare the mortality rate of *F. duorarum* to *L. vannamei*, and demonstrate that *M. adina* is susceptible to WSSV infection. In addition, we describe an inclusion in hepatopancreatic cells of *M. adina* that may be caused by a different naturally occurring virus.

MATERIALS AND METHODS

Test Animals and Viral Stock

The *L. vannamei* used in these experiments were obtained from the Oceanic Institute, Hawaii. These shrimp are from the original unselected population of shrimp (Kona stock) that have been maintained by the United States Marine Shrimp Farming Program (Lotz 1997). *Farfantepeneaus duorarum* and *M. adina* used for the experiments were captured in Mississippi Sound, Mississippi, USA. All shrimp used weighed between 2 and 3 grams, and *M. adina* weighed between 0.5 to 25.0 g. The isolate of WSSV used was obtained from mainland China in 1996 and has been maintained in *L. vannamei*.

Experiment 1: Estimating survival rates for *L. vannamei* vs. *F. duorarum*

We used an experimental procedure that is based on a mathematical epidemiology model to compare the survival rates of *F. duorarum* to *L. vannamei* from exposures to WSSV (Soto and Lotz 2000).

In epidemiology models with the Reed-Frost approach to pathogen transmission, transmission from infected host to susceptible individuals is represented by the following equation:

$$S_1 = S_0 - S_0(1-\beta)^{I_0},$$

where S_0 and I_0 are the number of susceptible and infected hosts, respectively at the beginning of some time period, S_1 is the number of susceptible hosts after that time period, and β is the transmission coefficient which is the probability that a contact between a susceptible (S_0) and an infected (I_0) host will result in a transmission. By solving for β, an equation for estimating the transmission rate is obtained:

$$\beta = 1 - \exp\left(\ln\left(\frac{\frac{S_1}{S_0}}{I_0}\right)\right).$$

The transmission rate can be estimated from knowledge of the initial numbers of susceptible (S_0) and infected (I_0) shrimp and the number of susceptible shrimp (S_t) at the end of the time period of interest.

The experimental procedure involved exposing 12 uninfected susceptible shrimp to a single infected shrimp cadaver for a specified period of time and then isolating the exposed shrimp individually to determine the number of successful transmissions. The procedure for obtaining the transmission rate estimates is divided into three phases: preparation of I_0 (initially infected shrimp), exposure, and isolation.

I_0 Preparation

To prepare I_0 (the initial infected shrimp), we exposed two groups of 20 *L. vannamei* to WSSV. The shrimp were exposed in 115 L rectangular aquaria. Each aquarium was filled to a depth of 10 cm of chlorine disinfected seawater. Shrimp were exposed *per os* and received approximately 15 % body weight of frozen, minced cephalothoraces of shrimp known to have died of WSSV.

Exposure

In the exposure phase, susceptible shrimp (S_0) are exposed to infected shrimp (I_0). Twelve susceptible shrimp and one infected shrimp were placed in a cylindrical tank (1 m^2 bottom surface area by 0.6 m height). Each tank was filled to a depth of 10 cm of chlorine treated seawater. The susceptible shrimp were exposed to the infected shrimp for 16 hours. At the end of the exposure, the proportion of the dead infected shrimp consumed by the susceptible shrimp was noted. Water temperature in the exposure tanks was maintained at 27 ± 3 °C.

Isolation

To ensure no secondary transmission from newly infected dying shrimp, the exposed susceptible shrimp were isolated after the initial exposure period. After the 16-h exposure, all shrimp were placed in 1L jars. All jars were placed in a water bath, and each jar was supplied with air. Water temperature in the isolation jars was maintained at 26 ± 2 °C. The time of death of isolated shrimp was recorded. Shrimp were kept in these isolation jars for five days at which time the number of surviving specimens was recorded.

When a single infected shrimp is used, the transmission rate (β) is the proportion of susceptible shrimp getting infected. In a previous study using *L. vannamei*, we found that 100% of shrimp dying during the isolation phase, were WSSV positive, and 98.1% all shrimp that lived through the isolation phase were histologically negative for WSSV (Soto and Lotz 2000). Therefore, the mortality rate of WSSV is a good measure of transmission. We will report mortality rate, the proportion of susceptible shrimp dying, in this study.

Experiment 2: *Menippe adina* Challenge of WSSV

Each *M. adina* was exposed individually in 1 L jars. Each jar was placed in a water bath and supplied with air. Water temperature was maintained at 26 ± 1 °C. Four crabs were challenged by injection with a cell-free shrimp homogenate containing WSSV. The homogenate consisted of a 1:10 dilution of tissue of shrimp known to have died of WSSV in water. Each crab was injected with 0.02 ml per gram of crab into the infrabrachial sinus of the fifth pereiopod. Three crabs were injected with a virus free homogenate. For the per os exposures, 15 crabs received a piece of WSSV infected tissue weighing approximately 5 % body weight, and four crabs received a piece of virus-free shrimp tissue.

Crabs dying were fixed in Davidson's solution following procedures outlined by Lightner (1996). Crabs were kept in these jars for five days at which time all surviving specimens were fixed in Davidson's solution. Each crab was examined histologically after staining with Hematoxylin and Eosin stains for the presence of WSSV intranuclear inclusions. For each crab, two non-serial sagittal sections were analyzed by routine histology. In addition, *in situ* hybridization was performed on a corresponding parallel section. *In situ* hybridization was performed with kits available from DiagXotics, Inc. *L. vannamei* were used as positive and negative controls.

RESULTS

Experiment 1: *L. vannamei* vs. *F. duorarum*

Susceptible *L. vannamei* and *F. duorarum* (S_0) in each tank completely consumed the infected material (I_0). The mean mortality rate from a WSSV exposure was 0.81 (95% CL 0.34 - 0.91) for *L. vannamei*, and 0.75 (95 % CL 0.41-0.87) for *F. duorarum*. A statistical difference was not detected in final mean

mortality rates between *L. vannamei* and *F. duorarum* (chi-square test, P = 0.45). Most animals died between 24 and 60 hours post-exposure for both *L. vannamei* and *F. duorarum* (Figure 1). No animals from either negative control group died during the experiment.

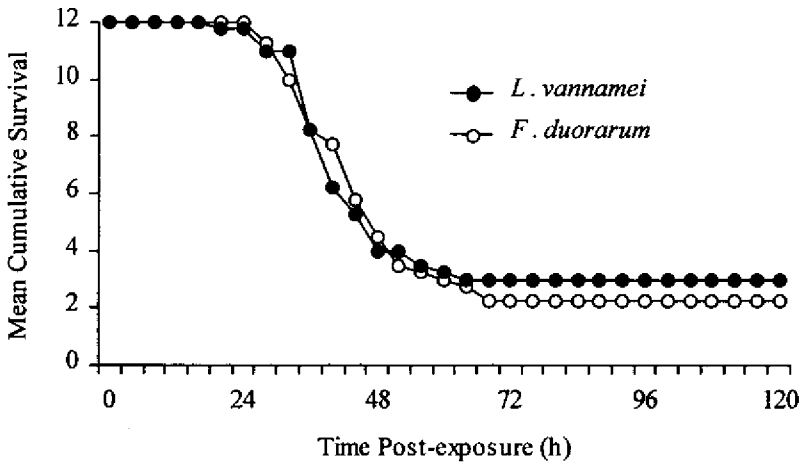


Figure 1. Mean cumulative survival in four-hour increments of *Litopenaeus vannamei* and *Farfantepenaeus duorarum* exposed to WSSV. No difference in final mean survival was detected (chi-square test, P = 0.45).

Experiment 2: *Menippe adina* Challenge of WSSV

From the *M. adina* challenge, two of the four crabs injected with WSSV died, and both of those were found to be histologically positive for WSSV associated lesions (with H&E stains). The crabs died at 60 and 71 hours post-exposure. One of the 15 crabs exposed *per os* was found to be histologically positive for WSSV. No WSSV associated lesions were observed in crabs used as negative control animals. Tissue tropism was similar to WSSV infections of penaeid shrimps (Lightner 1996). In infected crabs WSSV intranuclear inclusions were observed in cuticular epithelium, connective tissue, antennal gland, hematopoietic tissue, heart, and gill. With *in situ* hybridization, light reactions were observed in WSSV infected cells from crabs despite getting dark reactions in WSSV infected cells from the positive control shrimp.

In addition to the inclusions typically caused by WSSV, intranuclear inclusions were found in hypertrophied nuclei in cells of the hepatopancreas. Affected nuclei

were usually large but varied in size, contained a single basophilic to lightly eosinophilic inclusion, and displayed marginated chromatin. No occlusion bodies were observed in the inclusions. The inclusions were found in crabs exposed to WSSV, and in crabs used as negative control animals. Further, the inclusions were present in one of the two crabs that died during the experiment. Ten of the 24 crabs used in the experiment were positive for this hepatopancreas inclusion.

DISCUSSION

The results suggests that juvenile *F. duorarum* are as susceptible to mortality from WSSV as juvenile *L. vannamei*. In contrast, Lightner et al. (1998) and Wang et al. (1999) exposed juvenile *F. duorarum* and *L. vannamei* per os to WSSV and found juvenile *F. duorarum* to be more resistant to WSSV than juvenile *L. vannamei*. However in the study by Wang et al. (1999), they mention a preliminary experiment (unpublished) in which juvenile *L. vannamei* and *F. duorarum* were challenged per os to WSSV. In that study no difference in mortality rates was detected which corroborates our findings.

In a previous study the procedure for estimating transmission rate (β) used in this study was used to compare the transmission rates of WSSV by ingestion of an infected cadaver of *L. vannamei* to the transmission by ingestion of an infected cadaver of *L. setiferus* (Soto and Lotz 2000). In that study most shrimp were examined histologically to determine infection status. They determined that mortality rate was a good measure of transmission rate. In this study, since no histological examination has been performed on *F. duorarum*, it is possible that the transmission rate is even greater than the mortality rate.

Menippe adina were found to be susceptible to WSSV. *Callinectes sapidus* has also been found to be susceptible to WSSV (Flowers et al. 2000). Moreover, all three species of commercially important penaeid shrimps found in the Gulf of Mexico have been found to be susceptible to WSSV (Lightner et al. 1998, Wang et al. 1999, Soto and Lotz 2000). If successfully introduced, WSSV may pose a threat to the most economically important shrimp and crab fisheries in the Gulf of Mexico.

Tissue tropism of WSSV to *M. adina* was similar to WSSV infections of penaeid shrimps (Lightner 1996). WSSV typically infects cuticular epithelial cells, connective tissue cells, antennal gland epithelium, lymphoid organ sheath cells, hematopoetic tissues, and fixed phagocytes of the heart (Lightner 1996, Chang et al. 1996). WSSV has not been found to infect hepatopancreatic cells. Some researchers have found the hepatopancreas to be PCR positive for WSSV (Lo et al. 1997), but the hepatopancreas is composed of other types of cells including cuticular epithelial and connective tissue cells. The PCR positive results were probably due to the test reacting to infections in these cells.

It is possible that the inclusions observed in hepatopancreatic cells of *M. adina* were caused by another virus. The inclusions are similar to inclusions caused by Baculo-A virus described from *Callinectes sapidus* (Johnson 1980, 1983) and to Baculoviral Midgut Gland Necrosis (BMN), a virus that infects some penaeid

shrimps from south and southeast Asia, primariliy *Penaeus japonicus* and *P. monodon* (Lightner 1996).

It is important to note that the *M. adina* used in the experiments were kept in holding tanks for up to one year prior to the start of this experiment. In these tanks, *M. adina* were cohabitating with other crabs, specifically *C. sapidus*, *Panopeus simpsoni*, and *Eurypanopeus depressus*. Therefore, little can be said of the prevalence (41.6%) of the inclusion in *M. adina* in wild populations.

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LITERATURE CITED

Chang, P., C. Lo, Y. Wang, and G. Kou. 1996. Identification of white spot syndrome associated baculovirus (WSBV) target organs in the shrimp *Penaeus monodon* by *in situ* hybridization. *Diseases of Aquatic Organisms* **27**:131-139.

Flowers C.H., J.M. Lotz, and V. Breland. 2000. Experimental infection of the blue crab (*Callinectes sapidus*) with white spot virus. *World Aquaculture Society: Book of Abstracts.* World Aquaculture Society. Baton Rouge, Louisiana USA. 516 pp.

Johnson, P.T. 1980. *Histology of the blue crab, Callinectes sapidus: A model of the Decapoda.* Praeger Publishers, NY. 440 pp.

Johnson, P.T. 1983. Diseases caused by viruses, Rickettsiae, bacteria, and fungi. Pages 1-67 in: Bliss, D.E. (ed.) *The Biology of Crustacea: Pathobiology* Volume 6. Academic Press, Inc. New York, New York USA.

Lightner, D.V. 1996. *A Handbook of Shrimp Pathology and Diagnostic Procedures for Diseases of Penaeid Shrimp.* The World Aquaculture Society. Baton Rouge, Louisiana USA.

Lightner, D.V., K.W. Hasson, B.L. White and R.M. Redman. 1998. Experimental infections of Western Hemisphere Penaeid shrimp with Asian White Spot Syndrome Virus and Asian Yellow Head Virus. *Journal of Aquatic Animal Health* **10**:271-281.

Lo, C., C. Ho, C. Chen, K. Liu, Y. Chiu, P. Yeh, S. Peng, H. Hsu, H. Liu, C. Chang, M. Su, C. Wang, and G. Kou. 1997. Detection and tissue tropism of white spot syndrome baculovirus (WSBV) in captured brooders of *Penaeus monodon* with a special emphasis on reproductive organs. *Diseases of Aquatic Organisms* **30**:53-72

Lotz, J.M. 1997. Viruses, biosecurity, and specific pathogen-free stocks in shrimp aquaculture. *World Journal of Microbiology* **13**:405-13.

Lotz, J.M. and M.A. Soto. [2000]. A model of white spot syndrome virus (WSSV)

epidemics. *Diseases of Aquatic Organisms.* Submitted.

Soto, M.A. and J.M. Lotz. [2000]. Epidemiological Parameters of White Spot Syndrome Virus (WSSV) Infections in *Litopenaeus vannamei* and *L. setiferus*. *Journal of Invertebrate Pathology.* Submitted.

Stuck, K.C. and H.M. Perry. 1992. Life history characteristics of *Menippe adina* in Mississippi coastal waters. Pages 82-98 in: T.M. Bert (ed.) *Proceedings of a Symposium on stone crab (genus* Menippe*) Biology and fisheries.* Florida Marine Research Publications. St. Petersburg, Florida USA.

Wang, Q., B.L. White, R.M. Redman, and D.V. Lightner. 1999. Per os challenge of *Litopenaeus vannamei* postlarvae and *Farfantepenaeus duorarum* juveniles with six geographic isolates of white spot syndrome virus. *Aquaculture* **170**:179-194.

Spiny Lobster Fishery of the Saba Bank

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ABSTRACT

Over the past 12 months a comprehensive assessment has been made of the fish stock of the Saba Bank. The assessment was initiated by the Environmental Department of the Government of the Netherlands Antilles in Curaçao, whereby the condition of the fisheries resources of the Saba Bank was to be determined.

Over the past 12 months the Saba Bank fishermen engaged in two types of fishery: spiny lobster (*Panulirus argus*) fishery, and snapper fishery, with two main target species: silk snapper (*Lutjanus vivanus*) and blackfin snapper (*Lutjanus buccanella*). The main fishery activity on the Saba Bank is the lobster fishery; snappers are only targeted sporadically.

The objective of the fish stock assessment program was to collect fishery dependent data on the different target species of the Saba bank.
Alongside data on catch per unit of effort of the lobster fishery, biological data, such as, length frequency, length weight relationship, sex, number of females carrying eggs, and the number of lobsters in ecdysis, were collected.

During the study it became apparent that a high percentage of lobsters landed were under-sized and a substantial percentage of berried lobsters were landed. Furthermore a considerable number of traps were lost, due to passing by traffic and hurricanes. None of these traps were fitted with a biodegradable panel and the lost traps are extremely damaging to the ecology and consequently the fish stock of the Saba Bank.

As a result of this study, the following regulations are now being strictly enforced:

i) Presence of a biodegradable panel in each trap.
ii) Legal size limits for lobsters.
iii) Prohibition to land berried lobsters.
iv) Prohibition to land lobsters in ecdysis.
v) Prohibition to fish without a licenses in both the Saban territorial waters and the Economic Fishery Zone (EFZ) of the Netherlands Antilles.

Collecting fishery data alongside enforcement of the fishery regulations will enable successful management and will in the end result in sustainable exploitation of the fishery resources of the Saba Bank.

KEY WORDS: Spiny lobster, Saba Bank, stock assessment

BACKGROUND AND JUSTIFICATIONS OF THE RESEARCH

The Saba Bank (Figure 1) is a large, totally submerged shallow, marine area off the island of Saba. The Bank is important as a fishery resource for fishermen from Saba, St. Eustatius and St. Maarten.

Frequent reports of decreasing fish stocks, destructive fishing activities of foreign vessels, anchoring of oil tankers and tank cleaning, has raised concerns about the environmental state of the Bank. Meesters et al. (1996), commissioned by the Environmental Section reviewed the Saba Bank in 1996 in combination with a short study on location. He concluded that the habitat of the Saba Bank is particularly important for several reasons:

i) The significance of the sea-current patterns suggest that the reefs are potentially an important source of fish and shellfish larval disposal to the islands of Saba, St Maarten and to the islands in the eastern Greater Antilles;

ii) The coral reefs of the Saba Bank are relatively remote from intense human impact and may not only provide important scientific information on the status of reefs in relatively unspoiled condition, but are also a reserve of biodiversity for the region;

iii) The reefs of the Saba Bank are potentially a resource for dive-tourism and an essential resource for fishing.

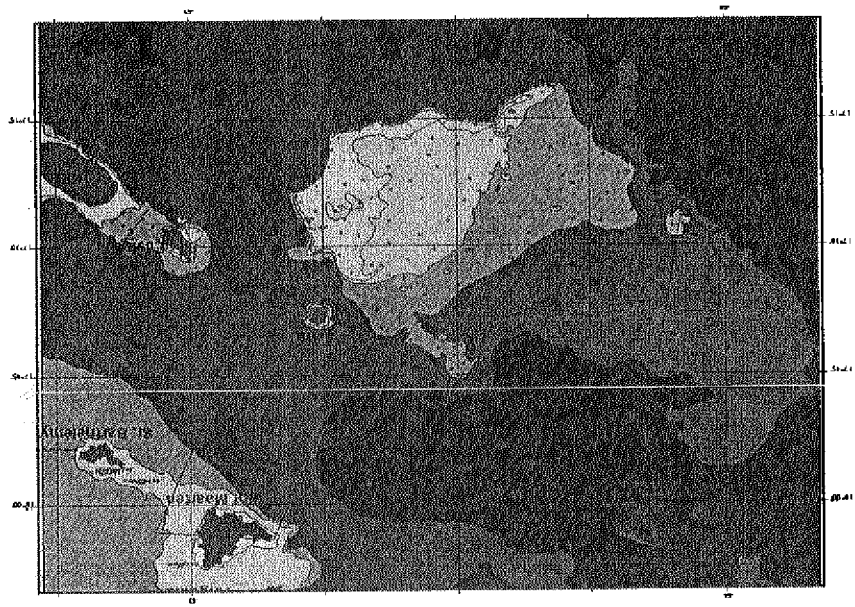


Figure 1. Map of the Saba Bank (Scale 1:550,000)

Meesters's study also recommended that a management plan should be developed in order to preserve this unique marine habitat. The National Policy paper "Contours of Environmental & Nature Conservation Policy for the Netherlands Antilles" incorporated this recommendation, and again in the National Nature Policy Plan of 2000 the development of a management plan for the Saba bank is stated as an important objective. As a first step to realize such a management plan, the Environmental Section initiated a comprehensive fishery catch assessment survey in order to get an impression of the fisheries resources of the Saba Bank.

During the time of the assessment (from April 23rd, 1999 to May 30th, 2000) an abundance of fishery dependent data was collected, which will contribute to formulation of an adequate management plan for sustainable exploitation of the fishery resources of the Saba Bank.

MATERIALS AND METHODS

The Saba Bank Fish fishery monitoring program has collected fishery-dependent data of the Saba Bank fishery from April 23, 1999 to May 30, 2000 commissioned by the Environmental Division of the Department of Public Health and Environmental Hygiene of the Netherlands Antilles, which is located in Curaçao. In an exploited fishery, assessment involves determining the current state of the resource, including the degree of exploitation. Extensive data had to be collected from the Saba Bank fishery in order to estimate population parameters. The monitoring program required several different types of information from the fisheries survey.

Before the program started a schedule was prepared, outlining all activities for the coming period, and establishing the standard way of measuring. Data were collected in the Saba harbor on length-frequency of the catch, collected during daily sampling from the stock, as well as data on total catch and effort. The lobsters (*Panulirus argus*) were measured as consistently and accurately as possible. In Saba harbor the carapace length (CL) of lobsters was measured to the nearest millimeter and 150 male and female lobsters were measured and weighed in order to obtain a reliable length-weight relationship. A kitchen-scale was used for this purpose. The length of the carapace of the lobsters was measured with a caliper.

During sampling, data were collected to obtain specific biological parameters useful in either estimating yield, or providing a basis for fisheries management strategies. In addition to the catch and effort data of the lobster fishery, biological data, such as, length frequency, length-weight relationship, sex, number of females carrying eggs, and the number of molting lobsters (lobsters in ecdysis) were collected.

Catch and effort data were collected on a daily basis in Saba harbor, including also the fishing grounds and species composition of the catch.

The data were entered on a data form, and later entered into Microsoft Excel, and/or MS-Access. Catch and effort data of landings on Saba and St. Maarten were stored in a central database (MS-Access) located in Saba, while length-frequency

data were stored in MS-Excel files. The required information included date, boat name, fishing hours, number of gear hauled, soak time, weight of catch and by-catch. Furthermore the monitoring program included a frame survey. The frame survey was conducted to detect the landing practices and to count the number of boats, the number of gear types, and the number of fishermen. The fishermen were interviewed in order to obtain this information.

An important part of the monitoring program consisted of giving feedback to all parties involved. At regular intervals the preliminary results and progress of the program were presented, which resulted in an excellent participation of the fishermen in the monitoring program. The collected fishery dependent data are now available at the Department of Public Health and Environment in Curaçao.

RESULTS

Catch and Effort Data

During the project a lobster catch of 89,235 kilograms was recorded. Although this is the great majority of the catch, not all lobsters caught were recorded. In order to obtain the approximate total lobster catch a raising factor is used to correct the recorded catch. An estimated 11.5 % of the lobster catch was not included in the records. This percentage is based on the number of days no data was collected. Total catch then comes to about 100 tons.

(Figure 2) displays the total lobster catch and effort distributed over the time of the project. The lobster catch and effort over the year fluctuates considerably (Figure 2). The hurricane season (from July till December) had a great impact on the lobster catch and effort. Lobster catch and sale were fairly good from May, 1999 till August, 1999. September is considered the month most hurricanes occur, and consequently tourism decreases during this month. September, October and November are considered low season months for tourism and as a result there is only limited sale for lobsters. On October 20, 1999 hurricane José passed over the Windward islands, followed by hurricane Lenny on November 18-19. These hurricanes had a negative influence on the lobster catch and fishing effort, since most fishermen took their boats out of the water before the hurricanes, and lost a considerable number of gear. Although the fishermen suffered great losses i.e. gear, boats, etc., the lobster catch increased substantially within two months after the hurricane season, in an attempt to meet the demand for lobsters, since the months of December to May are considered high season months for tourism.

Biological Data

Size —The carapace length (i.e. the distance from the base of the supraorbital horns to the posterior edge of the carapace) is the usual measure of body length in spiny lobster. The fishery law of the Netherlands Antilles forbids catching of lobsters with a carapace length smaller than 9.5 cm. This carapace length is approximately equivalent to a total body length of 25 cm, and a weight of 680 gram. This minimum

length originated from the Harmonized Fisheries Legislation Project, guided by the FAO, which had the objective to match the fisheries legislations of the islands of the Lesser Antilles.

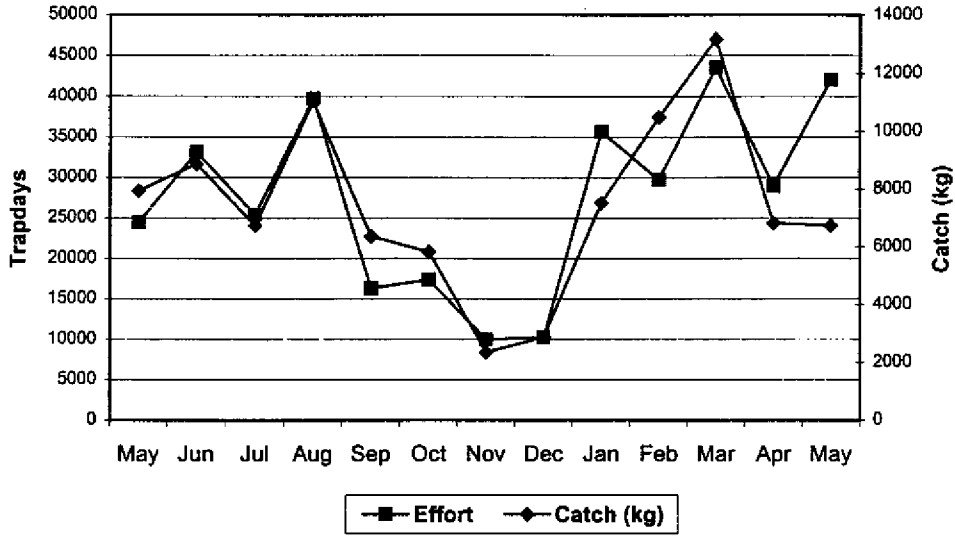


Figure 2. Distribution of the monthly lobster catches and effort from May, 1999 to April, 2000.

From April 23, 1999 to, May 30, 2000 53,522 lobster traps were hauled and 70,914 spiny lobsters, (*Panulirus argus*) with a corresponding weight of 89,235 kilograms were recorded caught. The carapace length (CL) of 29,802 lobsters was measured. The total amount of lobsters sampled, the percentage of lobsters with a CL of less than 9.5, the average length and average weight of the sampled lobsters are shown in Table 1. The average CL displays a fall in the months of April to September. Length-frequency analysis of the lobster catch shows that this maybe due to recruitment of small lobsters.

As shown in the table, 28.0 percent of the lobsters sampled over the past 12 months had a CL of less than 9.5 cm. The high percentage of under-sized lobsters has been reason for serious concern, because it could indicate that the lobster stock of the Saba Bank was being over-harvested. The latter was reason for the Government to take action to halt the high percentages of under-sized lobsters. The Coast Guard of the Netherlands Antilles has started to enforce the fishery regulations. After the first control on 21st of March one could notice that the fishermen practically stopped landing illegal size lobsters. Consequently, the average CL increased as the number of under-sized lobsters landed decreased.

Table I. Number of lobsters measured per month, number of lobsters with a carapace length (CL) less than 9.5 cm and average CL sampled

	# Measured	# CL < 9.5	% CL < 9.5	CL avg. (cm.)
April	1,377	203	14.7	11.5
May	2,562	607	23.7	11.0
June	3,518	1109	31.5	10.6
July	2,245	830	37.0	10.5
August	3,468	1,420	40.9	10.2
September	2,191	924	42.2	10.0
October	1,857	598	32.2	10.4
November	681	180	26.4	10.9
December	1,655	468	28.3	10.7
January	2,930	750	25.6	10.8
February	1,892	480	25.4	10.8
March	3,230	540	16.7	11.1
April	1,146	76	6.6	11.7
May	1,050	81	7.7	11,7
Total:	29,802	8,266	28.0	10.7

In the size composition of the catches, length-frequencies of male lobsters exceed those of female lobsters. Furthermore both absolutely and relatively more under-sized females than under-sized males are captured. A length-converted catch curve (assuming $L\infty = 19.00$ and $k = 0.3$) for males and female lobsters gives a Z (total mortality) males = 0.97 and a Z females = 1.9. This indicates a much higher fishing mortality of female lobsters with an equal natural mortality (M = 0.4 - 0.5). In other words female lobsters are much more liable to enter the traps than males. In Florida males attain the size of 7.6 mm CL in an average of 23 months, whereas females require an average of 30 months (Muller et al. 1997). Catches on the Saba Bank consist for a large part of lobsters of 3 -5 years of age. Legal sized lobsters (9.5 mm CL) have the approximate age of 4-5 years, whereas 3 years old lobsters are predominantly under-sized.

The percentages of under-sized lobsters captured are particularly high in the relative shallow parts of the Saba Bank.

Analysis of the monthly length-frequency graphs shows that on the relative shallow fishing grounds in particular, the smaller lobsters were more frequently being

captured than on the other fishing grounds. It is possible that the shallower parts of the Bank are the habitat of the sub-adults (7.0 - 9.0 mm CL), which migrate to the deeper parts of the Saba Bank as they grow bigger. Recruitment is visible particularly in the shallow parts of the Bank in the months June-September/October and less in the deeper fishing grounds.

Reproduction

Male/Female ratio — In general the percentage of male lobsters exceeds the percentage of female lobsters. During the winter months however the percentage of female lobsters among the lobsters sampled increased substantially, and in the month of February even surpassed the percentage of male lobsters.

Berried lobsters and lobsters in ecdysis — Size of first maturity was found to be in the range 7.8-8.3 cm CL for all countries in the Western Central Atlantic Fishery (WECAF) region. In Brazil, the size at first maturity was estimated at 201 mm total length by Soares and Cavalcante (1985). For Cuba, the smallest size that a berried lobster was captured was 6.7 cm CL (Cruz and León 1991), and the estimated sizes at 50% and 100% maturity were 8.1 and 9.7 cm CL respectively. In the Turks and Caicos Islands, tar spot data were recorded from sampled landings. A logit model was used to separate seasons and size (Medley and Ninnes 1997). The results largely agree with other assessments, size at first maturity was 8.3 cm CL, 50% fecundity occurred at 9.3 cm CL and full fecundity at approximately 10.8 cm. CL. The smallest size that a berried lobster was captured on the Saba Bank during the time of the monitoring was 7.6 cm CL.

Besides legal size limits for lobsters the Fishery Law of the Netherlands Antilles also prohibits landing berried lobsters, and lobsters in ecdysis (molting lobsters). Berried lobsters and spermatophoric mass on the female's sternum (tar spot) were observed during the whole period of the project.

Table 2 shows the number of berried lobsters and the number of lobsters in ecdysis among the lobsters sampled from August, 1999 to May, 2000.

As is very clear from the table, the fishermen practically discontinued landing berried lobsters and lobsters in ecdysis after the Government commenced to enforce the fishery regulations on March 21, 2000.

Table 2. Number of female lobsters sampled, percentage of berried lobsters, and percentage of lobsters in ecdysis from April 23, 1999 to May 30, 2000.

	# Measured	females sampled	# berried lobsters	% berried lobsters	# lobsters ecdysis	% lobsters ecdysis
August	3,468	1,282	59	4.6	0	0.00
September	2,191	814	49	6.0	1	0.05
October	1,857	685	32	4.7	2	0.11
November	681	298	5	1.7	1	0.15
December	1,655	786	9	1.1	3	0.18
January	2,930	1,381	19	1.4	12	0.41
February	1,892	981	17	1.7	4	0.21
March	3,230	1,450	162	11.2	6	0.19
April	1,262	489	1	0.20	0	0.00
May	1,047	405	2	0.49	2	0.19
Total:	20,213	8,571	353	4.1	29	0.14

DISCUSSION AND SIGNIFICANCE OF THE WORK

During the monitoring program it became evident that the Saba Bank fishery sector is of great importance to the island economy of Saba. The Saba Bank lobster fishery has developed into a viable semi-industrial fishery, and the means of production used in the fishery are among the most advanced utilized in the Netherlands Antilles. The contribution of the Saba Bank fishery sector, which generated approximately 1.1 million US$ in 1999, is substantial to the island economy of Saba (GDP 15.7 million US$);

i) The sector provides employment to a relatively large number of people (8% of the economically active population). About 20 people generate a living exclusively from the fishery, while a relatively large group of approximately 30 people find part-time employment in it and so generate additional income in the fishery sector;
ii) The added value and the generation of foreign exchange to the island economy of Saba are high.

It became apparent that a substantial part of the landings of lobsters consisted of illegal lobster catch. High percentages of under-sized lobsters and berried lobsters in the catch are a serious concern. Of all lobsters sampled during the study, 28 percent were under-sized. Practically all fishermen were landing large numbers of under-sized lobsters, which was encouraged by the restaurants, since small lobsters sell faster than large lobsters.

Throughout the course of the survey, relatively large amounts of berried lobsters were landed. It became apparent that certain fishermen were consistently landing berried lobsters, while others did not, unless there was a high demand for lobsters on the market. Most fishermen were willing to adhere to the regulations, but as others were repeatedly landing berried lobsters, they felt the "obligation" to do the same.

Although several fishery regulations have been in existence for quite some time, until recently they were not adequately enforced. The effectiveness of management measures is directly related to the extent they are accepted by the fishermen, and to the level of enforcement by the authorities. Most of the Saba Bank fishermen have the environmental awareness to exploit the resources of the Saba Bank in a sustainable manner. They are willing to adhere to the regulations, as long they are consistently and without exception enforced by the Government.

Enforcement is a key factor to create sustainable fisheries. The benefit to the resource users will only increase if the resource is effectively protected. As a direct result of this catch assessment survey, the Coast Guard of the Netherlands Antilles has commenced to strictly enforce the fishery regulations.

The following regulations are currently being enforced:

i) Requirement of valid fishing licenses for both the Saban territorial waters and the Economic Fishery Zone (EFZ) of the Netherlands Antilles;
ii) Use of the biodegradable panel;
iii) Legal size limits for lobsters;

iv) No landing of berried lobsters;
v) Legal mesh size;
vi) No landing soft-shell lobsters (lobsters in ecdysis).

The implementation of the fishery regulations by the Coast Guard of the Netherlands Antilles resulted in a substantial decline in illegal fishery activities:

i) The number of under-sized lobsters decreased, and practically no berried lobsters and lobsters in ecdysis were brought in;
ii) Illegal (non-licensed) fishing activities from both foreign and domestic vessels have practically stopped.

Regulation practices in the Netherlands Antillean lobster fishery differ slightly from those in the region. Regulations in the region rest on three main bases; minimum legal size, limited entry, and closed season.

Legal Size

The minimum legal size regulation in the Netherlands Antilles (minimum CL of 9.5 cm) is intended to allow the lobsters to achieve sexual maturity and to have the opportunity to spawn at least once, in order to preserve the stock's reproductive capacity. Other regional minimum legal sizes include: Cuba, 6.9 cm CL, (Estela de León and Puga 1997), Mexico, 7.4 cm CL, (Sosa-Cordero et al. 1997), USA, 7.62 cm CL, (Muller 1998), Jamaica, 7.62 cm CL, (Grant 1997), Bahamas, 8.25 cm CL, (Deleveaux et al. 1998), Bermuda, 9.2 cm CL, (Luckhurst 1998), St Lucia, 9.5 cm CL, (Joseph 1997), and Venezuela 12.0 cm CL, (Fernandez 1997). One can notice that the legal size in the Netherlands Antilles is among the highest, thus most restrictive, in the region.

Countries with a high level of management and research and large stocks can reduce their legal size, and adjust total fishing effort whenever necessary; for countries that do not possess the mechanisms to quickly adjust total fishing effort when necessary, such a more restrictive legal size is needed.

Limited Entry

Most of the WECAF-nations such as Bermuda, Cuba, the USA, Mexico, Colombia, Honduras, Jamaica, Nicaragua, Brazil, and Venezuela have some system of limited entry in place, where either the number of fishermen and/or the number of fishing units is restricted. In both the Saba island territorial waters as the Netherlands Antillean waters (EFZ) no lobster fishing can take place without a fishing license, but there are no restrictions to the number of fishing units per vessel. However, within the framework of the National Fishery Law it is possible to introduce such restrictions quite easily via a National Decree.

Closed Season

The main lobster producing countries in the region have a closed season in place. The closed season regulation has three main objective:

i) Ensure reproduction during the peak spawning period;
ii) Protect the molting period;
iii) Allow growth and thus increase in weight, of a major part of the population (Cruz 1998).

The Netherlands Antilles has no closed season regulation in place as yet, but it might consider either closing the lobster fishery during the spring months in order to ensure reproduction during the peak spawning period or closing the lobster fishery during the hurricane season. During the hurricane season lobster sale and, consequently, fishing effort are traditionally low.

Closing the lobster fishery during the hurricane season has the following advantages:

i) Prevent loss of fishing gear;
ii) Allow precise counting and tagging of the lobster traps;
iii) Allow growth and thus increase in weight, of a major part of the population (Cruz 1998).

Furthermore, the fishery regulations in all countries include a permanent prohibition to catch or land lobsters in ecdysis and female lobsters in reproductive condition. This also applies in the case of the Netherlands Antilles.

LITERATURE CITED

Develeaux, V., G. Bethel. 1997. National Report on The Spiny Lobster Fishery in the Bahamas. Pages 166-172 in: *FAO Fisheries Report No 620*. Rome, Italy. Estela de León and M. R. Puga. 1997. Lobster Fisheries in Cuba. Pages 201-206 in: *FAO Fisheries Report No. 620*. Rome, Italy..

Fernandez, J.C. 1997. La pesqueria de langostas en Venezuela. Pages: 123-127 in: *FAO Fisheries Report No. 620*. Rome, Italy..

Grant, S. 1997. National Report of Jamaica. Pages: 220-230 in: *FAO Fisheries Report No. 620*. Rome, Italy.

Joseph, W. 1997. Saint Lucia Country Report. Pages: 257-259 in: *FAO Fisheries Report No. 620*. Rome, Italy.

Luckhurst, B.E. 1997. National Report of Bermuda. Pages 180-182 in: *FAO Fisheries Report No. 620*. Rome, Italy.

Meesters, E.H., H. Nijkamp, and L. Blijvoet. [1996]. Towards sustainable management of the Saba Bank. Aide Environment Amsterdam, the Netherlands. 58 pp. Unpubl. Ms.

Muller, R., 1997. Additional Report of the United States of America Pages: 281-284 in: *FAO Fisheries Report No. 620*. Rome, Italy.

Soares, C.N.C. and P.P.L. Cavalcante. 1985. Caribbean Spiny Lobster (*Panulirus argus*) and smooth tail spiny lobster (*Panulirus laevicauda*) reproductive dynamics on the Brazilian Northeastern coast. Pages 200-217 in: *FAO Fish Report No. 327*. Rome, Italy.

Sosa-Cordero, E., V. Ríos Lara, A.M. Acre, and M.A. Cabrera Vázquez, 1997. La Pesquería de Langosta en México, Yucatán y Quintana Roo. Pages: 231-240 in: *FAO Fisheries Report No. 620*. Rome, Italy.

Preliminary Estimations of Growth, Mortality and Yield Per Recruit for the Spiny Lobster, *Panulirus argus*, in St. Croix, USVI

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ABSTRACT

Preliminary growth and mortality parameters for the spiny lobster *Panulirus argus* were estimated from length frequency data collected from the St. Croix commercial fisheries from 1995 through 1999 using the FISAT software package. The corresponding values of L_∞ for female spiny lobsters using ELEFAN I ranged from 170 to 177 mm CL, and K values were 0.20 to 0.23. For males the L_∞ values ranged from 185 to 197 mm CL, and K values ranged from 0.23 to 0.28. The length-converted catch curve and Beverton and Holt Z estimates ranged from 1.24 to 1.91 for males and 0.8 to 1.58 for females. The Z estimated from Jones length cohort analysis ranged from 0.83 to 1.15 for males and 0.65 to 0.83 for females. The exploitation ratios from length catch curve ranged from 0.73 to 0.82 for males and 0.58 to 0.76 for females. Meanwhile, exploitation rates from Jones length cohort analysis ranged from 0.59 to 0.70 for males and 0.47 to 0.64 for females. Nevertheless, average exploitation ratios from the two different methods were well above the optimum exploitation rate (E = 0.5) suggesting that the St. Croix spiny lobster is overfished. The Beverton relative yield per recruit model analysis for 1999 for males implies that with values of E = 0.66 and Lc = 95.4 mm the current lobster fishery is harvesting approximately 98% of the potential yield. Likewise, the analysis for females shows that with a value of E = 0.58 and Lc = 89.36 mm the fishery is harvesting 95% of the potential yield in females. According to these results, it is very important for all fishery agencies in the US Caribbean to reevaluate the status and conditions of the spiny lobster stocks and the definitions of overfishing for this economically important resource.

KEY WORDS: Growth, mortality, *Panulirus argus*

INTRODUCTION

The spiny lobster, *Panulirus argus*, is the most economically important crustacean caught throughout the entire Caribbean, and it is widely distributed in the Western Atlantic from Bermuda to Brazil (FAO 1993). In St. Croix, US Virgin Islands (USVI), the spiny lobster is fished commercially by free diving, scuba diving, and by fish traps. This species represented almost 6% of the total catch reported during 1998 - 1999 (Tobias 2000). The fishery has been managed under territorial and federal jurisdictions with a fishery management plan (FMP) administered by the

Caribbean Fishery Management Council (CFMC) since 1985 after indications of overfishing were observed in the US Caribbean during the early 1980s (CMFC 1985). The established regulations are:

i) A minimum size of 89 mm in carapace length,
ii) A prohibition against retaining egg-bearing lobsters,
iii) A requirement to land lobster whole, and
iv) Gear restrictions prohibiting the use of poisons, drugs or other chemicals as well as spears, hooks explosives, or similar devices in harvesting spiny lobsters.

Growth and mortality parameters have been estimated for the spiny lobster throughout the Caribbean using different techniques, such as tagging studies (Munro 1974, Olsen and Koblic 1975, Clairovin 1980, Waugh 1981, Lozano et al. 1991, Muller et al, 1997) and length frequency analysis from commercial fishery data (Baez et al. 1991, Phillips et al. 1992, Haughton and King 1992, Leon et al. 1995). However, estimating growth rates of *P. argus* by length frequency analysis has been unsuccessfully attempted for the USVI (Bohnsack et al. 1992). On the last spiny lobster stock assessment workshop held by the Caribbean Fishery Management Council, the scientific panel attempted to build reliable yield per recruit analysis models using length frequency data from the Puerto Rico and USVI commercial fisheries. However, they could not get reliable estimates of growth parameters, such as L_∞ (asymptotic length) and K (body growth coefficient), for various reasons: data were limited and carapace measurements were to the nearest one tenth inch, which was too wide an interval to show distinct size frequency peaks.

This study attempts to evaluate the use of length frequency analysis based upon biostatistical data from the St. Croix commercial lobster fishery to estimate growth and mortality parameters, and to construct a reliable yield per recruit analysis.

METHODS

Information of historical landings, harvest rates, and fishing effort data (i.e. number of boat trips, number of traps) was obtained through the National Marine Fisheries Service (NMFS) Cooperative Statistics Program. Biostatistical data of *P. argus* were collected by port agents from 1995 to 1999. Each lobster was weighed to the nearest 25 g. Carapace length (CL) was measured to the nearest 0.1 mm and sex was determined. The sample size per month ranged from 0 to 636 individuals per month. Biostatistical data were entered into the Trip Interview Program (TIP) developed by the National Marine Fisheries Service (NMFS), Southeast Fishery Science Center. Later, the data were converted and analyzed in Excel. To enhance modal definition for length frequency analysis, samples were pooled tri-monthly for each year and assigned a single collection date for each year. Differences on length frequency distributions by sex and by years were examined using Kolmogorov-Smirnov test (KS) (Sokal and Rohlf 1981).

Estimation of Growth Parameters and Mortality

Analysis of growth parameters assumes Von Bertalanffy growth: $L_t = L_\infty (1-Le^{k(t-t_0)})$, where L_t is the carapace length at time t, L_∞ is the asymptotic length an individual would reach if it lived indefinitely, and k is the rate at which L_∞ is approached. The growth parameters L_∞ and K were estimated using ELEFAN I from the FISAT software package (Gayanilo et al. 1995). Comparisons of different estimates of growth parameters were done using the empirical equation of Pauly and Munro (1984): phi= Log_{10} K + 2 Log_{10} (L_∞).

Instantaneous total mortality (Z) (Beverton and Holt, 1957), fishing mortality (F) and length at first capture (Lc) were calculated using length-converted catch curve (Ricker, 1975, Pauly 1984). These analyses were performed by converting the data of each monthly sample to percent frequency and then weighting by square roots of the sample size. Giving all monthly samples equal weight prevents a single large monthly sample from being a major source of bias or from overly affecting the total annual sample. Since estimates of natural mortality (M) of spiny lobster in the USVI are unknown, we are using estimates from literature for subsequent analysis (M = 0.34) CFRAMP/FAO Spiny Lobster Stock Assessment Workshop (CFRAMP 1997). Exploitation rates were calculated with the Pauly and Soriano (1986) exploitation rate formula: E=F/Z. Jones' length cohort analysis (Jones 1984) was used to estimate stock size biomass, as well as total and fishing mortalities and exploitation ratios. Yield per recruit analyses were conducted using Beverton and Holt yield/recruit relative (Y'/R) and biomass/recruit relative (B'/R) models (Beverton and Holt 1957). Maximum sustainable yield (MSY) for *P. argus* was calculated using Fox (1970) and Schaefer (1954) surplus yield models. Catch data and effort data, which could be used to calculate MSY, were available for the 1993 - 1998 fishing seasons.

RESULTS

Commercial Landings Data

Spiny lobster landings increased steadily from 1978 to 1998, from landings of 3,400 kilograms (kg) to more than 17,700 kg. Average landings during the 1980s were 3,550 kg while in the 1990s averaged 13,732 kg (Figure 1). Divers accounted for approximately 85% of the total landings throughout the years from 1990 to 1998 (Figure 2). Fishing effort for 1993 - 1998 fishing seasons (as defined by number of fishing trips) has averaged about 4,690 trips per year (Figure 3) while number of fish traps per year averaged about 1,488 traps (Figure 4). Mean total catch per unit effort (CPUE) for 1993 - 1998 fishing seasons varied from 2.9 kg per trip in 1993 to 4.5 kg in 1998 (Figure 5). The number of kilograms landed per fishing trips by gear for 1993-1998 fishing seasons has averaged 7.2 kg per trip for divers and 0.7 kg for fish traps. Mean CPUE by trap averaged 1.3 kg per trap (Figure 6).

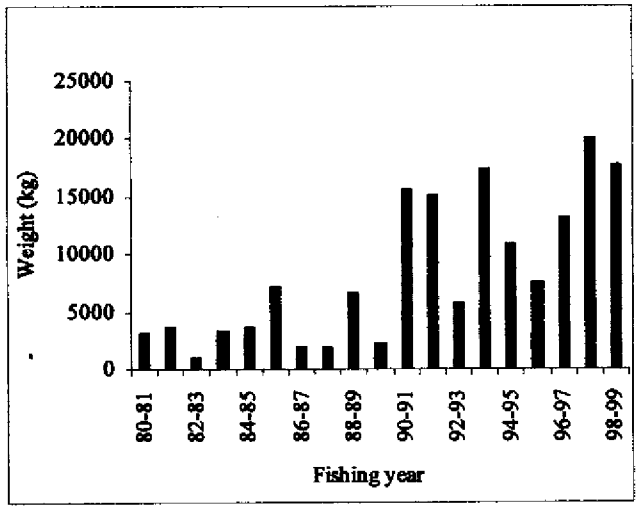


Figure 1. Spiny lobster *P. argus* commercial landings from fishing years 1980 - 1998 in St. Croix USVI.

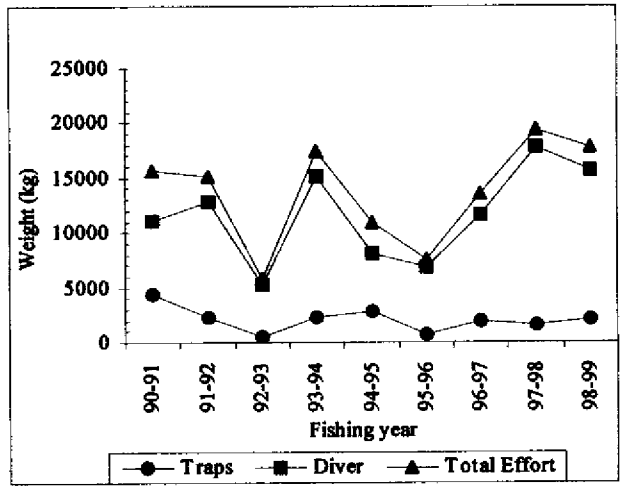


Figure 2. Landings of *P. argus* reported by gear and all gears combined during the 1990 - 1998 fishing years in St. Croix, USVI.

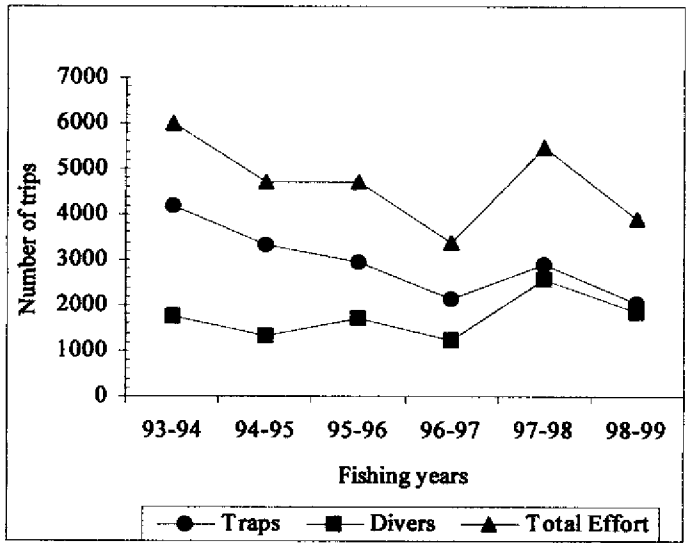


Figure 3. Number of fishing trips by gear and all gears combined (total effort) during the 1993-1998 fishing years in St. Croix, USVI

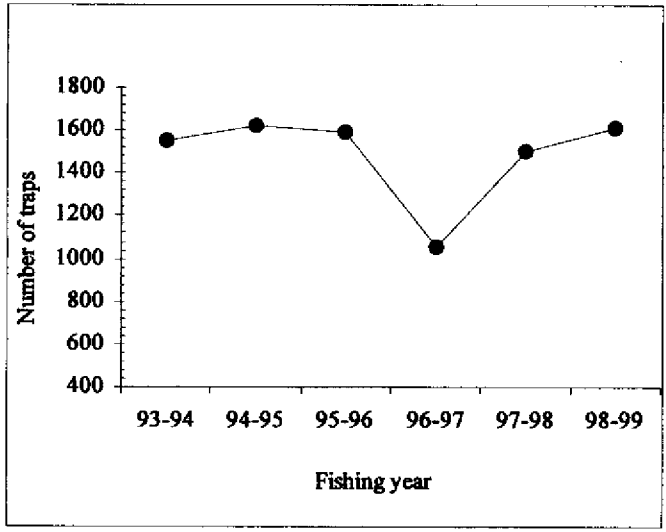


Figure 4. Total number of traps per fishing years 1993 - 1998 in St. Croix, USVI

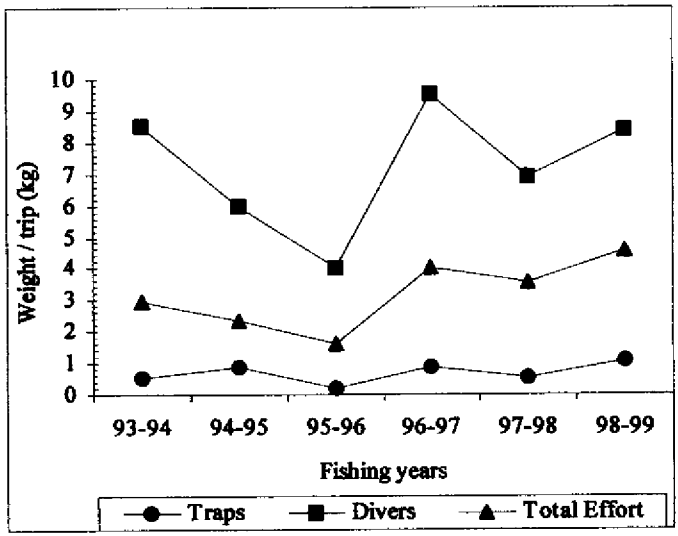


Figure 5. Average weight (kg) per trip by gear and all gears combined (total effort) for *P. argus* during the 1993 - 1998 fishing years in St. Croix, USVI.

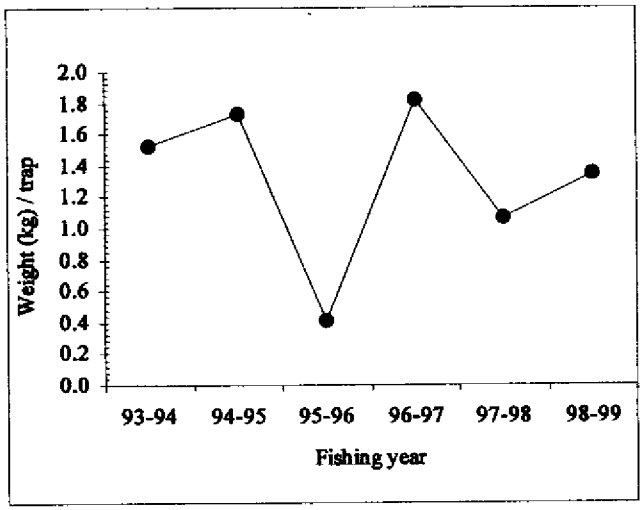


Figure 6. Mean catch (kg landed) per trap for *P. argus* during the1993 - 1998 fishing years in St. Croix, USVI.

Size Distribution

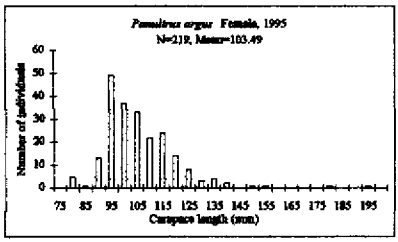
During the period of 1995 - 1999, 2,862 lobsters were measured, of which 1,734 were males and 1,128 females. The male:female sex ratio was skewed toward males (1.5) most likely because females with eggs were not landed, and this caused to bias the ratio. The size range was from 75 mm to 190 mm carapace length (CL). The mean CL for males and females were 108.44 mm and 103.42 mm, respectively. The average modal lengths for males and females were 100 mm and 93 mm, respectively. CL for males was significantly larger than those of the females (KS, $p = 0.014$) (Figure 7). Less than 4% of the lobsters measured from 1995 to 1999 were under the legal size limits. When average lengths were compared by years, there was a significant decline in mean CL in males from 1995 to 1999 (KS, $p = 0.01$) but not in females (KS, $p = 0.16$).

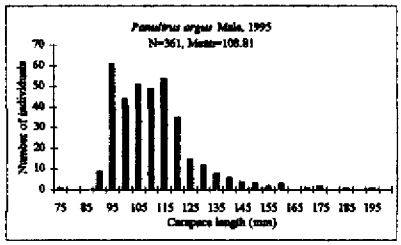
Growth and Mortality Parameters

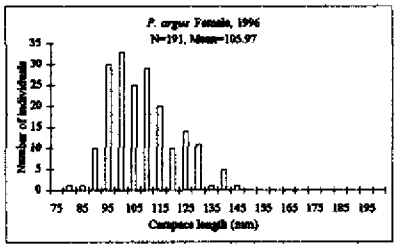
The estimated values of L_∞ for females ranged from 170 to 177 mm CL (Table 1), and K values ranged from 0.20 to 0.23. For males the L_∞ values ranged 185 to 197 mm CL, and K values ranged from 0.23 to 0.28. These results showed that males had a faster growth rate and attained their maximum size more quickly than females. Females had higher good fitness indices (Rn) of ELEFAN I.

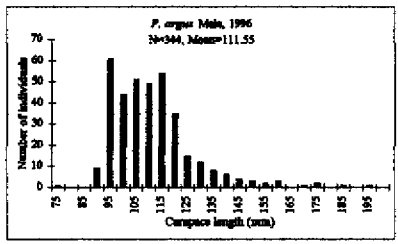
The length-converted catch curve and Beverton and Holt Z estimates ranged from 1.24 to 1.91 for males and 0.8 to 1.58 for females (Table 1). Length at first capture (Lc) for males ranged from 94.8 to 108.6 mm and 89.3 to 93.3 mm for females. The Z estimated from Jones length cohort analysis ranged from 0.835 to 1.15 for males and 0.65 to 0.83 for females (Table 2). The exploitation ratios from length converted catch curve ranged from 0.73 to 0.82 for males and 0.58 to 0.76 for females. Whereas, exploitation rates from Jones length cohort analysis ranged from 0.59 to 0.70 for males and 0.475 to 0.64 for females. Average exploitation ratios from the two different methods were well above the optimum exploitation rate ($E = 0.5$) suggesting that the St. Croix spiny lobster is overfished.

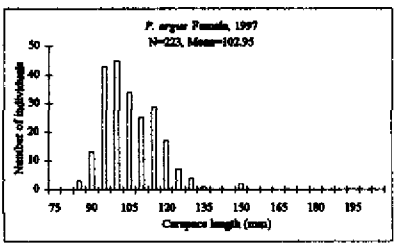
Estimates of stock size and fishing mortality were obtained using Jones length cohort analysis (Table 3). The results suggest that approximately 91,530 lobsters in the 82 to 84 mm range were recruited to the fishery for 1999. The total catch for 1999 was approximately 57,300 lobsters. Estimate of total biomass was 87 metric tons (t). The total number of survivors was 33200. The mean fishing mortality and exploitation ratio for fully recruited length groups was 0.472 and 0.581 for females while 0.663 and 0.670 for males, respectively. Due to the tendency of length catch curve methods to overestimate mortality parameters due to variable recruitment and migration of larger specimens we decided to use the results from Jones length cohort analysis for the yield per recruit analysis.

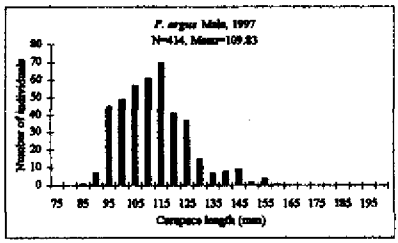


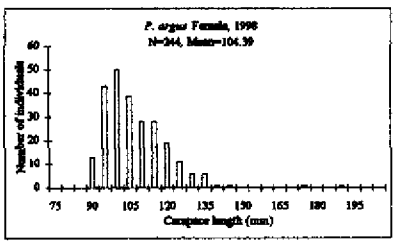


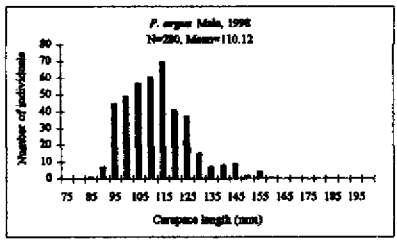


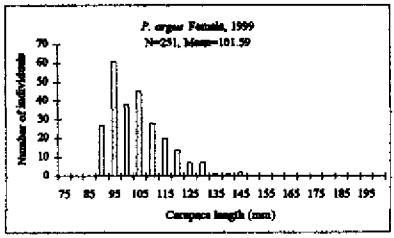












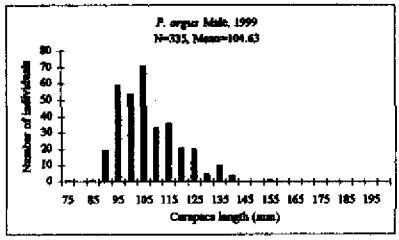


Figure 7. Length frequency distributions for male and female spiny lobster, *P. argus*, for the 1995 - 1999 fishing years in St. Croix, USVI.

Table 1. Estimates of length (L_∞), body growth rate (K), goodness of fit index (Rn), age at birthday (T_0), fishing mortality (F), exploitation ratio (E=F/Z), and length at first capture (Lc) by sex for the spiny lobster, St. Croix, USVI.

Sex/ Parameters	L_∞	K	Rn	T_0	Z_1	Z_2	F	E	Lc
Male									
1995	197	0.28	0.155	0.35	1.84	1.82	1.48	0.81	94.80
1996	195	0.26	0.182	0.38	1.91	1.84	1.50	0.82	108.67
1997	185	0.24	0.142	0.42	1.43	1.24	0.90	0.73	100.10
1998	193	0.25	0.141	0.40	1.41	1.44	1.10	0.76	96.12
1999	191	0.23	0.144	0.44	1.60	1.90	1.56	0.82	99.18
Female									
1995	172	0.23	0.142	0.45	1.17	1.22	0.88	0.72	91.38
1996	172	0.20	0.161	0.52	0.80	0.87	0.53	0.61	91.63
1997	177	0.23	0.176	0.45	1.28	1.58	1.24	0.78	93.34
1998	170	0.20	0.142	0.52	0.83	0.81	0.47	0.58	90.10
1999	173	0.22	0.180	0.47	1.25	1.41	1.07	0.76	89.30

Z_1= Beverton and Holt,Z
Z_2=Length Catch Curve Z

Table 2. Estimation of abundance (N), biomass (T), fishing mortality (F), exploitation ratio (E), and instantaneous total mortality (Z), by sex using Jones length cohort analysis for the spiny lobster at St. Croix, USVI.

Sex/ Parameter	N	T	F	E	Z
Male					
1995	41862	37.53	0.82	0.71	1.16
1996	40805	34.84	0.61	0.64	0.95
1997	91036	83.31	0.50	0.59	0.84
1998	47440	43.92	0.59	0.63	0.93
1999	49299	42.35	0.67	0.66	1.01
Female					
1995	37208	32.08	0.54	0.62	0.88
1996	45561	42.54	0.31	0.48	0.65
1997	38487	32.99	0.60	0.64	0.94
1998	63984	56.25	0.38	0.53	0.72
1999	51450	45.05	0.47	0.58	0.81

Table 3. Comparison of length (L_∞) and body growth rate (K) by sex using Pauly's equation Φ (phi) (Pauly 1984) for the spiny lobster from different areas in the Caribbean.

Area	Sex		(L_∞)	K	J (phi)	Source
Brasil	M		141	0.34	3.82	Dos Santos et al., 1964
		F	148	0.38	3.92	
USVI	M		153	0.44	4.01	Olsen and Koblick, 1975
		F	133	0.32	3.72	
Martinique	M		190	0.25	3.96	Clairovin, 1980
		F	188	0.23	3.91	
Bahamas	M		190	0.26	3.97	Waugh, 1981
		F	190	0.23	3.92	
Cuba	M		169	0.22	3.80	Cruz et al., 1981
		F	139	0.31	3.77	
Bermuda	M		204	0.18	3.87	Evans, 1988
		F	192	0.15	3.74	
Cuba	M		142	0.30	3.78	Baez et al., 1991
		F	122	0.3	3.65	
Mexico	M		257	0.2	4.12	Arce et al., 1991
		F	215	0.25	4.06	
Mexico	M		198	0.24	3.97	Gonzalez-Cano, 1991
		F	165	0.22	3.77	
Cuba	M		250	0.27	4.23	Phillips et al., 1992
		F	171	0.39	4.06	
Jamaica	M		210	0.24	4.02	Haughton and King, 1992
		F	195	0.28	4.03	
Nicaragua	M		169	0.23	3.82	Castano and Cadima, 1993
		F	160	0.40	4.01	
Cuba	M		190	0.31	4.05	Leon et al., 1994
		F	174	0.24	3.86	
Cuba	M		178	0.21	3.82	Baez et al., 1994
		F	171	0.21	3.81	
Cuba	M		185	0.23	3.90	Leon et al., 1995
		F	154	0.19	3.65	
Brazil	M		207	0.26	4.04	Gonzalez-Cano and Rocha, 1995
		F	162	0.18	3.67	
Mexico	M		217	0.25	4.07	Gonzalez-Cano and Rocha, 1995
		F	146	0.22	3.67	
Brazil	M		257	0.229	4.02	Ivo, 1996
		F	233	0.236	3.92	
St. Croix	M		192	0.25	3.96	Mateo and Tobias, 2000
		F	172	0.22	3.81	(this study)

Yield Estimates

The Beverton relative yield per recruit model for males in 1999 implies that with values of E =0.66 and Lc =95.4 mm the current lobster fishery is harvesting approximately 98% of the potential yield (Figure 8a). Likewise, the analysis for females show that with a value of E= 0.58 and Lc= 89.36 mm the fishery is harvesting 95% of the potential yield in females (Figure 8b). The results also indicate that the current levels of fishing pressure have not exceeded the maximum sustainable levels. The E_{MSY} (exploitation rate at its maximum sustainable yield) for

males and females (0.71 and 0.72, respectively) have not been surpassed by the current exploitation ratios (0.66 and 0.58).

Estimates of MSY varied from 15,300 to 15,500 kg within the two models. The number of trips required to harvest the MSY ranged from 5,688 to 7,644 trips.

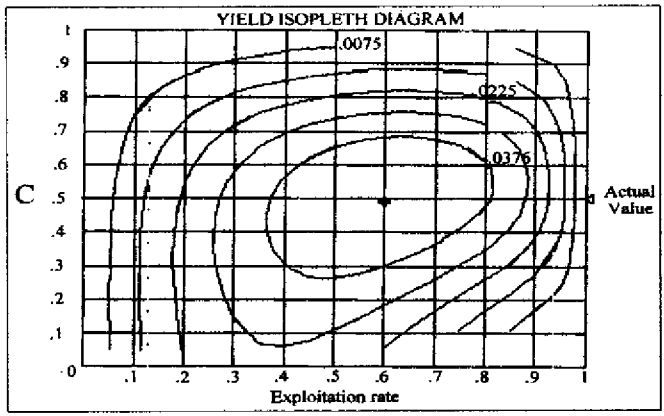


Figure 8a. Yield per recruit isopleth for male P. argus as a function of exploitation ratio (E) and size at first capture relative to asymptotic length (C).

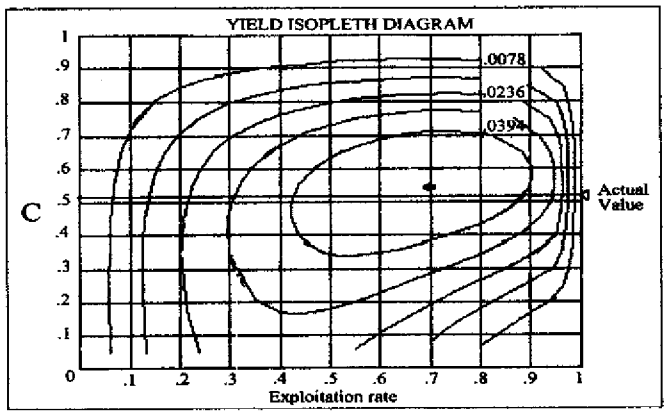


Figure 8b. Yield per recruit isopleth for female P. argus as a function of exploitation ratio (E) and size at first capture relative to asymptotic length (C).

DISCUSSION

The estimation of growth and mortality rates for *P. argus* by any presently known method is quite troublesome in nature. The adequacy of Von Bertalanffy (1938) growth functions as a reliable description of growth rates in *P. argus* depends on the validity of the assumption that growth rate is constant throughout the year (Leon et al. 1995). However, this is not the case for *P. argus* where molting frequency varies seasonally (Lipcius 1985). Previous works by Munro (1974) and Lipcius (1985) state that lobster growth is a function of two processes – molting frequency and change in size during molting. Munro (1974) stated that *P. argus* had an average of four molts per year with length increment between 5 and 8 mm in each molt. Molting frequencies do not remain constant and change throughout life. Therefore, *P. argus* juveniles have successive molts till they reach sexual maturity, and individuals of larger size molt once a year and they reproduce twice during spring-summer season.

Overall, the growth curves estimated using ELEFAN I represented a rather poor fit to the peaks in the restructured data. The goodness of fit (Rn), that can reach to a maximum of 1, was generally low ranging from a minimum of 0.142 to a maximum of 0.182. The relatively poor fit of the growth curves was probably a result of spawning year all round and the effects of seasonal growth. Previous studies on estimates of growth parameters indicate that *P. argus* is long lived, slow growing, and has low rates of natural mortality (Munro 1974, Olsen and Koblic 1975, Clairovin 1980, Waugh 1981, Lozano et al. 1991, Baez et al. 1991, Phillips et al. 1992, Haughton and King 1992, Leon et al. 1994, Leon et al. 1995). However, comparisons of growth rates by females and males found on different areas have several discrepancies. While authors such as Cruz and de Leon (1991), Baez et al. (1991), Lozano et al. (1991), Phillips et al. (1992) Castano and Cadima (1993), Haughton and King (1992) and Ivo (1996) give higher K values for females, other workers found that females had lower growth rates than males (Olsen and Koblic 1975, Clarovin 1980, Waugh 1981, Evans 1981, Gonzalez-Cano 1991, Leon et al. 1994, Leon et al. 1995, Gonzalez-Cano and Rocha 1995). These differences may be due to the sample size used and the different methods used to estimate growth. Furthermore, in some of these studies data on smaller sizes or larger sizes above 120 mm are scarce, therefore diminishing the precision and accuracy of L_∞ as well as K values. Nevertheless, Kanciruk (1980) states that *P. argus* males attain larger sizes at a faster growth rate than females similar to other species from the Panuliridae family (*P. guttatus*). This is suggested that female lobsters need to allocate their metabolic energy between growth and reproduction. Table 3 gives estimates of growth parameters for *P. argus* from different parts of the Caribbean. Growth coefficients from *P. argus*, sexes combined, are generally low ranging from 0.16 to 0.45. Estimates of L_∞ have been reported to vary from 154 to 225 mm. Our estimate of growth performance index (3.96) from *P. argus* males lies well within a 95% confidence interval (3.86 - 4.03) of phi (φ) based on a mean of 3.97 (SE = 0.03). Similarly, for females our estimate of growth performance index (3.86) lies well within a 95% confidence interval (3.78 - 3.97) of phi based on a mean of 3.85

(SE = 0.03). In brief, the results from this study are in agreement with other growth studies of *P. argus*.

Estimation of mortality parameters in *P. argus* is also difficult due to the lack of accurate age-based data and the migratory behavior of this species (Baisre and Cruz 1994). Shifts in length frequency distributions toward larger sizes in deeper waters are known for many marine organisms including the spiny lobster (Kanciruk and Hernkind 1976, Lyons et al. 1981, Baisre and Cruz 1994), reflecting ontogenetic migrations from inshore/shallow areas to offshore/deeper areas. This can produce a major problem. If migration of larger individuals into deeper waters had an effect on the length frequency distribution data from this study, it is expected that the mortalities derived from the catch curve and Beverton and Holt formula would be overestimated. The amount of bias will depend on the magnitude of K and L_∞ values and will increase if K values are low and L_∞ are high.

Total mortalities (Z) from length catch curves and Beverton and Holt (1957) formula ranged from 1.24 to 1.91 for males and 0.8 to 1.58 for females. These mortality estimates are more in agreement with data using length based methods from other highly exploited lobster populations in the region such as those of the Bahamas: Z = 1.44 (Waugh 1981); Jamaica: Z = 2.19 males, 2.88 females (Haughton and King 1992); Florida: Z = 2.59 (Warner et al. 1977), Z = 4.09 (Lyons et al., 1981), Z = 1.18 (Powers and Bannerot, 1984), Z = 1.85 (Powers, 1985); Brazil Z = 1.27 (Fonteles-Filho 1994). However, average Z from Jones length cohort analysis for males ranged from 0.83 to 1.16 while females average instantaneous mortalities ranged from 0.72 to 0.83. These values were in agreement with other lobster stock assessment studies using length/age structured methods such as in Florida: Z = 1.09 for females, Z = 1.19 for males (Muller et al. 1997); Mexico: Z = 0.95 (Zetina and Rios 1998); St. Kitts: Z = 1.09 (Goodwin et al. 1986).

Exploitation rates from males and females calculated from all methods were greater than the accepted optimum level of 0.5 and suggest that the lobster populations in St. Croix are being overfished. MSY calculated from Schaeffer and Fox model were around 15,500 kg per year. Lobster landings in St. Croix have exceeded this figure in 1990 - 1991, 1993 - 1994, 1997 - 1998, and 1998 - 1999 fishing seasons. Given the limited data, these calculations should be treated cautiously. The implication is that the fishery is fully exploited.

The reliability of Beverton yield per recruit analysis and its application to lobster populations is limited by the quality of the input parameters (Baisre and Cruz 1994). This model does not consider the effect of variable recruitment. It also assumes that spiny lobster growth conforms a Von Bertalanffy growth function, and total mortality estimates are greatly affected by growth and natural mortality rates. Mortality estimations by length catch curves and Beverton and Holt formula are often overestimated by growth parameters affected by different factors such as variable recruitment and migration (Baisre and Cruz 1994). We decided to calculate yield per recruit using estimates of mortalities from Jones length cohort analysis because age and length structured models assume neither constant recruitment nor

constant mortalities across ages or size classes (Muller et. al. 1997). Consequently, they effectively model the patterns of the fishery because of their high precision.

According to the yield per recruit analysis, increasing length at first capture Lc with the current level of effort will not result in an increase of Y/R. Likewise, no gain in Y/R would be expected if effort were increased with the current length at first capture. Species that are slow growing and long lived such as *P. argus* can be susceptible even at low levels of exploitation. By maintaining the fishery at the present level or slightly lower, it will permit the harvest of most of the potential yield but might potentially affect the spawning stock. A more conservative approach would be warranted, given the Beverton model does not account for the effect of fishing pressure on the spawning stock.

Although the mortality estimates may be subject to considerable errors as consequences of the biases in the data collected from the commercial fishery and the violations of assumptions made during analyses, the present level of fishing mortality appears to be much greater than the optimum required level for the lobster fishery. The results of the yield per recruit analysis show that fishing pressure should be decreased considerably in St. Croix. Possible management options include implementation of catch quotas, seasonal closures, or limitation on the number of fishermen or traps.

Based on the *P. argus* life history characteristics and the present results from the yield per recruit analysis and surplus production models, the most promising of the various management options for the reduction of fishing pressure on the spiny lobster would be to create a seasonal closure of the fishery. Given the current law enforcement limitations around St. Croix, this option has the best chance to be implemented. Enforcement requirements would be limited on a temporal and spatial scale, and the closure would have little impact on other sectors of the fishery.

Finally, it is very important for all fishery agencies in the US Caribbean to reevaluate the status and conditions of the spiny lobster stocks and the definitions of overfishing regarding this economically important resource. According to the SAFE report (Bohnsack et al. 1992), the assessment team concluded that St. Croix lobster populations appeared to be healthy at the levels of fishing effort based on data from 1987 to 1989, and recommended increased compliance with the minimum size regulation. Our present results indicate that lobster populations in St. Croix are apparently overfished. Besides the enforcement of fishery regulations, successful management of the US Virgin Islands spiny lobster fishery will depend on more intensive biological research together with new approaches to stock assessment in order to improve the management decisions.

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LITERATURE REVIEW

Arce, A.M., J.C. Seijo, and S. Salas. 1991. Estimación del crecimiento de la langosta *Panulirus argus* mediante funciones de singularidad. *Rev. Invest. Mar.* **12**(1):184-192.

Baez, M., E. Díaz, R. Brito, and R. Cruz. 1991. Edad y crecimineto de la langosta en la plataforma suroccidental de Cuba. *Rev. Invest. Mar.* **12**(1-3):193-201.

Baez, M., E. Carmenati., and R. Coyula. 1994. Edad y crecimineto de la langosta *Panulirus argus*a partir del analysis de frequencias de tallas en la platoforma suroccidental de Cuba. *Rev. Cub. Mar.* 15.

Baisre, J. and R. Cruz. 1994. The Cuban Spiny lobster fishery. Pages 119-131 in: B.F. Phillips, J.S. Cobb, J. Kittaka (eds.) *Spiny Lobster Management.* Fishing News Books, London, England.

Beverton, R.J.H. and S.J. Holt. 1957. On the dynamics of exploited fish populations. *Ministry of Agriculture Fisheries Investigations Series 11.* **19**: 1-533.

Bohnsack, J., S. Meyers, R. Appeldoorn, J. Beets, I. Sadovy, and D. Matos. 1992. Stock assessment of Spiny lobster *Panulirus argus* in the US Caribbean. Final Report submitted to Caribbean Fishery Management Council. 26 pp.

Castano, O. and Cadima, E. 1993. Biología y evaluación de la langosta espinosa *Panulirus argus.* Simposio sobre evaluación y Manejo de las pesquerías de Crustaceos en Nicaragua, Managua. Nicaragua 6-7 Diciembre 1993. Centro de Investigacion de Recursos Hidrobiológicos (CIRH)/NORAD) 53 pp.

CFMC. 1985. Caribbean Fishery Management Council, Spiny Lobster Fishery Management Plan. 32 pp

CFRAMP. [1997]. CFRAMP/FAO Spiny Lobster Stock Assessment Workshop. Belize. In Press

Clairovin, N. 1980. Contribution a l'etude du stock de langouste *Panulirus argus* en Martinique. *Science et Peche Bull. Peches Marit.* **300**:7-18.

Cruz, R., R. Coyulla, and A.T. Ramírez. 1981. Crecimiento y mortalidad de la langosta espinosa (*Panulirus argus*) en la plataforma suroccidental de Cuba. *Rev. Cub. Inv. Pesq.* **6**(4):89-119.

Cruz, R. and M.E. de Leon. 1991. Dinámica reproductiva de la langosta *Panulirus argus* en el archipiélago cubano. *Rev. Invest. Mar.* **12**(1-3): 234-245.

Dos Santos, E.D., R.S. da Costa, and S.J.C. de Moura. 1964. Growth of the spiny lobster *Panulirus argus* quantitatively aspect. *Arq. Est. Biol. Mar. Univ. Ceara, Fortaleza* **4** (2): 41-44.

Evans, C.R. 1988. Population dynamics of spiny lobster *Panulirus argus* and *P. guttatus* at Bermuda 1986/87. Final Report to Overseas Development Administration, UK. 98 pp.

FAO. 1993. Marine Fishery Resources of the Antilles: Lesser Antilles, Puerto Rico and Hispaniola, Jamaica, Cuba. FAO Fisheries Technical Paper. No. 326. Rome. 235 pp.

Fonteles-Filho, A.A. 1994. State of the lobster fishery in the north-east Brazil. Pages 108-118 in: B.F. Phillips, J.S. Cobb, J. Kittaka (eds.) *Spiny Lobster Management*. Fishing News Books. London, England.

Fox, W.W. 1970. An exponential surplus-yield model for optimizing exploited fish populations. *Transactions of the American Fisheries Society* **99**(1): 80-88

Gayanilo, F.C. Jr., P. Sparre, and D. Pauly. 1995. The FAO-ICLARM stock assessment tools (FISAT) Users's Guide FAO Computerized Information Series Fisheries, #8. Rome FAO. 126 pp.

Gonzalez-Cano, J.M. 1991. *Migration and Refuge in the Assessment and Management of the Spiny Lobster Panulirus argus in the Mexican Caribbean.* Ph.D. Dissertation. Imperial College. London, England. 478 pp.

Gonzalez-Cano, J.M. and C.A.S. Rocha. 1995. Problems on the estimation of growth parameters for the spiny lobster *Panulirus argus* in the Caribbean and Northeast of Brazil. Proceedings of the World Fisheries Congress Theme 5: Assessment, methodologies and management.

Goodwin, M.H., S.J, Heyliger, and R.M. Wilkins. 1986. Progress report on development of a management plan for the St. Kitts / Nevis Spiny lobster fishery. Fisheries Division, Ministry of Agriculture, St Kitts. 19 pp.

Haughton, M. and D. King. 1992. Stock assessment of the Spiny lobster *Panulirus argus* in Jamaica. *Proceedings of the Gulf and Caribbean Fisheries Institute* **42**:119-126.

Ivo, C.T.C. 1996. Biologia pesca e dinamica populacional das langostas *Panulirus argus* (Latreille) e *Panulirus laevicauda* (Latreille) (Crustacea:Palinuridae), capturadas ao longo da plataforma continental do Brasil, entre os estados do Amapa e do Espiritu Santo. Tese de Doutorado, departamento de Hidrobiologia , Universidad Federal de Sao Carlos, Sao Carlos. 277 pp.

Kanciruk, P. and W.F. Herrnkind. 1976. Autumnal reproduction in the spiny lobster *Panulirus argus* at Bimini, Bahamas. *Bulletin of Marine Science* **28**:601-623.

Kanciruk, P. 1980. Ecology of juvenile and adult (spiny lobsters). Pages 59-96 in: J.S. Cobb, B.F. Phillips (eds.) *Biology and Management of Lobsters, Vol. II.* Academic Press. New York, New York USA.

Jones, R. 1984. Assessing the effects of changes in exploitation patterns using length composition data (with notes on VPA and cohort analysis). *FAO Fisheries Technical Paper* **256.** 118 pp.

Leon, M.E., R. Puga, and Y.R. Cruz. 1994. Estimación de los parámetros de crecimiento del *Panulirus argus* del Golfo de Batabano, Cuba. *Rev. Cub. Inv. Pesq.* **18**(10): 9-12.

Leon, M.E., R. Cruz, and R. Puga. 1995. Actualización de la edad y el crecimiento de la langosta espinosa *Panulirus argus*. *Rev. Cub. Inv. Pesq.* **5**:3-9.

Lipcius, R.N. 1985. Size dependency reproduction and molting in spiny lobster and other long-lived decapods. Pages 129-148 in: H. Wenner (ed.) *Crustacean Issues, Vol. 3: Factors in adult growth.* Balkema, Rotterdam, Holland

Lozano, E., P. Briones, and B. F. Phillips. 1991. Fishing characteristics, growth and movements of spiny lobster *Panulirus argus* in Bahía de la Ascención, Mexico. *Fisheries Bulletin* **89**(1):79-89.

Lyons, W.G., D.G. Barber, S.M. Foster, F.S. Kennedy, and G.R. Milano. 1981. The Spiny Lobster *Panulirus argus*, in the middle and upper Florida keys: Population structure, seasonal dynamics and reproduction. *Florida Marine Research Publication* **38**:1-38.

Muller, R.G., J.H. Hunt, T.R. Matthews, and W.C. Sharp. 1997. Evaluation of effort reduction in the Florida Keys spiny lobster *Panulirus argus*, fishery using an age-structured population analysis. *Marine and Freshwater Research* **48**:1045-1058.

Munro, J.L. 1974. The biology, ecology, exploitation, and management of Caribbean reef fishes: crustaceans (spiny lobster and crabs). *Res. Rep. Sool. Dpr. Univ. West Indies.* 3(VI). 57 pp.

Olsen, D. and I.G. Koblic. 1975. Population dynamics ecology and behavior of spiny lobster *Panulirus argus* of St. John, Virgin Islands 2 Growth and mortality. *Natural History Museum of Los Angeles Bulletin* **20**:17-21.

Pauly, D. 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Studies and Reviews 8. Manila, Philippines. 325 pp.

Pauly, D. andJ.L. Munro. 1984. Once more on the comparison of growth of fish and invertebrates. *Fishbyte* **2**(1):21.

Pauly, D. and M.L. Soriano. 1986. Some practical extensions to Beverton and Holt relative yield per recruit model. Pages 491-496 in: J.L. Maclean, L.B. Dizon, and L.V. Hosillo (eds.) *The First Asian Fisheries Forum.* Asian Fisheries Society. Manila, Philippines.

Phillips, B.F., M.J. Palmer, R. Cruz, and J.T. Trendall. 1992. Estimating growth of the spiny lobster *Panulirus cygnus*, *Panulirus argus*, and *Panulirus ornatus*. *Australian Journal of Science Research* **45**(5).

Powers, J.E. 1985. An update of spiny lobster assessment data. National Marine Fisheries Service, Southeast Fisheries Center ML1-85-28. 10 pp.

Powers, J.E. and S.P. Bannerot. 1984. Assessment of spiny lobster resources of the Gulf of Mexico and southeastern United States. National Marine Fisheries Service, Southeast Fisheries Center, Miami, FL. 25 pp.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada* 191. 382 pp.

Schaefer, M.B. 1954. Fisheries dynamics and the concept of maximum equilibrium catch. *Proceedings of the Gulf and Caribbean Fisheries Institute* **6** 53-63.

Sokal, R.R. and F.J. Rohlf. 1981. *Biostatistics, 2nd Edition.* Freeman. San Francisco, California USA.. 859 pp.

Tobias, W. [2000]. State/Federal Cooperative Fishery Statistics Program. Final Report, Government of the US Virgin Islands. In Press.

Von Bertalanffy, L. 1938. A quantitative theory of organic growth. *Human Biology* **10**(2):181-213.

Warner, R. E., C.L. Combs, and D.R. Gregory. 1977. Biological studies of the Spiny lobster, *Panulirus argus* in South Florida. *Proceedings of the Gulf and Caribbean Fisheries Institute* **29**:166-183.

Waugh, G.T. 1981. Management of juvenile spiny lobster *Panulirus argus* based on estimated biological parameters from Grand Bahamas Island Bahamas *Proceedings of the Gulf and Caribbean Fisheries Institute* **33**:271-289

Zetina, M.C.and G.V. Rios. 1998. Estimación del tamaño de la población de langosta *Panulirus argus* en las costas de Yucatán, usando diferentes modelos de evaluación. *Proceedings of the Gulf and Caribbean Fisheries Institute* **50**: 163-175.

Movement Patterns of Tagged Spiny Lobsters *Panulirus argus* on the Bermuda Reef Platform

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ABSTRACT

A tagging program for spiny lobsters (*Panulirus argus*) commenced in April 1997 using mainly sub-legal sized (< 92 mm CL) lobsters obtained from commercial trap fishers during the lobster open season (September 1- March 31). As of October 2000, a total of 576 lobsters have been tagged with Floy anchor T-bar tags. There have been 51 recaptures of tagged lobsters to date for a recapture rate of 8.9 %. The longest distance (point-to-point) moved by a recaptured lobster was 45.9 km, which is essentially the length of the long axis (NE to SW) of the Bermuda reef platform. Similar movements by other recaptured lobsters demonstrate that movements of this magnitude occur in both directions on the platform. All recaptures except one have been reported by commercial lobster trap fishers, the one exception being a recapture reported by a recreational lobster diver. The mean straight-line distance travelled by all recaptured lobsters regardless of time at liberty was 12.2 (± 11.4, SD) km. The range of days at liberty was 9 - 700 days with a mean value of 294 (± 168 SD) days. The assessment of movement patterns of spiny lobsters is an important element in the management of the limited entry lobster fishery because of the use of defined trapping areas on the reef platform as an integral part of the management program.

INTRODUCTION

Traditionally, commercial lobster fishing around Bermuda was conducted using Antillean arrowhead wire traps set on the reef platform and two offshore banks. These traps were used for both lobsters and fish with the funnel configuration and baiting procedure being modified dependent on the target species.

Knowledge of spiny lobster movement patterns on the Bermuda reef platform is limited. Sutcliffe (1952) examined the size frequency and sex ratio of lobsters caught in traps around Bermuda during the summer months. He found that migrations were associated with breeding and that there was as a definite relationship between depth and/or distance from shore and size of lobsters. Evans and Lockwood (1996) conducted a tag-recapture program for sub-legal sized (< 92 mm CL) *P. argus* on the Bermuda reef platform from August 1986 to September 1987. They concluded that undersized lobsters, particularly females, were capable of swift and lengthy migrations.

In 1990, the use of fish traps was banned as a management measure to aid in the recovery of overfished reef fish stocks. As a consequence, the commercial harvest

of spiny lobsters was curtailed as the same traps were used for lobsters. As the spiny lobster population was considered to be healthy, an experimental fishery was established to develop and test designs for a lobster-specific trap which would have a minimal reef fish by-catch. After testing several different designs and sizes with commercial fishers (Ward and Luckhurst 1996), an acceptable trap design was developed. In 1996, a highly regulated limited entry commercial lobster fishery was established (Luckhurst 1999) with the Bermuda Government leasing fixed allotments of standard lobster traps to licence holders on an annual basis. For the first three months of the lobster season (1 September- 30 November), trapping is restricted to waters beyond the 10-fathom bathymetric contour. However, for the remaining four months of the season (December - March) fishers are permitted to bring their traps into one of two designated inshore areas (see Figure 1). The central portion of the reef platform is permanently closed to commercial lobster fishing and acts as a reservoir for spiny lobster where there is only limited recreational lobster diving.

The availability of lobsters to the commercial fishery in the two designated inshore areas is dependent to some extent upon the movement of lobsters from surrounding localities into the two areas to replenish lobster numbers as they are removed by the fishery. One of the management concerns in developing this spatial configuration for the fishery was that these two inshore areas might become depleted of lobsters due to the concentrated fishing effort. The objective of the present study was to increase our understanding of spiny lobster movement patterns over the Bermuda reef platform by conducting a long term tag-recapture study to evaluate movements in relation to the spatial configuration of the fishery.

METHODS

The tagging program for spiny lobsters began in April 1997 and is ongoing, but the results reported in this paper are inclusive of those obtained up to October 2000.

The majority of the lobsters used in this tagging program were obtained during the last two months of each spiny lobster season (February, March). Sub-legal sized lobsters (< 92 mm carapace length (CL)) were obtained from commercial trap fishers. Each lobster was measured (CL), sexed, tagged between the carapace and abdomen on its dorsal side with a Floy anchor T-bar tag, and then released on the reef platform. Global Positioning System (GPS) readings were taken at each release site.

When a tagged lobster was recaptured, the site of capture was noted, the lobster was re-measured (for growth increment) and then returned to the fisher, provided it was of legal size (min. 92 mm CL), otherwise it was returned to the sea. It was not always possible to obtain all of the requested data for the recaptured lobster. GPS readings for the site of recapture were often not available and thus the recapture location was estimated based on information provided by the fisher.

For each recaptured lobster, the sites of release and recapture were plotted on a chart of Bermuda (British Admiralty chart No. 334) and the distance between the two points was measured to give the straight-line distance (km) moved by the

lobster. This is a minimum estimate of distance travelled as there was no active tracking of tagged lobsters. Also, the time at liberty (days) (= date of release to date of recapture), and growth increment (mm) (= CL at recapture - CL at release) were calculated.

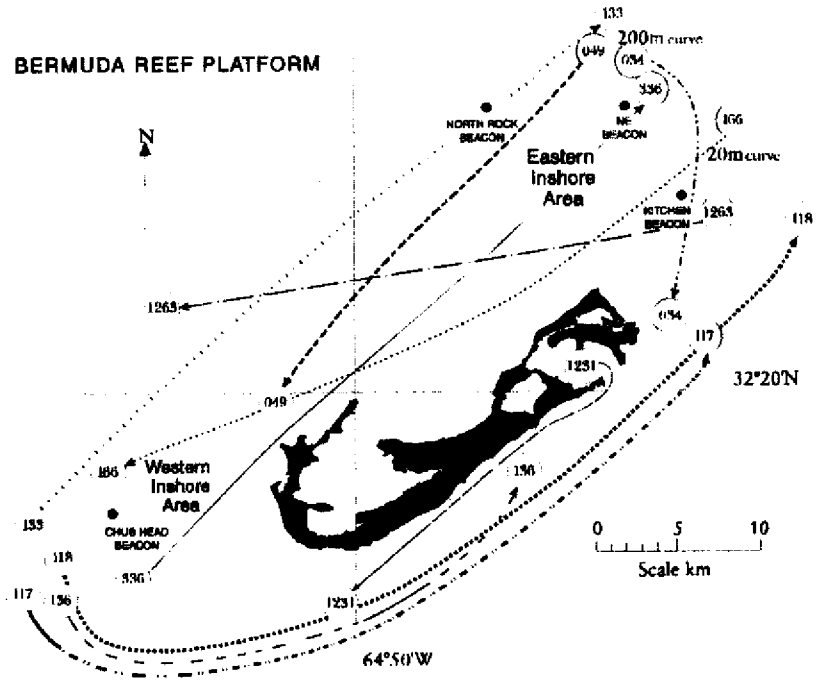


Figure 1. Map of Bermuda reef platform indicating minimum distance tracks of selected tagged lobsters and location of the two inshore areas designated in the lobster management program.

RESULTS

Five hundred and seventy-six *P. argus* were tagged between April 1997 and October 2000. By the end of October 2000, 51 tagged lobsters were recaptured (Table 1) for a recapture rate of 8.9 %. All but one of the tag returns were from commercial trap fishers, the one exception was a lobster caught by a recreational diver.

Table 1. Summary data for Bermuda spiny lobster tag-recapture program.

Tag #	Date of release	Size at release (mm CL)	Sex	Growth Increment (mm CL)	Days at Liberty	Distance Moved (km)	Nominal Direction
T1209	16-Apr-97	82.0	F	13	216	14.6	NNE
T1231	16-Apr-97	91.0	M	?	189	20.8	SW
T1263	17-Apr-97	84.0	M	12	200	22.5	W
T1264	17-Apr-97	90.0	F	?	700	1.6	S
T1280	17-Apr-97	86.0	M	28	665	4.7	SW
T1330	17-Apr-97	90.0	F	6	258	3.2	NW
T1358	17-Apr-97	89.0	F	?	520	5.6	NE
T1383	17-Apr-98	120.0	M	15	281	7.4	N
T0006	28-Oct-98	85.0	M	0	21	0.0	-
T0021	3-Nov-98	91.0	M	?	132	9.5	N
T0034	3-Nov-98	88.0	F	0	9	3.4	N
T0048	20-Nov-98	90.0	M	?	129	13.2	WSW
T0049	20-Nov-98	86.0	F	8	435	27.0	SW
T0055	20-Nov-98	89.0	M	0	125	6.4	SW
T0057	20-Nov-98	88.0	M	?	50	7.7	SSW
T0060	20-Nov-98	89.0	F	2	335	13.0	W
T0077	20-Nov-98	90.0	M	23	465	10.5	S
T0078	20-Nov-98	88.0	F	?	303	?	?
T0082	20-Nov-98	84.0	M	?	45	10.5	W
T0084	20-Nov-98	85.0	F	0	55	4.7	WSW
T0087	20-Nov-98	84.5	F	23	429	10.5	SW
T0091	20-Nov-98	87.0	M	22	419	8.4	SW
T0117	1-Dec-98	85.0	M	13	339	38.0	ENE
T0118	1-Dec-98	87.0	M	8	296	45.5	ENE
T0127	1-Dec-98	87.0	F	?	672	9.3	SSE
T0133	1-Dec-98	87.0	M	18	359	42.6	NE
T0136	1-Dec-98	82.0	M	13	286	24.1	ENE
T0139	1-Dec-98	90.0	M	20	457	12.1	E
T0151	4-Dec-98	87.0	F	11.5	670	1.6	S
T0153	4-Dec-98	87.0	F	8	298	6.6	S
T0155	4-Dec-98	85.0	M	0	108	9.7	SW
T0156	4-Dec-98	87.0	F	4.5	285	10.9	NW
T0163	4-Dec-98	85.0	F	?	106	9.2	W
T0166	4-Dec-98	87.0	F	9	419	31.5	SW
T0183	21-Jan-99	87.5	F	?	69	12.4	SE
T0188	21-Jan-99	91.3	M	13	413	7.7	SE
T0216	12-Feb-99	85.4	F	11.6	391	20.9	W
T0221	12-Feb-99	81.1	F	12.5	227	12.2	NE
T0267	29-Mar-99	88.0	F	9	332	5.6	W
T0290	1-Apr-99	89.0	F	9	304	0.0	-
T0302	1-Apr-99	87.3	F	13	280	9.5	NNW
T0304	1-Apr-99	87.8	F	7	350	6.4	W
T0305	1-Apr-99	92.0	F	7.5	333	3.2	W
T0306	1-Apr-99	90.9	M	19	336	5.6	N
T0312	1-Apr-99	90.5	M	17.5	309	7.7	NNW
T0317	16-Dec-99	84.5	F	12.5	310	4.0	S
T0334	16-Dec-99	91.5	M	?	297	4.0	S
T0336	16-Dec-99	90.0	M	5	298	45.9	NE
T0346	16-Dec-99	90.5	F	?	292	4.0	S
T0361	29-Jan-00	88.0	F	7	233	16.4	SW
T0274	23-Mar-00	90.0	F	5	163	4.8	SW

The results indicate that tagged lobsters show highly variable movement patterns. Of the 51 tag-recaptured lobsters, 25% were caught within 5 km of the release site (Table 1) while 10 tagged lobsters undertook movements exceeding 20 Km from their release site. The longest straight-line movement documented in our study was 45.9 km (Table 1) which is essentially the entire length of the Bermuda reef platform. A select number of the longest movements of tagged lobsters on the reef platform are indicated in Figure 1. These results suggest that lobsters readily move in either compass direction following the long axis (NE - SW) of the reef platform. However, as these are straight-line projections, there are no means to determine the actual track followed by tagged lobsters and these projections thus provide only minimum estimates. Active tracking could be accomplished by acoustic tagging of lobsters but this aspect was beyond the scope of the present study.

An example of a relatively rapid movement of a tagged lobster was an individual which moved 9.5 km in just nine days (Table 1). In contrast, two of the tagged lobsters were recaptured at their respective release sites with one being at liberty for over 10 months (Table 1). However, it is not possible to determine whether these lobsters had moved extensively during their time at liberty. A preliminary analysis suggests that there is no clear difference in the average distance moved by sex although the sample size is small. As virtually all of the tagged lobsters were sub-legal (<92 mm CL), it is not possible to determine if there is a size effect on distance moved. The mean straight-line distance moved by all recaptured lobsters regardless of time at liberty was 12.2 km (± 11.4 SD). This suggests that movements are generally quite extensive although the sample size is insufficient to make a broad generalization.

The range of days at liberty was 9 – 700 with a mean value of 294 days (± 168 SD). Tagged lobsters were released during different months of the season (Table 1) but those released in April could not be recaptured during the five month closed season (April 1 - August 31). This factor could bias the estimate of mean days at liberty. However, the results indicate that lobsters are at liberty on average about 10 months. The longest period at liberty was almost two years (Table 1).

Accurate size measurements were obtained from 38 of the 51 recaptured lobsters allowing an estimate of the growth increment during the time at liberty (Table 1). The five recaptured lobsters which did not moult (zero growth increment) had a mean time at liberty of 64 days. All were released in November/ December when the water temperature is declining and therefore the lack of growth is not unexpected. In comparison, the maximum growth increment was 28 mm CL for a male released at 86 mm CL which remained at liberty for 665 days (Table 1).

DISCUSSION

The lobsters in our study exhibited highly variable but often extensive movement patterns on the Bermuda reef platform. Sutcliffe (1952) documented movement patterns associated with reproduction. He found that sexually mature

females migrated from the reef platform toward deeper water on the southern edge of the platform apparently after mating but before egg hatching. In a further study, Sutcliffe (1953) determined that lobsters larger than 145 mm CL were most frequently found in the lagoon area of the platform and were relatively uncommon further offshore. The majority of these large lobsters were males, and long term trapping results indicated that they did not migrate to the edge of the reef platform. Thus, it appears that smaller but sexually mature lobsters undertake the most extensive movements.

As the lobsters tagged in our study were almost all of sub-legal size (< 92 mm CL), we are unable to comment on movement patterns in relation to size. With a limited data set, Evans and Lockwood (1996) suggested that sub-legal sized lobsters might travel faster than larger, sexually mature individuals. The fastest movement documented in our study was an 88 mm CL female which moved 9.5 km in nine days (Table 1). The short-term movements of tagged lobsters in the study by Evans and Lockwood (1996) were generally smaller.

In terms of distance moved, there were 10 lobsters which were recaptured more than 20 km from their release sites. The maximum distance moved was 45.9 km by a 90 mm CL male with an additional three lobsters moving over 40 km (Table 1). The longest distance recorded by Evans and Lockwood (1996) for a tagged lobster was about 40 km, but the majority moved much smaller distances. Despite comments by Evans and Lockwood (1996) concerning clockwise or counterclockwise movements around the reef platform, it is not possible from conventional tagging data to make such assertions. A program with active tracking would be necessary to determine movement directions.

It is clear from the data presented here that lobsters are capable of extensive movements across the reef platform encompassing the two designated inshore areas used in the limited entry lobster management program. On the basis of these preliminary results, we conclude that lobster movements on the reef platform are probably sufficient to allow for the replenishment of these inshore areas following harvesting by the fishery at current levels of fishing effort. Close monitoring of the fishery will be necessary to ensure that the current management program can continue to provide sustainable harvest levels.

ACKNOWLEDGEMENTS

We wish to thank all of the commercial lobster fishermen who helped us to obtain sub-legal lobsters for tagging purposes. This program would not have been a success without the cooperation of lobster fishermen who returned tagged lobsters to us, particularly Linwood Outerbridge, Eugene Barnes, Michael Barnes, Leonard Outerbridge, Jason Payne, Robert Lambe and Sinclair Lambe. We appreciate the assistance of Fisheries staff who assisted with tagging and release of lobsters.

LITERATURE CITED

Evans, C.R. and A.P.M. Lockwood. 1996. Long-term migratory behaviour of undersizedspiny lobsters *Panulirus argus* (Latreille) on the Bermuda island shelf. *Gulf of Mexico Science* 14:35-39.

Luckhurst, B.E. 1999. National Report of Bermuda. P. 180 -182. In: FAO / Western Central Atlantic Fishery Commission. Report on the FAO/ DANIDA/ CFRAMP/ WECAFC Regional Workshop on the Assessment of the Caribbean Spiny Lobster (*Panulirus argus*). FAO Fisheries Report No. 620. FAO. Rome, Italy.

Sutcliffe, W. H. Jr. 1952. Some observations of the breeding and migration of the Bermuda spiny lobster, *Panulirus argus*. *Proceedings of the Gulf and Caribbean Fisheries Institute* 4:64-69.

Sutcliffe, W. H. Jr. 1953. Further observations on the breeding and migration of the Bermuda spiny lobster, *Panulirus argus*. *Journal of Marine Research* 12: 173-183.

Ward, J.A. and B.E. Luckhurst. 1996. Development of a lobster-specific trap in Bermuda and fisheries management considerations for the re-establishment of a commercial lobster fishery. *Proceedings of the Gulf and Caribbean Fisheries Institute* 44:566-578.

Fishing Effort and Resource Allocation in the Florida Stone Crab (*Menippe*) Fishery

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ABSTRACT

Fishery managers and fishermen have proposed limiting fishing effort in the Florida stone crab fishery because fishing effort increased substantially in the 1990s and there was no commensurate increase in landings. However, before the type of effort limitation could be decided upon, managers needed to quantify fishing effort and understand how effort limitation would affect the overall fishery as well as individual fishermen. In this study, we first determined the current number of traps in the fishery and developed a data set based on the fishing habits of individual fishermen. We then used this information to evaluate the seven fishing-effort allocation alternatives being considered as a means to limit the number of traps a fisherman could use.

By evaluating each of the alternatives for allocating fishing effort during the planning stages of the effort-limitation program, we were able to give both fishery managers and fishermen the data necessary to understand the consequences of each alternative. We concluded that the alternatives that use a single "bench-mark" year, selected from several past fishing seasons, included many retired or former fishermen and would allow more traps to be allocated to the fishery as a whole than were currently in use. Conversely, allocation alternatives that required several years of participation in the fishery tended to exclude recent entrants to the fishery. After examining our evaluations of the effort-allocation alternatives, fishery managers and the Florida legislature decided to allocated traps to fishermen based on any one fishing season during the most recent three seasons. This alternative would reduce current fishing effort, would include a high percentage of fishermen, and should have limited potential to affect future landings.

KEYWORDS: Fishing effort, limited entry, *Menippe adina*, *Menippe mercenaria*, stone crab

INTRODUCTION

The demand for fishery resources is increasing, and the allocation of these resources to competing interests is an important issue in many fisheries. To resolve these issues, the Magnuson Fishery Conservation and Management Act provides for the fair and equitable allocation of fishing privileges among commercial fishermen (16 U.S.C. 1801 *et seq.*, Loomis and Ditton 1993). In Florida, intense competition

and overcapitalization in the stone crab fishery jeopardizes the sustainability of this fishery, so some form of resource allocation among fishery participants is required.

Stone crabs support a large fishery in Florida that in the past 10 years, has usually exceeded 3 million pounds (1,300 mt) of claws (Florida Fish and Wildlife Conservation Commission, unpubl. data). The fishery targets two species of stone crabs: *Menippe mercenaria* and *M. adina* and their hybrids (Bert 1986, Gulf States Marine Fisheries Commission 1995). Only the claws are harvested; claws greater than 2-3/4 inches (70 mm) are removed, and the crab is released back into the water to regenerate either one or both claws. Sullivan (1979) found that 20 - 25% of legal-sized crabs were regenerating claws, but the 20 - 25% reflects only the number of crabs missing one or two claws who have survived; it does not tell us if these crabs grew to sufficient size to re-enter the fishery (Davis et al. 1979). Other studies estimated that between 7.6% and 19% of claws in the harvest were regenerated (Savage et al. 1975, Simonson and Hochberg 1992, Wilber 1995, Muller and Bert 2001).

Landings of stone crab claws increased progressively from the 1960s to the early 1990s (Bolden 1994) but have remained stable from the 1990 - 91 fishing season to the present (Figure 1). According to those in the industry, the increased landings in the 1990s were the result of fishery expansion into previously underused areas. However, since 1992, increases in the number of traps have not resulted in increases in landings (Figure 1). Several studies have concluded that the resource is partitioned among too many traps (Sullivan 1979, Zuboy and Snell 1980, Southerland 1988, Ehrhardt et al. 1990, Phares 1992, Bert 1992). Muller and Bert (1997) concluded that the estimated 798,000 traps in the fishery in 1995 - 1996 was perhaps twice the number of traps required. They have subsequently revised their estimates of the number of traps in the fishery, and these estimates are shown in Figure 1 (Muller and Bert 2001).

Because of their concern about the continued expansion of the stone crab fishery, the Florida Legislature and the Gulf of Mexico Fishery Management Council (GMFMC) – with the advice of the commercial fishing industry – enacted moratoriums on new stone crab fishing licenses in 1995. Both moratoria were subsequently extended until July 1, 2001 (Florida Statute 370.13, GMFMC 2000). However, the moratoria did not restrict the number of traps each license holder could use, and the number of traps in the fishery continued to increase.

Fishery managers and some members of the fishing community agreed that too many traps were in the fishery. Individual commercial fishermen indicated that they supported some form of fishing-effort limitation, but they lacked information on the optimal number of traps for the fishery and how limiting fishing effort would affect them. The need to decease the number of traps for the entire fishery conflicted with the individual fisherman's desire to increase his own harvest by using more traps. In other words, the goals of the group were in conflict with the goals of the individual (Leventhal 1976), and a classic example of the "tragedy of the commons" (Hardin 1968) had developed. Resolution of the fishing-effort conflict required that considerable attention be focused on the initial determination of how many traps

each participant should be allocated, herein referred to as the "individual fishing-effort allocation" or for the entire fishery, the "trap allocation".

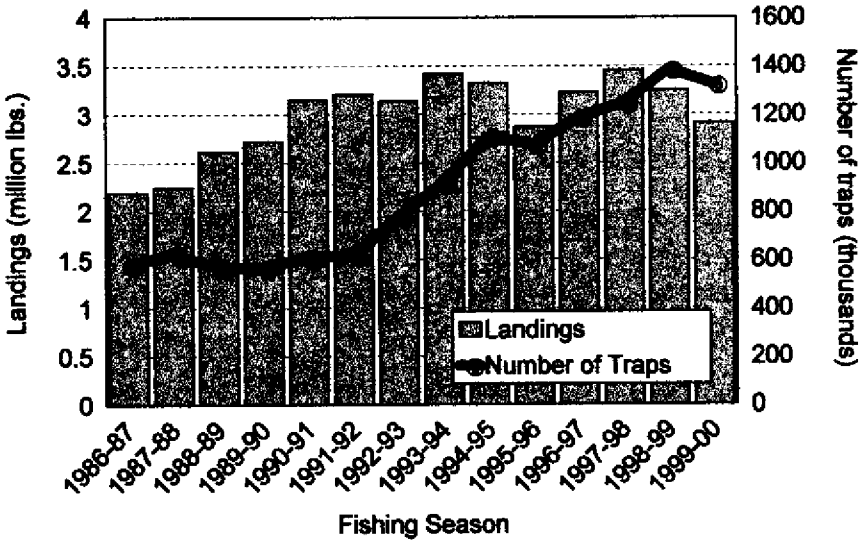


Figure 1. Commercial landings of stone crab claws from Florida during the 1986-87 to 1999-2000 fishing seasons as reported in the Florida Marine Fisheries Information System. The number of traps in the fishery is from the National Marine Fishery Service General Canvass except for 1992-93 through 1996-97 and 1999-2000; these were estimated from the number of traps on the Saltwater Products License applications (Muller and Bert 2001).

The Florida Fish and Wildlife Conservation Commission (FWC) organized a series of workshops in which an individual fishing-effort allocation plan and guidelines for limiting fishing effort in the stone crab fishery could be developed. The workshop participants developed general guidelines for an effort allocation plan but were unable to resolve which fishing seasons or how many fishing seasons would be used to qualify an individual fisherman for an initial trap allocation. Fishery managers and fishermen identified six alternative methods by which to qualify an individual for a trap allocation, but they were unable to resolve which allocation alternative best met the goals of the program. A seventh alternative was later added by the Florida Legislature. The purpose of this study was to evaluate the seven trap allocation alternatives. Each trap allocation alternative was evaluated with respect to how closely the number of traps allocated to the entire fishery matched the current number of traps in the fishery, how many fishermen were included in the plan, and how landings might be affected.

MATERIALS AND METHODS

We developed an individual fishing-effort database that contained information describing the fishing history for each stone crab fisherman in Florida. Saltwater Products License (SPL) applications were one of our sources for the number of traps each fisherman used. Florida's Marine Fisheries Information System (commonly known as trip tickets) contains records of each fisherman's landings. A phone survey of commercial stone crab fishermen was conducted to obtain additional data on the fishing habits of individual fishermen. The FWC–in cooperation with two commercial fishing industry organizations, Monroe County Commercial Fisherman (MCCF) and Organized Fishermen of Florida (OFF)–used this information to identify how different fishermen use traps and ultimately to develop seven fishing effort allocation alternatives.

The original fishing effort allocation alternative developed by the FWC (FWC1) was as follows:

> "Cap the fishery by issuing to each permit [fishing license] the maximum number of traps stated on the permit qualifier's SPL application during 1993 - 1994 to 1997 - 1998 fishing years but do not issue more traps than the permit qualifier's highest annual landings (during that period) divided by two pounds per trap."

Stone crab fishermen were also required to land 300 lbs (135 kg) or more claws in at least one fishing season from 1993 - 1994 to 1997 - 1998 to qualify for an allocation. This alternative was later modified to specify that each qualifying permit would receive a trap allocation and that the allocation would then be assigned to an individual. The intent of the allocation alternative was to allocate each fisherman the number of traps he used as reported using on his SPL application but only after the minimum landings per trap were verified (Table 1). In all subsequent fishing-effort allocation alternatives, the rules and intent of FWC1 were maintained, but the qualifying years for valid SPL applications and which fishing seasons were used to meet the landings requirements were changed. The FWC also proposed FWC2 and FWC3. Representatives of MCCF proposed MCCF1, MCCF2, and MCCF3. The Florida Legislature developed the seventh allocation alternative (FINAL), which was ultimately implemented. The FINAL allocation alternative would require fishermen to qualify for an allocation by having landings of a least 300 lbs in one season during the 1993-94 to 1998-99 period. Once qualified, the allocation was determined by using the landings records and number of traps reported on each SPL application from any one fishing season from 1995 - 96 to 1997 - 98. The allocation was determined by whichever was less:

i) The number of traps on the SPL application or,
ii) The total landings for the season divided by 2 (representing a minimum landings requirement of 2 pounds per trap).

Table 1. Requirements for fishing-effort allocation alternatives for the Florida stone crab fishery. Fishing-effort allocation alternatives were developed by the Fish and Wildlife Conservation Commission (FWC), Monroe County Commercial Fisherman (MCCF), and the Florida Legislature (FINAL). Number of traps allocated was the hypothetical total number of traps given to all fishermen by the allocation alternative. The "Saltwater Products License (SPL) application qualifying fishing season" lists which fishing season(s) license applications may be used to determine trap allocations. The "trip ticket landings qualifying fishing season" lists which fishing season(s) landings may be used to verify trap allocations.

Allocation Alternative	Number of traps Allocated	SPL Application Qualifying Fishing Season	Trip Ticket Landings Qualifying Fishing Season
FWC1	1,577,390	Any 1 season 1993-94 to 1997-98	Any 1 season 1993-94 to 1997-98
FWC2	1,474,181	1 season 1997-98	Any 1 season 1993-94 to 1997-98
FWC3	989,787	1 season 1997-98	1 season 1997-98
MCCF1	1,354,675	Any 2 seasons 1993-94 to 1997-98	Any 2 seasons 1993-94 to 1997-98
MCCF2	1,258,320	Any 1 season 1996-97 to 1997-98	Any 1 season 1996-97 to 1997-98
MCCF3	1,048,725	Any 3 seasons 1993-94 to 1997-98	Any 3 seasons 1993-94 to 1997-98
FINAL	1,294,734	Any 1 season 1995-96 to 1997-98	Any 1 season 1995-96 to 1997-98

Two phone surveys were conducted in 1998. The first included all 1,487 licensed fisherman whose reported landings were 300 lbs or greater from any fishing season between October 1993 and May 1998. In the second survey, we contacted 500 of the 3,500 licensed fishermen whose landings were less than 300 lbs. (including those with no landings) for the same time period. The questionnaire used in both surveys was designed cooperatively with Responsive Management Inc. (Duda et al. 1998). We requested fishermen's opinions on limiting fishing effort, the number of traps they fished, their trap storage locations, and when they built traps.

A concentrated effort was made to visit every trap storage location in the state to identify the owner of and count every stone crab trap. Trap storage locations were identified during the phone surveys and by systematic searches of coastal roads

and known fishing communities. In many instances, local fishermen acted as guides to the trap storage locations. Trap ownership was determined by the stone crab permit number on each buoy or in the concrete of the trap and cross-referencing that number with the SPL database. When possible, fishermen at the trap storage locations were interviewed to ascertain the number of additional traps they planned to build and deploy and how many traps they wanted to deploy in the upcoming fishing season. The trap count was conducted during the five weeks preceding the date traps could be deployed (October 5, 1998) to minimize the effect of additional trap construction after the survey.

The SPL applications constituted one of four sources of data used to estimate the number of traps in the fishery. Many fishermen had multiple SPLs, and duplicate records of traps were common. To resolve this issue, the number of traps reported on the SPL applications were categorized as active, inactive, or unreported: traps were considered active if the corresponding license had landings, traps were considered inactive if the corresponding license had no landings, and traps were considered unreported if the corresponding license had landings but did not report the number of traps used. The number of unreported traps was estimated based on the average pounds-per-trap from each fisherman that reported landings on trip tickets and the number of traps utilized on their SPL. The pounds-per-trap estimate was recalculated as traps-per-pound which was multiplied by the number of pounds of stone crab claws landed as reported on licenses that had no indication of the corresponding number of traps.

The second estimate of the number of traps in the fishery was determined from the trap counts at trap storage locations. These traps were also categorized as active, inactive, or unreported. A trap counted during the survey was classified as active if the owner of the trap had reported landings from the previous fishing season. Traps were categorized as inactive if the trap owner had no reported landings from the previous fishing season. It was likely that some traps were missed during the trap count, and if the fishermen had landings from the previous fishing season, these traps were considered unreported. The number of traps associated with the landings of fishermen whose traps were missed during the trap count was estimated from a pounds-per-trap estimate that was developed from the landings associated with traps that were reported during the trap count.

The third estimate of the number of traps in the fishery was determined from the phone surveys. The traps an individual fisherman reported in the survey were classified as active if that fisherman reported landings on trip tickets from the previous fishing season or as inactive if no landings were reported. Traps were classified as unreported if no survey response was received from the fisherman and if the fisherman reported landings from the previous fishing season. The number of traps associated with the landings for fishermen not participating in the survey (unreported) were calculated from a pounds-per-trap estimate that was developed from the landings associated with traps that were reported during the survey.

The trip-ticket database provided data for the fourth estimate of the number of traps in the fishery. For each fishing trip, the number of traps retrieved and the soak

time (the number of days a trap was deployed) were multiplied to calculate the number of trap-fishing days. The number of trap-fishing days for each fishing trip was then summed for each month. For records with trap soak times spanning multiple months, the number of trap-fishing days was divided appropriately between each month based on the date the trip occurred. The number of trap-fishing days each month was then divided by the number of days in the month to determine the number of traps deployed each month. This method underreported the number of traps deployed in months when traps were initially deployed or were returned to land, so the estimated number of active traps was based on the average number of traps determined for November, December, and January–the second, third, and fourth months of the fishing season. The number of unreported traps was determined for incomplete trip ticket records–trip tickets without the number of traps used or soak time–by multiplying the total number of pounds of stone crab claws landed from incomplete records by the traps-per-pound estimate calculated from complete records. Because the trip-ticket records are based on landings, we were not able to estimate the number of inactive traps in the fishery from trip-ticket records.

The number of traps allocated to each fisherman was determined for each of the seven fishing effort allocation alternatives following the methods described previously and summarized in Table 1. For each allocation alternative, all individual trap allocations were summed and the total number of traps allocated to the fishery was determined.

Each allocation alternative was evaluated to determine its potential effect on landings and participation in the fishery. We calculated the percentage of landings and the percentage of fishermen that would have had landings or been allowed to use traps during past fishing seasons as if each trap allocation alternative had been in place during that season. The percentage of landings included was calculated by dividing the sum of the landings attributed to those fishermen that hypothetically would have received a trap allocation by the total landings of that fishing season and converting the result to a percentage. The percentage represented the landings each fishing season attributed to fishermen who would have received a trap allocation for each allocation alternative. The percentage of fishermen who would have received a trap allocation was calculated for each fishing season by dividing the number of fishermen potentially receiving a trap allocation by the total number of fishermen who had landings that season and converting that number to a percentage. This percentage represented the fishermen with landings greater than 300 pounds who hypothetically would have received a trap allocation from each allocation alternative.

RESULTS

Data from the Florida Marine Fisheries Information System (trip tickets) was used to provide some insight into participation in the fishery. Of those fishermen with landings, many did not participate in the stone crab fishery every fishing year. Of the fishermen with landings each fishing season, almost one-third did not have landings in the previous fishing season and about one-third did not have landings the following season (Table 2a). To a lesser extent, the same trend existed for fishermen with landings of 300 lbs or more: one-fourth of the fishermen entered and one-fourth left the fishery each season (Table 2b). Nearly two-thirds of licensed stone crab fishermen did not fish for stone crabs. During the 1997 - 1998 fishing season, 1,400 of 4,684 licensed stone crab fishermen landed and sold stone crab claws (Table 2a), and 883 of those 1,400 landed and sold more than 300 lbs of claws (Table 2b). The overall number of fishermen with landings declined after 1993-94 (Table 2a), but the number of fishermen with more than 300 lbs of landings increased during the same period (Table 2b). In the survey of license holders with no landings or with landings less than 300 lbs, 29% stated that they maintained their license because it was free, 29% had fished for stone crabs, 20% wanted to fish for stone crabs in the future, and 10% landed stone crab claws as bycatch from other fisheries.

Table 2a. The number of stone crab licenses in Florida, the number of people with landings each fishing season, and the number of people that did not have landings in the previous or subsequent fishing season.

Fishing Season	Total Number of Licenses	Number of People with Landings	Number of People without Landings in the Previous Season	Number of People without Landings in the Subsequent Season
1993-94	6624	1621	.	602
1994-95	7237	1604	585	581
1995-96	6040	1502	479	400
1996-97	5388	1555	453	465
1997-98	4684	1400	310	.

Table 2b. The number of people in Florida with 300 lbs or more landings of stone crab claws each fishing season and the number of people that did not have 300 lbs of landings in the previous or subsequent fishing season.

Fishing Season	Number of People Landing >300 lbs	Number of People without Landings in the Previous Season	Number of People without Landings in the Subsequent Season
1993-94	619	.	170
1994-95	667	218	174
1995-96	723	230	149
1996-97	885	311	248
1997-98	883	206	.

Landings records for the stone crab fishery, which were substantiated by data from the mail surveys, also indicated depressed landings-per-trap for most participants, despite sustained total annual landings of more than three million pounds of claws for all but two fishing seasons since the 1990 - 1991 fishing season (Figure 1). From the phone survey, fishermen landing more than 300 lbs reported harvesting an average 4.75 lbs of crab claws per trap per season, but almost 50% of these fishermen reported landing 2 lbs or less per trap and 25% reported landing 6 lbs or more crab claws per trap per season.

The disparity between fishermen with high landings, those with low landings, and the nonfishing members of the industry resulted in a diverse array of opinions concerning the stone crab fishery. Among the respondents who landed more than 300 pounds of claws, bad weather (33%) and trap robbing (29%) were reported almost equally as the most important problems. Regulations were the biggest problem for 17% of the fishermen, and 17% considered fishing effort issues–either cost (3%), number of traps (3%), or the number of other fishermen (11%) – to be the most important problem in the fishery. Slightly more than one-half of the fishermen (51%) believed that additional stone crab traps would hurt the future harvest of stone crabs in Florida, whereas 34% did not believe so. Two thirds of all respondents supported limiting the number of new stone crab fishermen, but only 40% supported limiting the total number of traps through a certificate program. Approximately 38% of the respondents were members of commercial fishing organizations (Duda et al. 1998).

The number of traps in the fishery estimated from SPL applications increased by 650,000 from 1993 - 1994 to 1997 - 1998 even though the number of license holders in the fishery declined (Table 2a). However, the accuracy of this estimated increase was compromised because individuals had multiple licenses and inconsistently reported the number of traps used on each license. Another indication that the number of traps did indeed increase was a 19% increase in trap soak time over the same time period calculated from the trip ticket database. An independent estimate of the number of traps in the fishery was not available for this time period.

The four methods used to estimate the number of traps in the fishery all determined the number of active traps independently, but relied on trip-ticket records to determine unreported or inactive traps (Figure 2). The number of traps in the fishery, estimated from SPL applications in 1997 - 1998, indicate that fishermen with landings used 1.540 million active traps. The best estimate of the number of traps in the fishery from the SPL database would include only the active and unreported traps. Fishermen without landings reported approximately 1.47 million inactive traps. These inactive traps were probably traps that were reported on the fishermen's second SPL and existed only on paper. In Florida, many fishermen have both individual and vessel fishing licenses (SPL) for one fishing operation. An estimated 234,000 traps may have been unreported. The estimate of 234,000 unreported traps was the average number of traps that would be required to land the additional 459,000 lbs (208 mt) of claws that were landed by fishermen who did not report using traps on their SPL application (Figure 2). It is unlikely that

these stone crab claws were landed by other fishing methods because phone survey results indicated that only a small fraction (3.5%) of stone crab landings were landed as bycatch from other fisheries. The number of active and unreported traps estimated from the SPL database are probably real, suggesting that 1.774 million traps were in the fishery.

During the trap count, observers found and counted 1.086 million stone crab traps. Of these traps, 951,000 belonged to fishermen who harvested 2.53 million lbs. (1,148 mt) of claws during the 1997 - 1998 fishing season. These traps were considered active. The remaining 135,000 traps had no landings from the previous fishing season and were considered inactive; these traps may represent the traps of new entrants in the fishery. An additional 351,000 traps may have existed and were considered unreported. The number of unreported traps was calculated based on the average number of traps that would be required to account for the landings of fishermen whose traps were not counted. Our interviews with fishermen at the trap storage locations indicated that less than 1% of the traps we counted might not be used during the upcoming fishing season; consequently all 1,437,000 of the active, inactive, and unreported traps counted or estimated during the trap count may be in the fishery.

In the phone surveys, we received responses from fishermen who used a total of 781,000 traps to land 1.962 million lbs. (890 mt) of claws in 1997-98 fishing season. These traps were considered active traps. An additional 64,000 traps were reported but had no associated landings that season and so were considered inactive. The estimated 604,000 additional traps that would be required to account for the remaining landings that season were considered to be unreported. Although the 64,000 inactive traps were reportedly used during the 1997 - 1998 fishing season, the landings from those traps were probably included in the calculations that determined the number of unreported traps. Therefore, the inactive traps should probably be excluded from the phone-survey estimate of the number of traps in the fishery, so the phone survey yielded an estimate of 1.385 million traps being used in the fishery.

Trip ticket records that included the number of traps used, soak time, and landing data were also used to estimate the number of active traps in the fishery. These records indicated that an estimated 468,000 traps were used during the peak of the fishing season–November, December, and January. An additional 145,000 traps may have been unreported based on the average number of traps required to harvest the poundage of stone crab claws associated with incomplete records. This method resulted in the lowest estimated number of traps in the fishery, 613,000.

DISCUSSION

The stone crab fishermen strongly supported limiting additional entrants into the fishery, but less than half were willing to impose fishing-effort limitation upon themselves. These attitudes are understandable for a well-established fishing community, and may allow fishery mangers the opportunity meet the desires of

current fishermen while obtaining long-term reductions in fishing effort by limiting the number of trap permits issued to new participants. The proposed fishing-effort limitation plan would allocate trap permits (one permit allows the use of one trap) to individuals, and the number of trap permits would be reduced when the fishermen sold their fishing business; thus, through attrition of existing fishermen, the number of trap permits (and thus traps) would decline. The reduction of traps as fishermen leave the fishery on their own volition has been termed "passive trap reduction". This plan appears feasible because of the irregular participation of the participants in the fishery; the more transfers of trap permits there are, the more the number of trap permits can be reduced. The program will also stop the rapid increase in fishing effort among existing fishery participants.

The allocation of trap permits and a passive trap reduction was acceptable to fishermen because it limited additional entrants to the fishery but did not limit an individual participant's current fishing effort. Ideally, current fishermen would be unaffected by the new regulations except for a modest fee for each trap permit, which would be recouped when they left the fishery and sold their trap permits.

The relationship between the number of traps in the fishery, landings, and the sustainability of the fishery is unclear. Muller and Bert (1997) estimated that there were 798,000 traps in the fishery in 1995 and concluded that this was more than double the number of traps required to maintain landings. Estimates of the number of traps in the fishery for the 1998 - 1999 fishing season varied widely, but our two independent measures, the phone survey and the trap count, indicated that 1.437 or 1.385 million traps were in use. The large number of inactive traps with no associated landings encountered during the trap count may have been attributed to new stone crab fishermen who were building traps for use in the subsequent fishing season. Likewise, some traps would have been attributed to fishermen who had landings in the 1997 - 1998 fishing year, but who no longer fished in 1998 - 1999. Trap estimates from SPL applications include many inactive traps that may have been associated with an individual's second SPL and so probably do not represent real traps. By disregarding the number of traps listed on SPLs that did not have landings during the most recent fishing season, the SPL trap estimate was 1.77 million active and unreported traps. This estimate may still be high, because the SPL application was an estimate of how many traps each fisherman intended to fish during the upcoming season, not the number of traps that were fished. Estimates of the number of traps from the trip ticket data were calculated from trap-soak time and the reported number of traps retrieved each fishing trip. The soak time and number of traps fished did not vary on many trip tickets and appeared to report intended trap soak times, not actual soak times. No direct observations of stone crab trap soak time are available, but after comparing the soak times for lobster traps reported on trip tickets to direct observations of lobster traps, we concluded that soak times were often underreported on trip tickets by up to 50% (Hunt et al. 1994). If soak times were longer than reported on trip tickets, there were probably more traps in the fishery than estimated from the trip ticket records.

Fishing effort needs to be measured and incorporated into stock assessments. Even though landings in the stone crab fishery appear stable, the inability to measure the level of fishing effort required to maintain these landings prohibits fishing-effort-based assessments of the health of the fishery. The yield from regenerated claws to the fishery has been reported to be between 7.6 and 11.9% (Savage et al. 1975, Simonson and Hochberg 1992, Wilber 1995), but recent statewide monitoring suggests that 19% of landings were from regenerated claws (Muller and Bert, 2001). Again, it is difficult assess how a change in the percent contribution of regenerated claws in the landings would affect the health of the fishery. We cannot ascertain if the putative increase in the percentage of regenerated claws is from better handling practices by fishermen, an increase in the percentage of the stone crab population affected by fishing practices, or if the current estimate of the percentage of regenerated claws is simply more inclusive of the entire fishery and nothing has changed.

After evaluating the seven proposed fishing-effort allocation alternatives we realized that allocating more traps would not necessarily distribute traps to more fishermen. The FINAL trap allocation alternative would issue 180,000 fewer traps to the fishery than alternative FWC2, but would issue the remaining traps to 3% more fishermen. None of the proposed alternatives would account for or include all of the landings or fishermen (Table 3). A few fishermen did not complete or improperly completed some portion of their SPL application every year. In the case of FWC1, the most inclusive alternative, 5% of the fisherman, who accounted for 7% of the landings, never indicated how many traps they used. Alternatives FWC1 and FWC2 would allocate more traps than have ever been in the fishery (Table 1), and in the case of FWC2, the additional allocation of traps, compared to several other alternatives, would include fewer fisherman and landings in the more recent fishing seasons. FWC3 would allocate the fewest traps (Table1) and would exclude more fishermen than other alternatives would (Table 4), but considering that FWC3 would allocate 39% less traps than the most liberal alternative would, landings for the fishery would hypothetically be diminished by only 7%. By allowing only one year to qualify, alternative FWC3 would eliminate fishermen who incorrectly completed their SPL application in one year. The probability of these fishermen incorrectly completing the SPL application was lessened when one of several years was allowed to qualify a fisherman for an allocation.

Two of the MCCF proposals were promulgated in an attempt to include fishermen who have multiple years of fishing experience in a trap-allocation plan. MCCF1 and MCCF3 would limit trap allocations by requiring two (MCCF1)or three years (MCCF3) of participation in the fishery (Table 1). These alternatives provided trap allocations to fewer fishermen, but the fishermen included accounted for a disproportionately high amount of the landings (Table 3). MCCF1 and MCCF2 were intended to include fishermen with consistent fishing histories. However, these allocation alternatives include few fishermen because they inconsistently reported their fishing activity between years. MCCF2 would allocate a number of traps slightly below that estimated from the trap count (Table 1 and Figure 2) and would

include the second highest number of fishermen (Table 4) and quantity of landings (Table 3) from the most recent fishing seasons.

The FWC recommended MCCF2 as the best allocation alternative for the stone crab fishery. The number of traps that would be allocated by MCCF2 was near that suggested by the trap counts, would account for an average of 93% of the landings in more recent fishing seasons (Table 3), and would include 89% of current fishermen (Table 4). MCCF2 allocated 320,000 less traps than the most liberal alternative did but appeared to provide little disruption to the current fishermen's participation or landings. The Florida Legislature amended MCCF2 to include the 1995-96 fishing season, and the FINAL allocation alternative was scheduled for implementation in the 2002-3 fishing season.

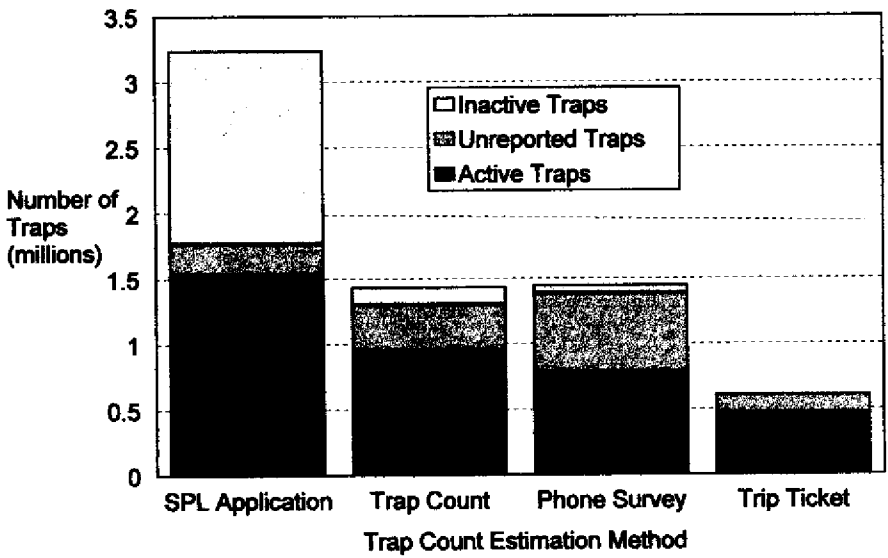


Figure 2. Estimated number of commercial stone crab traps in Florida. The Saltwater Products License (SPL) application estimate was from the number of traps listed on each fisherman's Saltwater Products License application for 1997-98. The trap count estimate was from a physical count of stone crab traps conducted in September 1998. The phone survey estimate was from interviews of fishermen during 1998. Trip-ticket estimate is from the 1997-98 fishing season. Active traps were traps that were reported or counted and had landings on the associated license. Inactive traps were traps that were reported or counted but had no landings on the associated license. Unreported traps were traps that were not reported or counted but had landings on the associated license.

Table 3. The percentage of stone crab landings in Florida each fishing season accounted for by each allocation alternative from the 1993-94 to 1997-98 fishing seasons. Fishing-effort allocation alternatives were developed by the Fish and Wildlife Conservation Commission (FWC), Monroe County Commercial Fisherman (MCCF), and the Florida Legislature (FINAL). The percentage was calculated by dividing the landings attributed to fishermen receiving a trap allocation by the total landings that fishing season multiplied by 100.

Allocation Alternative	Landings Included (%) Each Fishing Season				
	1997-98	1996-97	1995-96	1994-95	1993-94
FWC1	95	95	91	88	82
FWC2	90	88	83	80	73
FWC3	88	78	75	71	65
MCCF1	90	87	87	84	77
MCCF2	93	91	85	81	74
MCCF3	77	73	75	75	66
FINAL	93	92	86	82	74

Table 4. The percentage of stone crab fishermen in Florida receiving a trap allocation from each allocation alternative from the 1993-94 to 1997-98 fishing seasons. Fishing-effort allocation alternatives were developed by the Fish and Wildlife Conservation Commission (FWC), Monroe County Commercial Fisherman (MCCF), and the Florida Legislature (FINAL). The percentage was calculated by dividing the number of fishermen receiving a trap allocation by the total number of fishermen with at least 300 lbs of landings that season multiplied 100.

Allocation Alternative	Fishermen Included (%) Each Fishing Season				
	1997-98	1996-97	1995-96	1994-95	1993-94
FWC1	93	90	87	79	74
FWC2	86	84	80	73	67
FWC3	84	78	72	61	49
MCCF1	74	73	76	70	63
MCCF2	89	85	74	65	60
MCCF3	53	53	60	56	49
FINAL	89	85	81	75	62

Our evaluation of the different allocation alternatives clearly revealed that with sufficient knowledge of individual fishing practices, allocating of a limited number of traps could provide most fishermen the traps they required to maintain their fishing operations. A critical aspect of any fishing-effort allocation plan is to avoid allocating trap permits to former or infrequent fishermen. In the stone crab fishery this could be accomplished by limiting the number of past fishing seasons that qualify fisherman for a trap allocation. The allocation of traps to former fishermen would

provide a reservoir of traps that could enter the fishery at any time. The allocation of traps to the hundreds of license holders that are not currently fishing could cause a new influx of traps into the fishery, as was seen in the Maine lobster fishery when all lobster license holders, most of which had never used traps, were provided trap fishing permits (Acheson 2001).

Fishery managers for the stone crab fishery have had the luxury of developing a fishery management plan that principally focused on economic and gear-conflict issues. Apparently no biological imperative existed that would require the radical alteration of current fishing practices. By capping the number of traps at the current level and reducing the number of traps through attrition as people leave the fishery, the health of the fishery should gradually improve. A more decisive trap-reduction plan might improve the economic return to the fishery more quickly and might immediately resolve some of the gear-conflict issues with commercial shrimp fishermen and recreational boaters, but it might also force the removal of more than 50% of the current fishermen and their crews. A gradual approach to fishing-effort limitation in the stone crab fishery appears to be a feasible approach for maintaining the stone crab resource and for allowing the uninterrupted activity of the fishing industry.

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LITERATURE CITED

Acheson, J.M. 2001. Confounding the goals of management: response of the Maine lobster industry to a trap limit. *North American Journal of Fisheries Management* **21**:404-416.

Bert, T.M. 1986. Speciation in the western Atlantic stone crabs (genus *Menippe*): the role of geological processes and climatic events in the formation and distribution of species. *Marine Biology* **93**:157-170.

Bert, T.M. 1992. Summary of workshop on current issues related to stone crab(genus *Menippe*) biology and fisheries. Pages 108-115. in: T. M. Bert (ed.) *Proceedings of a symposium on stone crab (genus Menippe) biology and fisheries*. Florida Marine Research Publications, Number 50. 118 pp.

Bolden, S.K. 1994. Summary update of the Florida gulf coast stone crab fishery from 1962 to 1993. National Marine Fisheries Service Report # MIA-93/94-81, 26 pp.

Davis, G.E., D.S. Baughman, J.D. Chapman, D. MacArthur, and A.C. Pierce. 1979. Mortality associated with declawing stone crabs, *Menippe mercenaria*. U. S. National Park Service Rep.T-522. 23 pp.

Duda, M., K. Young, T. Graham, L. Earles, A. Lanier, and S. Bissell. 1998. Fishing effort and resource allocation in the stone crab fishery: results of a stone crab angler survey. Responsive Management Inc., Harrisonburg, Virginia USA. 168 pp.

Ehrhardt, N.M., D.J. Die, and V.R. Restrepo. 1990. Abundance and impact of fishing on a stone crab (*Menippe mercenaria*) population in Everglades National Park, Florida. *Bulletin of Marine Science* **46**:311-323.

Florida Statute. 2000. Chapter 370.13 Stone crab; regulation.

Gulf of Mexico Fisheries Management Council. 2000. Amendment 7 to the Fishery Management Plan for the Stone Crab Fishery of the Gulf of Mexico. 65 pp. plus appendix.

Gulf States Marine Fisheries Commission. 1995. A profile of the western Gulf stone crab, *Menippe adina*. V. Guillory, H. M. Perry, and R. L. Leard (eds.) GSMFC Rep. No. 31, 62 pp.

Hardin, G. 1968. The tragedy of the commons. *Science* **162**:1243-48.

Hunt, J.H., R.D. Bertelsen, C.Cox, T.R. Matthews, and W.C. Sharp. 1994. Commercial and recreational harvest of the spiny lobster, *Panulirus argus* (Latreille), in Florida during the 1993-94 season. Report to the Florida Marine Fisheries Commission. 42 pp. + appendix.

Leventhal, G.S. 1976. The distribution of rewards and resources in groups and organizations. Pages 91-131. in: L. Berkowitz and E. Walster (eds.) *Advances in Experimental Social Psychology*, Vol. 9. Academic Press. New York, New York USA.

Loomis, D.K. and R.B. Ditton. 1993. Distributive justice in fisheries management. *Fisheries* **18**:14-18.

Muller, R.G. and T.M. Bert 1997. 1997 Update on Florida's stone crab fishery. Report to the Florida Marine Fisheries Commission, Florida Marine Research Institute Publication No. IHR1997-001. St Petersburg, Florida USA. 18 pp.

Muller, R.G. and T.M. Bert 2001. 2001 Update on Florida's stone crab fishery. Report to the Florida Marine Fisheries Commission. Florida Marine Research Institute Publication No. IHR2001-008. St Petersburg, Florida USA. 20 pp.

Phares, P.L. 1992. Analysis of trends in catch, effort, and catch per unit effort in the Florida stone crab (genus *Menippe*) fishery. Pages 18-25. in: T. M. Bert (ed.), *Proceedings of a Symposium on Stone Crab (Genus Menippe) Biology and Fisheries*. Florida Marine Research Institute Publication No. 50. St. Petersburg, Florida USA. 118 pp.

Savage T., J.R. Sullivan, and C.E. Kalman 1975. An analysis of the stone crab(*Menippe mercenaria*) landings on Florida's west coast, with a brief synopsis of the fishery. Florida Marine Research Institute Publication No. 13. St. Petersburg, Florida USA. 37 pp.

Simonson, J. L. and R. J. Hochberg. 1992. An analysis of stone crab (genus *Menippe*) claws and their use in interpreting landings on Florida's west coast. Pages 26-35. in: T. M. Bert (ed.), *Proceedings of a symposium on stone crab (genus Menippe) biology and fisheries*.Florida Marine Research Institute Publication No. 50. St. Petersburg, Florida USA. 118 pp.

Southerland, D.L. 1988. Stone crab stock assessment data, 1962-1987. NOAA/ NMFS/SEFC Coastal Resource Division, Contrib. No. CRD-87/88-29. 16 pp.

Sullivan, J. R. 1979. The stone crab, *Menippe mercenaria*, in the Southwest Florida fishery. Florida Marine Research Institute Publication No. 36. St. Petersburg, Florida USA. 37 pp.

Wilber, D.H. 1995. Claw regeneration among North Florida stone crabs (Genus *Menippe*) and its implications to the Southwest Florida fishery. *Bulletin of Marine Science* **56**:296-302.

Zuboy, J.R. and J.E. Snell. 1980. Assessment of the Florida stone crab fishery. NOAA Tech. Mem. NMFS-SEFC-21. 29 pp.

Abundancia Relativa e Incidencia de Postlarvas de Camarones Peneidos en la Zona Litoral Norte de Campeche, México

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RESUMEN

Se hace un estudio de las postlarvas planctónicas de Peneidos en las localidades de Seyba-Playa e Isla Arena Campeche; a través de un ciclo anual (1999 - 2000) analizando su abundancia relativa (ind/m^3), así como sus relaciones con los efectos de las lunas llena y nueva, la salinidad y la temperatura del mar.

Se determina la presencia del género *Farfantepenaeus* con dos picos de abundancia, uno en el mes de Octubre y otro en Julio, se encontró una mayor cantidad de individuos entre las 18:00 hrs. y las 02:00 hrs. y no se presentan con la luz del día, con preferencia a las temperaturas de 29 y 30°C, así como salinidades de 31 a 36 ups.

Se presume que utilizan una estrategia de dispersión con migraciones verticales en la columna de agua durante la noche, asociadas al flujo de marea, las corrientes y los vientos, para regresar a los pastos marinos durante el día.

PALABRAS CLAVE: Postlarvas, abundancia relativa, estrategia de dispersión

INTRODUCCION

La pesquería de camarón rosado en la Sonda de Campeche muestra actualmente signos de colapso, hay varios factores que causan esta condición, entre los que se encuentran las fallas en el reclutamiento y en la tasa de reclutamiento, la pesca excesiva de juveniles y la posible alteración de hábitats críticos entre otros (Arreguín-Sánchez 2000), normalmente se ha estudiado la pesquería con la información de los datos de captura de la flota industrial, sin embargo es necesario en este tipo de recursos conocer el ciclo de vida completo, para determinar los puntos clave de cada fase, como son: el ingreso de las postlarvas a las zonas de pastizales, la migración de los juveniles y la edad de reclutamiento, así como la maduración y la longevidad, en el caso del camarón rosado poco se ha estudiado acerca de las etapas de postlarva planctónica, postlarva bentónica y de los juveniles que encuentran refugio en las grandes zonas de pastizales de las areas comprendidas entre Champotón e Isla Arena, Campeche. Varios autores han estudiado el

reclutamiento de postlarvas de camarones peneidos en el Golfo de México, como por ejemplo (Christmas et al. 1966, Baxter y Renfro 1967, Caillouet et al. 1968, 1970, Ford y St. Amant 1971 - todos citados por De Lancey, et al. 1994.) y en México, García y Gracia (1992) han trabajado con la abundancia de las fases estuarinas del camarón rosado en la laguna de Términos, pero existen pocas referencias de las postlarvas de este camarón de las zona del litoral norte de Campeche.

En este trabajo se hace un estudio de las postlarvas planctónicas de camarones peneidos en las localidades de Seyba-Playa e Isla Arena, Campeche. A través de un ciclo anual, analizando su abundancia relativa (ind/m^3), así como sus relaciones con los efectos de las lunas llena y nueva, la salinidad dada en ups (unidades potenciales de salinidad) y la temperatura del mar. Se presume que utilizan una estrategia de dispersión con migraciones verticales en la columna de agua durante la noche, asociadas al flujo de marea, el efecyo de la luna, las corrientes y los vientos, para regresar a los pastos marinos donde permanecen durante el día.

MATERIALES Y METODOS

Para realizar los muestreos entre los 1,500 y 2000 m del frente de playa en las localidades de Seyba-Playa, municipio de Champóton y en Isla-Arena, municipio de Calkiní, en el estado de Campeche, México (Figura 1). Se emplearon dos redes de plancton de 500 y 335 micras de luz de malla, con 0.30 m de diámetro y 1.5 m de longitud, con un flujómetro adaptado a la boca de la red para conocer la cantidad de agua filtrada. Se hicieron lances de cinco minutos cada hora a bordo de una lancha equipada con motor fuera de borda; y para determinar la magnitud de los muestreos previamente se hicieron pruebas de 24 hrs. en cada sitio para detectar la presencia de las postlarvas, las cuales resultaron tener actividad nocturna, con mayor presencia entre las 18:00 a las 02:00 hrs. y sin actividad con la luz del día. Antes de cada lance se anotaron los datos de la temperatura y la ups (unidades potenciales de salinidad), la hora del día, la fase de la luna y cualquier actividad de tipo meteorológico que pudiera influir en la calidad de las muestras.

Las muestras se fijaron con solución de Davidson para su traslado al laboratorio donde se identificaron hasta nivel de género, con la ayuda de microscopios estereoscópicos y los trabajos de Cook (1966), Ringo y Zamora (1968), y Pérez-Farfante (1970).

Las cantidades obtenidas de postlarvas fueron convertidas a un índice de Abundancia Relativa, dado por el número de individuos capturados y dividido entre los metros cúbicos de agua filtrada (individuos / metro cúbico). Para el análisis estadístico las cantidades de ind/m^3 las tranformamos con la formula de Ln $(n+1)^2$ (García Le Reste 1986, Castillo y Arias 1998) las cantidades obtenidas se separaron por luna llena y luna nueva, aplicamos el Análisis de Varianza de una vía (ANOVA) para probar si existe diferencia entre las abundancias de las postlarvas con los efectos de las lunas nueva y llena en cada localidad y utilizamos el análisis de regresión para conocer la relación de las postlarvas con la temperatura, la ups

(unidades potenciales de sal) y la hora del muestreo para cada luna. Además se hicieron gráficas de la abundancia relativa de las postlarvas de cada muestreo en el lapso de un año para conocer los picos de mayor abundancia

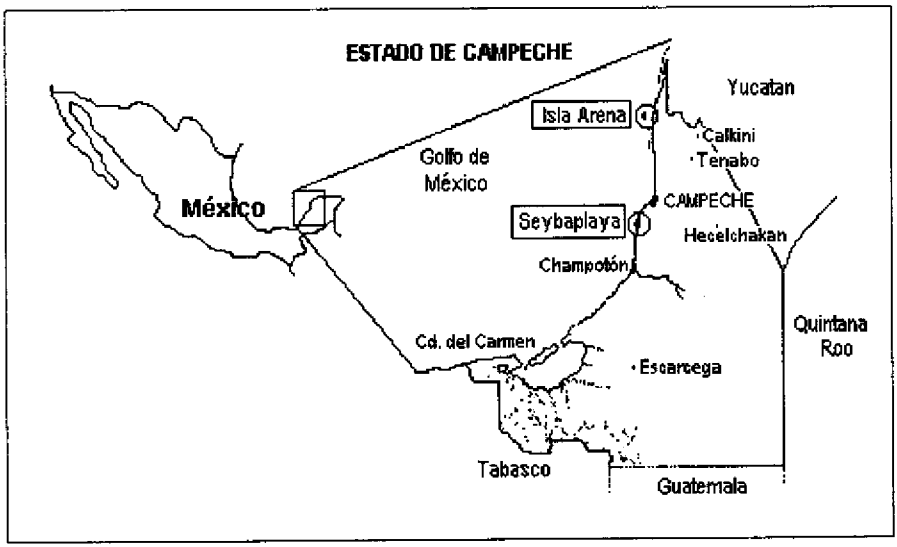


Figura 1. Zonas de muestreo, Litoral Norte de Campeche

RESULTADOS

Un total de 83 (70 en la luna llena y 13 en la luna nueva) y 50 (40 en luna llena y 10 en luna nueva) postlarvas planctónicas de peneidos fueron colectadas en Seyba-Playa e Isla Arena respectivamente, desde octubre de 1999 hasta septiembre del 2000, la mayoría fueron identificadas hasta genero (*Farfantepenaeus*), solo se tuvo incertidumbre en un 6% de los individuos colectados en Isla Arena, no fue posible la identificación hasta especie pero existe la confianza de que pertenezcan a la especie *Farfantepenaeus duorarum*, ya que la mayoría de los juveniles colectados para otro estudio se identificaron como camarón rosado con una certeza del 99% (Santos y González 2000). Los picos de abundancia se manifestaron uno más grande en la luna llena de octubre (2.05 ind/m^3) y otro secundario en las lunas llena y nueva de julio (0.39 y 0.15 ind/m^3) y la llena de agosto (0.108 ind/m^3), en la localidad de Seyba-Playa. En Isla Arena encontramos el mayor pico de abundancia en la luna llena del mes de julio (0.73 ind/m^3), y otro menor en la luna llena del mes de septiembre (0.39 ind/m^3).

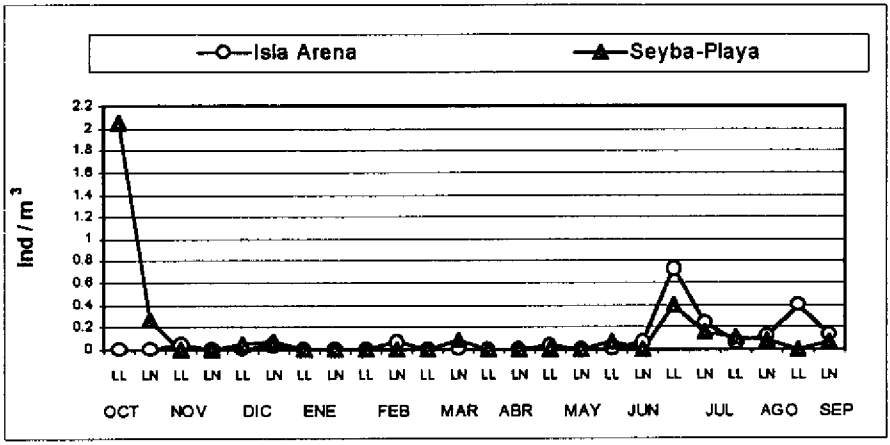


Figura 2. Abundancia relativa de postlarvas planctónicas de *Farfantepenaeus* sp. Octubre 1999 – Septiembre 2000.

En Seyba-Playa tenemos que las horas de mayor presencia fueron más abundantes entre las 18:00 y las 02:00 horas de la luna llena, y entre las 19:00 y las 02:00 horas en la luna nueva, con una máxima a las 21:00 y 22:00 horas en la luna llena y a las 00:0 y 01:00 horas en la luna nueva; los resultados del análisis de regresión reveló que no hay una relación significativa entre el número de las postlarvas y las horas de la noche ($r = -0.38$ en la luna llena y $r = 0.29$ luna nueva). La temperatura con mayor abundancia fue de 30°C. en la luna llena y en los 29 y 30° C. en la luna nueva, y hay una relación aunque no lineal entre las temperaturas y la cantidad de postlarvas ($r = 0.55$, $p < 0.05$), con un rango de los 28 a los 31°C. en la luna llena, y de los 25 a los 31°C en la luna nueva.

La salinidad varió entre los 31 y los 38 ‰ en la luna llena, con preferencia por los 31 ups y una relación significativa negativa a medida que aumenta la salinidad ($r = -0.86$, $p < 0.05$). Y en la luna nueva el rango fue de 35 a 38‰ con una preferencia por los 35‰ y una relación significativa negativa con el aumento de ups ($r = -0.94$, $p < 0.05$).

En Isla Arena las postlarvas se capturaron entre las 19:00 y las 02:00 horas tanto en la luna llena como en la luna nueva, con una máxima a las 22:00 horas en la luna llena y a las 21:00 horas en la luna nueva; los resultados del análisis de regresión reveló que no hay una relación lineal ($r = 0.36$ en la luna llena y $r = -0.13$ luna nueva) entre el número de las postlarvas y las horas de la noche. La temperatura con mayor abundancia fue de 29°C. en la luna llena y en los 28 y 29°C. en la luna nueva y existe cierta relación no lineal entre las temperaturas y la cantidad de

postlarvas de r = 0.49, p < 0.05, con un rango de temperatura de los 26 a los 31 °C en la luna llena; y r = 0.33, con un rango de temperatura de los 21 a los 31°C. La salinidad varió entre los 31 y los 38‰ en la luna llena, con preferencia por los 36 y 37 ups y una relación r = 0.47, p > 0.05. Y en la luna nueva la salinidad estuvo entre los 35 y los 38 ‰ con una preferencia por los 36 ups y una relación negativa con el aumento de ups (r = -0.34, p > 0.05).

Tabla 1. Rango y preferencia de la hora del día, temperatura y salinidad del agua

		HORA		TEMPERATURA (°C)		‰ (Unidades Potenciales de Sal)		# Ind.
		Rango	Preferencia	Rango	Preferencia	Rango	Preferencia	
A	LL	18:00 02:00	21:00 22:00	28 - 31	30	31 - 38	31	70
	LN	19:00 02:00	00:00 01:00	25 - 31	29 30	35 - 38	35	13
B	LL	19:00 02:00	22:00	26 - 31	29	31 - 38	36 37	40
	LN	19:00 02:00	21:00	21 - 31	28 29	35 - 38	36	10

A = Seyba-Playa B = Isla Arena LL = Luna llena LN = Luna nueva

Con los datos de las postlarvas por metro cúbico transformados a Ln $(n+1)^2$ (Castillo y Gómez op.cit. 1998) se realizó el análisis de varianza de una sola vía (ANOVA) para determinar si hubo diferencia entre las postlarvas de la luna nueva y la luna llena, la Hipótesis a demostrar fue; H_o: no existe diferencia significativa entre las postlarvas de la luna llena y luna nueva. Ha: si existen diferencias significativas entre las postlarvas de la luna llena y la luna nueva, obteniendo los siguientes resultados para Seyba-Playa los datos acumulados de cada muestreo se acepta Ho que indica que no hay diferencia significativa entre las dos lunas (f = 0.86, f-critica = 4.3, p = 0.86, α = 0.05), y para las medias de cada muestreo obtuvimos una f = 0.65 que es menor a la f-critica = 4.3, con p = 0.42, α = 0.05, por lo que también se acepta H_o.

Para Isla Arena, tenemos que se acepta Ho para los datos acumulados por que no se presenta diferencia significativa entre las dos lunas (fa 0.93, f-critica = 4.3, α = 0.05), y para las medias de cada muestreo se obtuvo una f = 0.35 que es menor a la f-critica = 4.3, con p = 0.55, α = 0.05, por lo que H_o se acepta pues no se encontraron diferencia significativa entre la luna nueva y la llena respectivamente.

DISCUSION

Ante el reto de conocer la migración de las postlarvas planctónicas que puedan relacionarse con las épocas de desove, se selecciono el tipo de muestreo que utilizamos, después de realizar colectas de 24 horas y que nos dio la pauta a seguir, por lo que implementamos una campaña de colectas de las 18:00 a las 02:00 horas,

esto con el fin de asegurar la captura de postlarvas de *Farfantepenaeus duorarum* , además se proyectó realizar los muestreos en cada efecto de luna para conocer la incidencia de las postlarvas en dos lugares equidistantes en la zona de distribución de *F. duorarum* de la costa norte de Campeche.

Los resultados concuerdan con el trabajo de Almaral-Mendivil (2000) para la zona norte de la costa de Campeche, ya que a las postlarvas de camarón rosado se les localizo en la zona marina de la costa y en zona de pastizales.

Los resultados nos dan una pauta para creer que tanto las épocas de desove como las corrientes, mareas, nortes y la época de lluvias intervienen en la distribución y en la dispersión de las postlarvas de camarón rosado y que pueden llegar a la zona marina de Isla Arena y Celestún, sin penetrar al estero de esta última localidad.(Almaral-Mendivil *op. cit.* 2000)

La manifestación de los picos de abundancia relativa de las postlarvas se relacionan con los picos de abundancia de los juveniles reportados por Santos y González op. cit.(2000), y con la reproducción en alta mar, además de que el segundo pico de las postlarvas que se dio en el mes de julio coincide con lo reportado por García y Gracia (1999), que encontraron una alta densidad de postlarvas que entran a la Laguna de Términos en la época de lluvias.

El método de dispersión es parecido al que describe Epifanio (1988) para las larvas de cangrejos, pues utilizan la actividad nocturna para incursionar en la columna de agua y después regresar a los pastos marinos donde encuentran protección durante el día y pueden avanzar de una área a otra y así sucesivamente, durante los muestreos realizados en las dos localidades la actividad de las postlarvas empezó después de las 18:00 horas y en los arrastres desde frente de playa hacia el mar en las zonas de pastizales encontramos una mayor actividad del zooplancton en general que fue menguando hacia las 02:00horas.

Si bien conocemos algo sobre la incidencia de las postlarvas en las zonas de pastos marinos, es necesario seguir investigando sobre el regreso de los juveniles a las zonas de crecimiento y reproducción.

RECONOCIMIENTOS

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LITERATURA CITADA

Almaral-Mendivil, A.P. 2000. Efectos de la heterogeneidad del hábitat sobre los patrones de distribución de las postlarvas planctónicas de camarones (*Farfantepenaeus* y *Litopenaeus*) en la laguna de Celestún, Yucatán. Tesis de Maestría. IPN-CINVESTAV unidad Mérida. 92 pp.

Arreguín-Sánchez, F. [2000]. Sobre la posible recuperación de la pesquería de camarón rosado en la Sonda de Campeche: un enfoque ecosistémico. XII Congreso nacional de Oceanografía, Huatulco, Oaxaca, México.

Baxter, K.N. and W C. Renfro. 1967. Seasonal occurrence and size distribution of postlarval brown and white shrimp near Galveston, Texas, with notes on species identification. *U.S. Fisheries Bulletin* **66**:149-158.

Caillouet, C.W., Jr., B.J. Fontenot, Jr. And R.J. Dugas. 1968. Diel fluctuations in catch of postlarval white shrimp, *Penaeus setiferus* (Linnaeus), with Renfro beam trawl. *Bulletin of Marine Science* **18**:829-835.

Caillouet, C.W., Jr., W.S. Perret And R.J. Dugas. 1970. Diel fluctuations in catch of postlarval brown shrimp, *Penaeus aztecus* Ives, with Renfro beam trawl. *Bulletin of Marine Science* **20**:721-730.

Castillo-Padilla, J. y J. Gómez A. 1998. *Estadística Inferencial Básica.* Grupo Editorial Iberoamericana, S.A. de C.V. 500 pp.

Christmas, J.Y., G. Gunter and P. Musgrave. 1966. Studies of annual abundance of postlarval penaeid shrimp in the estuarine waters of Mississippi, as related to subsequent commercial catches. *Gulf Research Reports* **2**:177-212.

Cook, H.L. and M.J. Linder. 1970. Synopsis of biological data on the brown shrimp *Penaeus aztecus* Ives, 1891. Pages 1471-1498 in: *FAO Fish. Rep. 57.*

Criales, M.M. y T.N. Lee. 1995. Larval distribution and transport of penaeoid shrimp during the presence of the Tortugas Gyre in May-June 1991. *U.S. Fisheries Bulletin* **93**:471-482.

Dall, W., B.J. Hill, P.C. Rothlisbreg, and D.C. Sharples. 1999. The Biology of the Peneaidae. Pages 333-355 in: J. H. Blaxter y A. J. Southward (eds.) *Advances in Marine Biology* Vol. 27. Academic Press, London, England. 489 pp.

DeLancey, L.B., J.E. Jenkins and J.D. Whitaker. 1994. Results on long-term, seasonal sampling for *Penaeus* postlarvae at Breach Inlet, South Carolina. *U.S. Fisheries Bulletin* **92**:633-640.

Epifanio, Charles E. 1988. Transport of crab larvae between estuaries and the continental shelf. Pages 209-305 in: B. O. Jansson (ed.) *Lecture Notes in Coastal and Estuarine Studies. Coastal-Offshore Ecosystem Interactions.* Springer-Verlag Berlin Heidelberg, Germany.

Ford, T.B. and L. St. Amant. 1971. Management guidelines for predicting brown shrimp, *Penaeus aztecus*, production in Louisiana. *Proceedings of the Gulf and Caribbean Fisheries Institute* **23**:149-161.

García del Real, R. y A. Gracia G. 1992. Abundancia de las fases estuarinas del camarón rosado, *Penaeus (Farfantepenaeus) duorarum* Burkenroad 1939, en el área de Puerto Real Laguna de Términos, Campeche, México. Pagina 181en: V. M. Rojas R., J. A. López M. y E. A. Zarza M. (eds.) Memorias IX Congreso Nacional de Oceanografía, Veracruz, México.

García, S. y Le Reste. 1986. *Ciclos Vitales, Dinámica, Explotación y Ordenación de las Poblaciones de Camarones Peneidos Costeros.* FAO Doc. Téc, Pesca. 180 pp.

Pérez-Farfante, I. 1970. Diagnostic characters of juveniles of the shrimps *Penaeus aztecus aztecus*, *P. duorarum duorarum* and *P. brasiliensis* (Crustacea, Decapoda, Penaeidae). *Sep. Mem. Soc. Cienc. .Nat. La Salle.* **30**:159-182.

Ringo, R. y G. Zamora. 1968. A penaeid postlarval character of taxonomic value. *Bulletin of Marine Science* **18**(2):471-476.

Santos V, J., M. E. González, E. González D. [2000]. Determinación de los cambios en la composición de especies de camarones presentes en la zona costera de Champóton, Campeche, INP-CRIP Lerma, SEPESCA Fideicomiso de Estudios y Proyectos de Investigación Pesquera y Acuícola del Gobierno de Campeche. 22pp. En Prensa.

Strombus gigas L. 1758 (Mesogasteropoda: Strombidae) y Su Periodo de Desove en el Arrecife Alacranes, Yucatán

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RESUMEN

Se realizó un estudio sobre el ciclo reproductor de *Strombus gigas* en el Arrecife Alacranes, de febrero de 1999 a marzo del 2000. Para el muestreo, se definieron tres sitios que fueron en las situaciones geográficas: 22°34'LN, 89°42'LW (sitio 1); 22°29'LN, 89°45LW (sitio 2) y 22°22LN, 89°39'LW (sitio 3), con base al estudio sobre distribución y abundancia realizado en 1998. En cada uno de los sitios se realizaron tres transectos al azar, de 100 m de longitud por 10 m de ancho. Dentro del área del transecto, se contaron todos los individuos en apareamiento, hembras en desove y presencia de masas de huevo. Se registró además, la biometría de los caracoles y la temperatura de fondo. En febrero, se encontraron las primeras dos hembras en desove. La máxima actividad reproductora referente al desove se registró en abril con siete apareamientos y ocho masas de huevo. En 9 000 m^2, para febrero del 2000, se encontraron cuatro masas de huevos y en marzo se observaron dos masas de huevo. En el periodo de estudio, el sitio ubicado en los 22°29' LN y 89°45' LW fue el que presentó mayor actividad reproductora, con 33 apareamientos, tres hembras en desove y 21 masas de huevos (3 transectos de 100 x 10 m). Para los tres sitios de muestreo, la media de la longitud sifonal de los organismos (n 458) fue de 229 mm (DE 13.32) y 16 mm de grosor de labio (DE 5.18). La temperatura de fondo promedio fue de 27°C, la mínima 24°C en enero y la máxima de 30°C de junio a septiembre.

Strombus gigas (Mesogasteropoda: Strombidae) Spawning on the Alacranes Reef, Yucatan

ABSTRACT

The reproductive season of *Strombus gigas* was determined in the Alacranes reef along February 1999 to March 2000. The sampling was in 22ª 34' LN, 89ª 42' LW (site 1); 22° 29' LN, 89° 45' (site 2) and 22° 22' LN, 89° 39' LW (site 3), based on a study about Distribution and abundance done in 1998. Each sites were used three 100 x 10 m transects. On the transect area, pairing, spawning and egg

laying, and conch morphology were documented. During February 2000, the first spawning pair was observed in a 9,000 m^2 area. The maximun reproduction activity was in april with seven pairings and eight egg masses. In February 2000, four egg masses were found and two in March. In this study, the site with more reproduction activity was 22°29'LN and 89°45', with 33 pairing, three spawnings and 21 egg masses. For the sites, the mean shell lenght was 229 ± 13.32 mm (S.D.) (n = 458) and for lip thickness 16 ± 5.18 mm. The mean low bottom water temperature was 27°C. The water temperature was 30°C from June to September, decreasing to 27°C in January.

INTRODUCCION

La pesquería de *Strombus gigas* en el Caribe, ha crecido considerablemente en los últimos 20 años; los desembarcos se han estimado en 6000 toneladas métricas con un valor de 60 millones de dolares americanos (Chakalall y Cochrane 1997). Las poblaciones de *S. gigas* se han visto afectadas drásticamente en todos los países donde es explotado a nivel comercial (Brownell y Stevely 1981, Davis y Hesse 1983), en particular en naciones donde la pesquería ha sido abierta al buceo con equipo SCUBA. El agotamiento de los stocks ha obligado al menos temporalmente al cierre de la captura de *S. gigas* en Bermudas, Florida, Cuba, Bonaire, y las Islas Vírgenes (Stoner y Schwarte 1994). Es así que para 1992, CITES incluyó a S. gigas en la lista de especies amenazadas (Appeldoorn 1994).

La biología de *S. gigas* ha sido estudiada en los países que lo explotan o explotaron a nivel comercial (Randall 1964, Brownell y Stevely 1981, Berg y Olsen 1989). Los sexos de *S. gigas* son separados y la madurez sexual ocurre a los tres años y medio de edad, unos meses después de que el labio se ha desarrollado (Egan 1985, Wilkins et al. 1987, Appeldoorn 1990). La fertilización es interna y después de la copulación, ocurre el desove (D'Asaro 1965). Una hembra puede desovar entre seis y siete veces durante la estación reproductora (Davis y Hesse 1983).

El periodo reproductor de *S. gigas* ha sido reportado para diferentes sitios del Caribe. D'asaro (1965) reporta para los Cayos de Florida un periodo de mayo a septiembre; Weil y Laughlin (1984) en Venezuela, de abril a noviembre; Davis *et al.* (1987) para Turks y Caicos de marzo a octubre; Appeldoorn *et al.* (1987) en Puerto Rico, de mayo a noviembre; Stoner *et al.* (1992) en Bahamas, de abril a octubre.

En México, *S. gigas* se encuentra en dos localidades, Banco Chinchorro en Quintana Roo y Arrecife Alacranes en Yucatán. El periodo reproductor, estimado por Cruz (1986) y Corral y Ogawa (1987) para Banco Chinchorro, fue de todos los meses en el año. Para Yucatán, Pérez (1996), en un trabajo realizado en el Arrecife Alacranes durante seis meses, estimó el periodo de reproducción para *S. gigas* de mayo a octubre. Este trabajo, aporta información acerca del apareamiento, desove y presencia de masas de huevo, de *S. gigas* en Yucatán,

relacionándolo con la temperatura y fotoperiodo en el Arrecife Alacranes, Yucatán durante 14 meses, de febrero de 1999 a marzo de 2000.

MATERIALES Y METODOS

Sitio De Estudio

El Arrecife Alacranes, es una de las áreas arrecifales más importantes de México, no solo por su extensión sino por su diversidad y complejidad ya que en él, se encuentra una gran variedad de corales como *son Montastrea anularis, Acropora palmata, Porites porites, Porites asteroides, Diploria spp, Manicina aerolata* y grandes extensiones de pastos principalmente de *Thalassia testudinum*. Existen 148 especies de peces arrecifales (Hildebrand et. al 1964) incluyendo varias de importancia comercial como es el mero rojo *Epinephelus morio*. La presencia de la langosta espinosa *Panulirus argus* ubica al arrecife como una de las áreas de pesca más importante para el pescador yucateco. El Arrecife Alacranes es un área de pesca utilizada por 117 pescadores yucatecos de cuatro Cooperativas de Producción Pesquera, que capturan especies de escama, tiburón, langosta y en el pasado el caracol *Strombus gigas*. El seis de junio de 1994 el arrecife fue declarado Parque Marino Nacional Alacranes (PMNAA) y esta condición hace necesario el establecimiento de un plan de manejo que concilie el uso y aprovechamiento de los recursos por los pescadores y la conservación de la biodiversidad.

El Arrecife Alacranes, se encuentra localizado a 135 kilómetros, al Norte del Puerto de Progreso, Yucatán, entre los 22° 21' 45'' y 22° 34' 55'' LN y los 89° 36' 47'' y 89° 47' 53'' LO. Es de forma oval y presenta su eje mayor con dirección Noroeste - Sureste y mide 26 Km de largo por 13 km en su porción más ancha con un área aproximada de 185 Km^2. El área de prospección se ubicó entre las coordenadas 22° 22' y 22° 34' LN y los 89° 37' y 89° 47' LO. En la Figura 1 se muestra la localización del Arrecife Alacranes.

Periodo Reproductor

El periodo reproductor, en base a las observaciones de apareamiento, desove y presencia de masas de huevo, fue estudiado durante 14 meses en forma mensual, de febrero de 1999 a marzo del 2000. Para efecto de establecer las localidades de muestreo, el arrecife alacranes fue dividido en una retícula de 13 números contra 15 letras cada minuto (cada milla náutica) comprendidas entre las latitudes 22° 21' y 22° 36' y entre las longitudes 89° 36' y 89° 48' (Figura 2). Se establecieron tres localidades de muestreo previamente identificadas como zonas de reproducción durante un muestreo de prospección realizado durante 1997, en base a observaciones de apareamientos y masas de huevo. Las localidades de muestreo fueron A-10, H-4 y M-7 (Figura 2). En cada localidad de muestreo se tendió un transecto de 100 m de longitud y 10 m de ancho. Dentro del área del transecto,

mediante buceo libre se registraron para cada individuo las siguientes actividades reproductoras:

i) Individuos solos: los individuos se les encuentra sin copular y sin depositar masas de huevo;
ii) Copulando (Apareamiento): individuos en copulación, con el pene del macho dentro del zurco genital de la hembra;
iii) Depositando: la hembra está colocando la masa de huevos en la arena; y
iv) El número de masas de huevo depositadas.

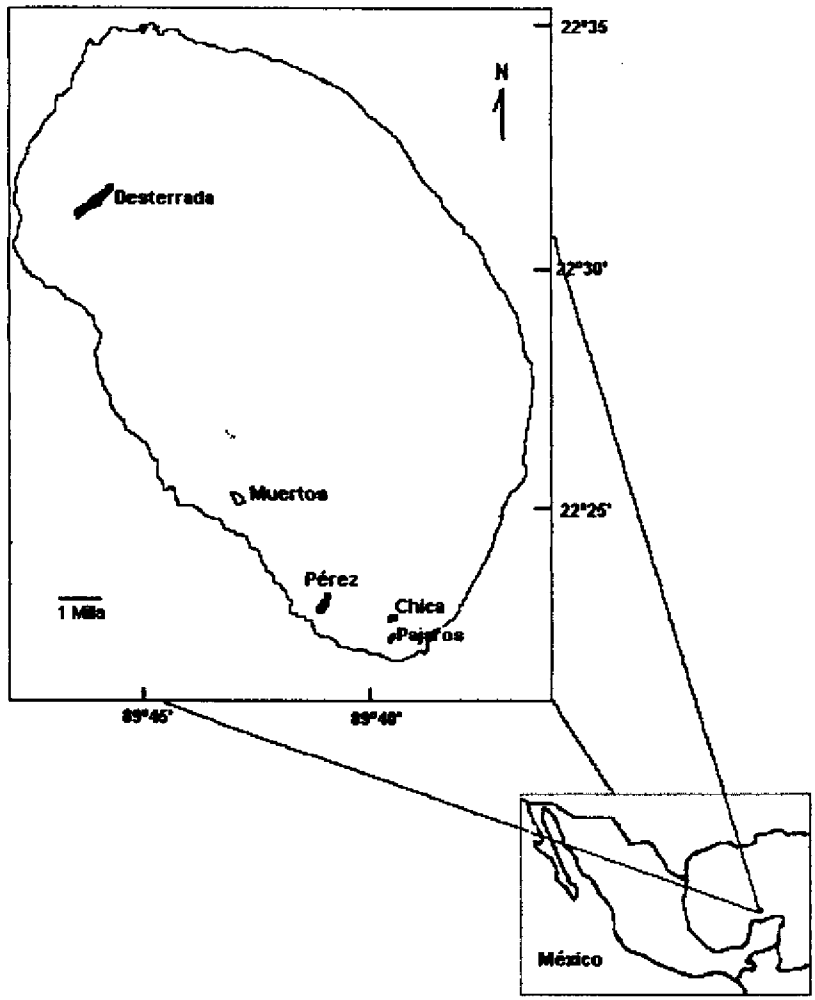


Figura 1. Localización del Arrecife Alacranes, Yucatán, México y la ubicación de las Islas dentro de la Laguna arrecifal.

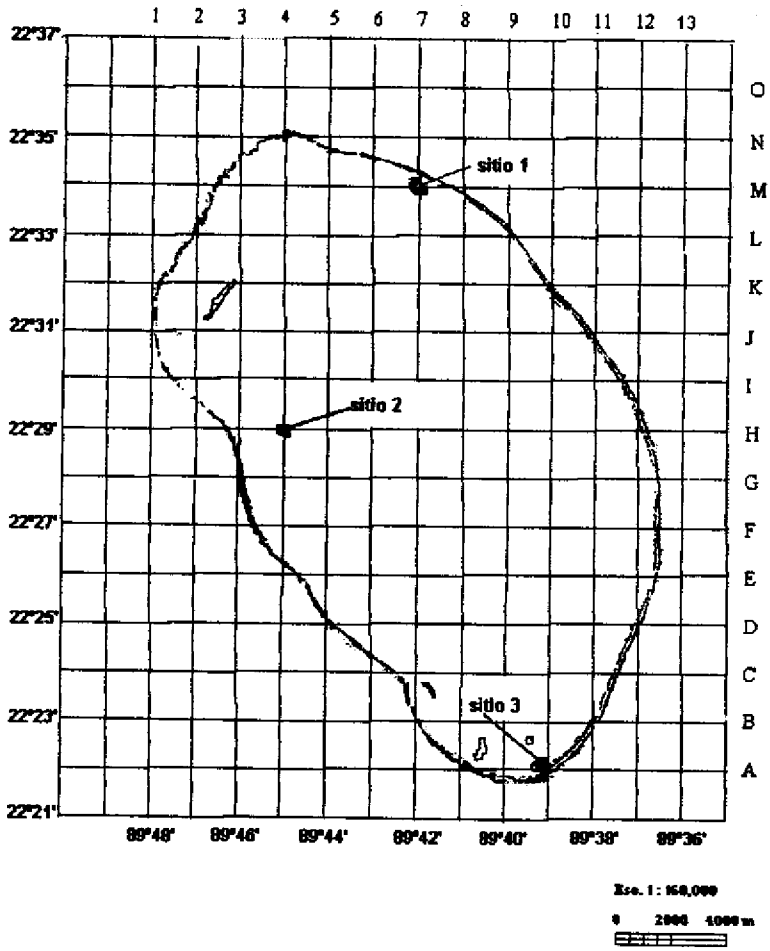


Figura 2. Localización de los puntos de muestreo de Strombus gigas en el Arrecife Alacranes, quedando identificado por el binomio letra y número en el cruce de la Latitud y la Longitud.

El periodo reproductor fue cuantificado registrando el porcentaje del número total de individuos sobre el fondo en cada actividad. Se tomó información del tipo de substrato (arena, restos de coral y arena con pastos) en las tres localidades de muestreo. Solo a los individuos que no se estaban apareando o desovando, fueron colocados en la embarcación donde se les registraron las medidas morfométricas longitud de la heliconcha o longitud sifonal (de la punta de la espira al inicio del canal sifonal) y el grosor del labio a la mitad de la distancia posterior de donde inicia el canal sifonal al inicio de la espira. Las medidas morfométricas fueron registradas al mm más cercano.

Parametros Fisicos

Se registró la temperatura de fondo, de superficie y salinidad en las localidades de muestreo con un multianalizador YSI 85/25 FT, colocado a bordo de la embarcación, con el sensor a un metro de la superficie y del fondo. El multianalizador registró la temperatura y la salinidad con una precisión de una décima.

Para examinar la correlación entre el periodo reproductor y el fotoperiodo se construyó una curva del fotoperiodo (Figura 3). El número de horas y minutos entre el orto y el ocaso fueron calculados en forma mensual usando el almanaque náutico.

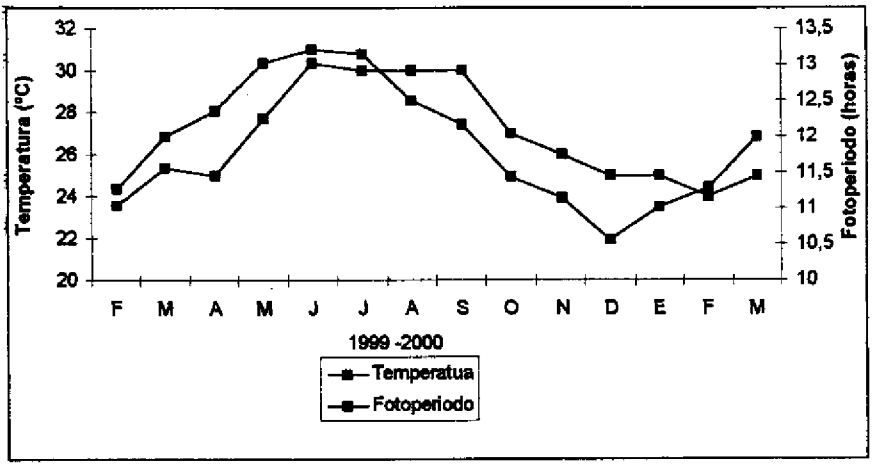


Figura 3. Temperatura del agua promedio a una profundidad de 4 m. Fotoperiodo durante los meses de muestreo para el Arrecife Alacranes, Yucatán, México.

RESULTADOS

El periodo reproductor para *Strombus gigas* en el Arrecife Alacranes, tomando como base las observaciones de apareamientos, desoves y presencia de masas de huevo, fue de febrero a octubre (Figura 4). El comienzo del periodo reproductor estuvo marcado por una concentración de caracoles en tipos de fondo de arena, restos de coral y camas de arena rodeadas por pastos de thalassia (Figura 6). En este último tipo de fondo, en el mes de febrero, se observó la primera cópula y puesta de huevos. En abril, se incrementó el número de hembras depositando masas de huevos y el número de masas de huevo (Figura 5). En agosto el 8% de los individuos observados realizaron actividades reproductoras; este porcentaje disminuyó en septiembre y octubre a ménos del

1%. Los últimos individuos en cópula y apareo fueron observados en el mes de octubre (Figura 4). La última masa de huevos fue observada en el mismo mes de octubre (Figura 5).

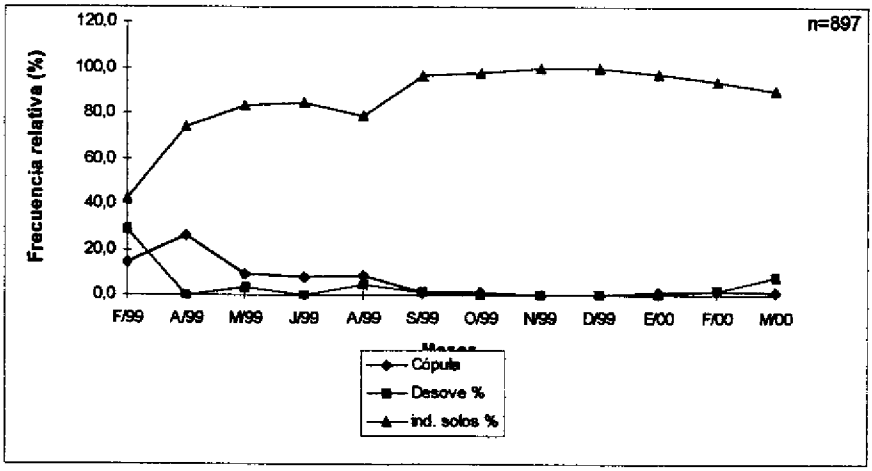


Figura 4. Actividad reproductora de Strombus gigas en el Arrecife Alacranes. Se presentan tres actividades: Apareamiento, desove y masas de huevo observadas.

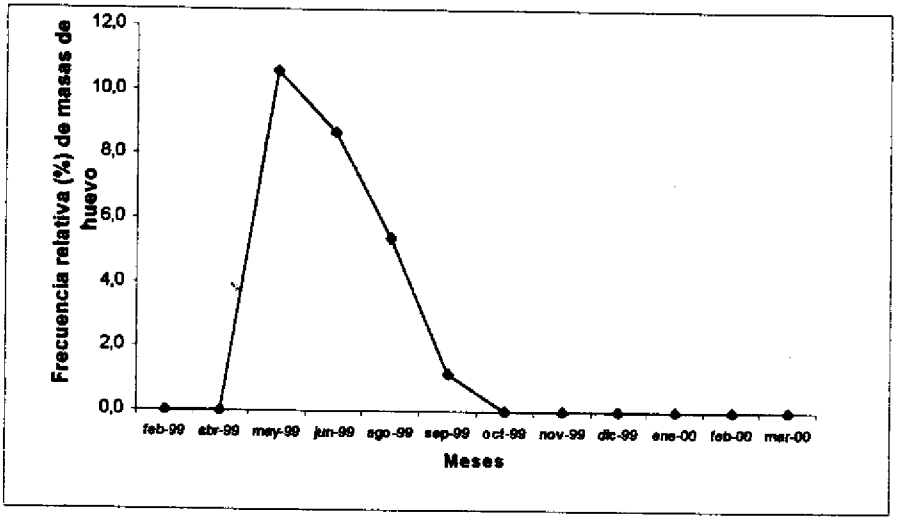


Figura 5. Frecuencia relativa de la presencia de masas de huevo de Strombus gigas en el Arrecife Alacranes, Yucatán en el periodo de muestreo.

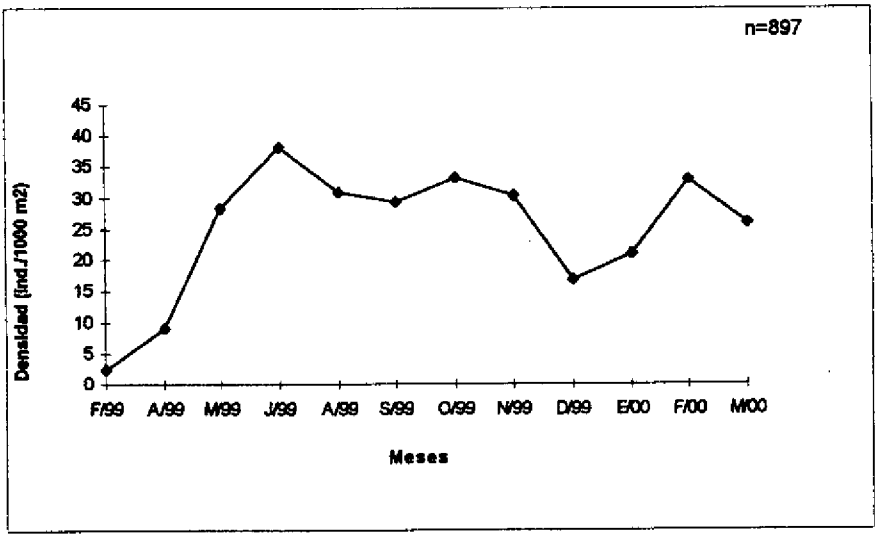


Figura 6. Densidad promedio de adultos de Strombus gigas en el Arrecife Alacranes, Yucatán de febrero de 1999 a Marzo del 2000.

El número de caracoles en actividad reproductora aumentó junto con el incremento de densidad de caracoles en los sitios de estudio, en febrero de 2 caracoles por cada 1000 m^2 a 40 caracoles por cada 1000 m^2 en el mes de julio. La densidad decreció en el mes de diciembre a 17 caracoles por 1000 m^2 (Figura 4).

Durante el periodo de muestreo, se realizaron observaciones de las temperaturas de fondo y de superficie (Figura 3). El primer apareamiento se observó a una temperatura de 23.8°C a mediados del mes de febrero, y la primera masa de huevos se observó a los 24.5°C en abril. El número de hembras copulando se incrementó en función de la temperatura hasta el mes de abril pero disminuyó en los siguientes meses hasta octubre que fue cuando se observó la última cópula. Se observó un coeficiente de correlación de 0.55 entre la temperatura y el apareamiento. Mientras que el coeficiente de correlación entre la temperatura y el número de masas de huevo observadas fue de 0.66. En los meses de junio a septiembre, la temperatura se mantuvo relativamente constante a 30°C; el último apareo y cópula fue en este periodo (Figura 3). A partir del mes de octubre, la temperatura decreció hasta los 27°C y la última masa de huevos fue observada en este mes. La mínima temperatura registrada fue de 23.8°C en el mes de febrero.

Todos los individuos en cópula y apareo se observaron en fotoperiodo entre 11.5 y 13 horas, mientras que la puesta de huevos se observó con fotoperiodo promedio de 12.5 horas. La más alta correlación ocurrió entre las horas luz del día y el apareamiento ($r = 0.870$), aunque tambien se observó una correlación significativa entre el fotoperiodo y la presencia de masas de huevo ($r = 0.809$).

A partir del mes de octubre, se observaron individuos semienterrados en la arena, posterior a las actividad reproductora.

La longitud promedio de la heliconcha de individuos copulando y con masa de huevos, en las localidades de muestreo fue de 229 mm (DE 13.32, n 458), mientras que el promedio del grosor de labio fue de 16.9 mm (DE 5.18, n 458).

La actividad reproductora de *Strombus gigas* en las localidades de muestreo fue sobre fondos de arena, restos de coral y sobre camas de arena rodeadas de pastos de *Thalassia testudinum* (Tabla 1).

Dentro de los transectos, se observaron un total de 904 individuos de los cuales 20 se encontraron desovando y 39 masas de huevos.

Tabla 1. Número y porcentaje de caracoles en actividad reproductora, masas de huevo y densidad promedio en tres tipos de fondo en el Arrecife Alacranes, Yuctán de febrero 1999 a marzo 2000. Los valores de apareo representan número de parejas hembras/machos.

	Comportamiento Reproductor			Densidad Promedio (Caracoles/1000 m²)
	Apareo	Desove	Masas de huevo	
Fondo de arena (M-7)	2 (5.6)	10 (52.6)	7 (28)	5
Restos de coral (H-4)	34 (94.4)	8 (42.1)	18 (72)	54
Camas de arena rodeadas de pastos (B-9)	0	1 (5.3)	0	4

DISCUSION

En el Arrecife alacranes, el periodo de reproducción de *Strombus gigas* comienza a finales del mes de febrero y termina a mediados del mes de octubre. Cruz (1986) junto con Corral y Ogawa (1987), reportan el periodo de reproducción más amplio para Banco Chinchorro, Quintana Roo, el cual es durante todo el año. El periodo más corto, de mayo a septiembre, es reportado por D'Asaro (1965) para Bahamas (Tabla 2).

La actividad reproductora de *S. gigas* en el Arrecife Alacranes, comienza con la elevación de la temperatura. Los resultados coinciden con lo reportado por Brownell (1977), por Weil y Laughlin (1984) para los Roques, Venezuela y por Stoner *et al.* (1992), para Bahamas (Tabla 2).

En el Arrecife Alacranes, la actividad reproductora se fue intesificando con el aumento de la temperatura hasta alcanzar la mayor actividad durante el periodo cálido. Brownell (1977), sugirió que la declinación de la temperatura, en el mes de noviembre y diciembre, es la responsable de la terminación del desove en los Roques. Stoner et al. (1992), en Bahamas, encuentra que el desove finaliza cuando la temperatura de fondo comienza a declinar de 28.6°C a finales de septiembre a 25.1°C en diciembre. En este estudio, el desove termina con la

disminución de la temperatura de 30°C en octubre a 24°C en noviembre. Por otro lado el apareo y cópula decreció entre septiembre y octubre a una temperatura promedio de 30°C.

Stoner et al. (1992), menciona que al igual que la temperatura, el fotoperiodo puede influir en la actividad reproductora de *S. gigas*. En este estudio el aumento y la disminución de la temperatura fueron posteriores al aumento y disminución del fotoperiodo, lo que correlaciona positivamente la actividad reproductora con el fotoperiodo.

Será necesario realizar observaciones más detalladas de la actividad reproductora de *S. gigas* con el fotoperiodo y el estado de mar en el Arrecife Alacranes. Asimismo, el análisis histológico de las gónadas nos ayudará a confirmar o a rechazar los resultados de este trabajo.

Tabla 2. Periodos de reproducción de Strombus gigas reportados para la región del Caribe. El periodo se refiere a alguna observación de comportamiento reproductor (en cópula, desovando o presencia de masas de huevo). Las referencias están citadas de acuerdo a la latitud de la localidad de origen.

Localidad	Periodo de Reproducción	Referencia
Cayos de Florida	Mayo a octubre	D'Asaro (1965)
Bahamas	Abril a octubre	Stoner et al. (1992)
Turks y Caicos	Marzo a octubre	Davis et al. (1987)
México	Enero a diciembre	Cruz (Banco Chinchorro, 1986)
	Enero a diciembre	Corral y Ogawa (Banco Chinchorro,1987)
	Febrero a octubre	Este estudio (Arrecife Alacranes).
Puerto Rico	Mayo a noviembre	Appeldoorn et al. (1987).
Islas Vírgenes	Febrero a diciembre	Randall (1964)
Venezuela	Junio a noviembre	Brownell (1977)
	Abril a diciembre	Weil y Laughlin (1984)

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LITERATURA CITADA

Appeldoorn, R.S. 1990. Fishing pressure and reproductive potential in strombid conchs: Is there a critical stock density for reproduction? *Mem. Soc. Cienc. Nat. La Salle.*

Appeldoorn, R.S. 1994. Queen conch management and research: Status, needs and priorities. Pages 301-319 in: R.S. Appeldoorn and B. Rodríguez (eds.) *Strombus gigas: Queen Conch Biology, Fisheries and Mariculture.*. Fundación Científica Los Roques. Caracas, Venezuela.

Appeldorn, R.S. , G.D. Dennis, y O. Montersosa Lopez. 1987. Review of shared demersal resources of Puerto Rico and the Lesser Antilles region. Pages 36-57 in: R. Mahon (ed.). *Report and Proceedings of the Expert Consultation on Shared Fishery Resources of the Lesser Antilles Region.* FAO Fish. Rep. 383.

Berg, C.J. y Olsen, D.A. 1989. Conservation and management of queen conch (*Strombus gigas*) fisheries in the Caribbean. Cap. 18. Paginas 421-442 en: Caddy, J.F. (ed.) *Marine Invertebrate Fisheries. Their Assessment and Management. 1 Edition.* John Wiley & Sons. New York, New York U.S.A.

Brownell, W.N. 1977. Reproduction, laboratory culture, and growth *of Strombus gigas, S. costatus* and *S. pugilis* in Los Roques, Venezuela. *Bulletin of Marine Science* **27**:668-680.

Brownell, W.N. and Stevely, J.M. 1981. The biology, fisheries, and management of the queen conch, *Strombus gigas. Marine Fisheries Review* **43**:1-12.

Chakalall, R. y K. Cochrane. 1997. The queen conch fishery in the Caribbean: An approach to responsible fisheries management. *Proceedings of the Gulf and Caribbean Fisheries Institute* **49**:531-554.

Corral, J.L. y Ogawa, J. 1987. Cultivo masivo de larvas de caracol *Strombus gigas* en estanques de concreto. *Proceedings of the Gulf and Caribbean Fisheries Institute* **38**:345-351.

Cruz, R. C. 1986. Avances en la experimentación de producción masiva de caracol en Quintana Roo, México. *Proceedings of the Gulf and Caribbean Fisheries Institute* **37**:12-20.

D'Asaro, C..N. 1965. Organogenesis, development and metamorphosis in the queen conch *Strombus gigas*, with notes on breeding habits. *Bulletin of Marine Science* **15**:359-416.

Davis, M. y R.C. Hesse. 1983. Third world level conch mariculture in the Turks and Caicos Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* **35**:73-82.

Davis, M., C. Hesse y G. Hodgkins. 1987. Commercial hatchery produced queen conch Strombus gigas, seed for research and grow-out market. *Proceedings of the Gulf and Caribbean Fisheries Institute* **38**:326-335.

Egan, D.B. 1985. Aspects of the reproductive biology of *Strombus gigas*. M.S. Thesis University of British Columbia. 147 pp.

Pérez, B.D.G. 1996. Descripción del ciclo gonádico del caracol rosa *Strombus gigas* Linneo 1758 (Mollusca Gasteropoda Strombidae) en Arrecife Alacranes, Yucatán México. Tesis de Licenciatura.

Randall, J.E. 1964. Contributions to the biology of the queen conch, *Strombus gigas*. *Bulletin of Marine Science* **14**:246-295.

Stoner, A.W. y K.C. Schwarte. 1994. Queen conch, *Strombus gigas*, reproductive stocks in the Central Bahamas: distribution and probable sources. *U.S. Fisheries Bulletin* **92**:171-179.

Stoner, A.W., VJ. Sandt y I.F. Boidron-Metairon. 1992. Seasonality in reproductive activity and larval abundance of queen conch *Strombus gigas*. *U.S. Fisheries Bulletin* **90**:161-170.

Weil, E. y Laughlin, R.A. 1984. Laboratory culture of *Strombus gigas* L. in the Dos Mosquises Marine Station, Los Roques National Park, Venezuela: Final results. Pages 275-294 in: R.S. Appeldoorn and B. Rodríguez (eds.) *Strombus gigas: Queen Conch Biology, Fisheries and Mariculture*. Fundación Científica Los Roques, Caracas, Venezuela.

Wilkins, R.M., M-H. Goodwin y D.M. Reid. 1987. Research applied to conch resource management in S.t. Kitts/Nevis. *Proceedings of the Gulf and Caribbean Fisheries Institute* **38**:370-375.

Abundance, Size Frequency, and Spatial Distribution of Queen Conch (*Strombus gigas*) in Southeastern Dominican Republic: A Four-year Population Study in Parque Nacional Del Este

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ABSTRACT

Since 1996, queen conch (*Strombus gigas*) density, distribution by benthic habitats, and size frequency distribution have been monitored in Parque Nacional del Este (PNE), southeastern Hispaniola. Delgado (1999) reported that queen conch are significantly more abundant in communities with sparse to moderate seagrass benthic coverage (< 30%). He also reported a marked decline in overall queen conch abundance from 1996 to 1997. As a recommendation from his findings, the government of the Dominican Republic declared Canal de Catuano as a permanent closed area for conch fishing as of 1999 and additionally implement a closed season for the fishery between 1 July and 31 October for the country.

The purpose of this study was to continue ongoing studies of annual changes in queen conch population structure in a large marine lagoon within the park, using a stratified sampling design based upon benthic community type distribution. Annual surveys have focused on the density and location of juvenile aggregations, and the presence of adults as potential spawning stock by habitat available in the lagoon. The results obtained since 1996 to 2000 are part of a database that also contains information from historical conch populations (Torres et al. in prep) that once lived in the shallow waters of PNE. Shell length, width, and lip thickness (adults only) were collected along 50m x 5m transects located in different community types of the park, to determine if there are significant differences in conch densities during the study. These estimates also provide a baseline for evaluating future changes in population abundance and size structure relative to the recent closure of the park's lagoon. An annual evaluation of conch populations in PNE will serve as performance measures for PNE's managers.

Annual surveys conducted by Delgado (1999) in 1996 and 1997 showed significant declines (orders of magnitude) in the densities of both juvenile and adult conch. Data collected during 2000 illustrate a continued decline in juvenile and adult densities, but less dramatically than in previous surveys. Conch density and size frequency distribution showed a significant difference among benthic community types in all years. There is no evidence of the effect of the closure of the lagoon from fishing or from the closed season. Continuation of annual surveys will help to evaluate the biological effects of the spatial and seasonal closures on queen conch in PNE, dependent, in part, on the ability of park managers to effectively implement the new regulations.

KEY WORDS: Benthic community, Dominican Republic, population abundance, *Strombus gigas*

INTRODUCTION

The queen conch (*Strombus gigas)* population in Parque Nacional del Este (PNE), southeastern Dominican Republic has declined dramatically, presumably due to the unregulated fishing of all sizes classes of conch in both shallow and deep water communities. The reduction in *S. gigas* abundance can have several impacts on the long-term population dynamics of the species, such as changes in growth rate (e.g. by fishery selection for larger individuals), or increased predation (e.g. as conch aggregate, predators may eat most if not all individuals in a small aggregation). The uncertainty of the effects of any reduction in population abundance makes it difficult to predict the restoration success of this important fishery. Declines in queen conch abundance are well documented throughout the tropical western Atlantic (Gibson et al. 1983, Goodwin 1983, Appeldoorn et al. 1987), particularly due to decades of commercial over-exploitation, but there is also evidence of historical depletion by traditional cultures, such as the Taino Indians (Keegan 1989, Vega 1987). Fishing practices appear to have a much more dramatic impact on local population size than environmental variability, even resulting in local extirpation, for example, in the Lesser Antilles. *S. gigas* has an enormous range dependent on dispersal via planktonic larvae. With the documented declines in density, a pertinent management issue is one concerning minimum viable population sizes, and why, having evidence of long-term intensive fishing in the area, does the local population still persist? Are such patterns due to high recruitment, sufficient optimal habitat, or asynchronous pulses in fishing pressure?

Questions concerning the viability of populations have followed two general areas of contemporary ecological research. First, community ecologists have focused on the habitat where populations occur, specifically investigating habitat change after the removal of key species (Moore 1962, Lovejoy 1980). Second, population biologists have focused on the assessment and characteristics of populations: once fishing or other anthropogenic influences have depleted populations, there may be environmental factors that prevent species recovery (Franklin 1980, Frankel and Soulé 1981, Shaffer 1981). Changes in sea level, circulation patterns, and sea surface temperature, for example, all produce changes in the distribution of benthic species and thus benthic habitats. For queen conch, long-term environmental variability may bring about changes in habitat distribution, resulting in changes in population dynamics and size. An evaluation of the population viability of queen conch, owing to its well-studied ontogeny, needs to consider habitat characteristics as well as population structure.

The queen conch population in PNE has recently shown clear signs of decline in both abundance and size of individuals, presumably due to intense fishing (Delgado 1999). The coastal zone of the park is not developed, and the marine lagoon in the eastern area of the park is some distance from coastal settlements and

large human populations. The nature of the benthic habitats in the coastal lagoon may reflect more influence from natural environmental variability than anthropogenic influence. Because of rapid increases in human populations and the concurrent increases in demands for food, one can anticipate severe consequences for natural resources if appropriate management actions are not taken (Mostafa 1989). The loss of species and the degradation of habitats are difficult concepts to explain to resource users, so it may be easier to think in terms of specific indicators of change (EPA 1992). The study of a single species such as queen conch can serve as an indicator of the health of the overall coastal lagoon system.

Population size (abundance) and size-frequency distribution are determined by several measures such as fecundity, mortality, growth, emigration, and immigration (Ricklefs 1990, Krebs 1994, Begon et al. 1996). The spatial variability (i.e. patchiness) and isolation of the local population influence the immigration and emigration of individuals; thus, local dynamics play an important role in the persistence of metapopulations by making simultaneous extinction of all local populations unlikely (Hanski 1999). Requirements for the long-term persistence of an assemblage of extinction-prone populations are density dependence, high colonization rates, and some degree in asynchrony in local dynamics (Hanski 1999). There are many localities with low densities of queen conch, and, not surprisingly, many of these populations are in deeper water (> 15m depth). Therefore, only a portion of these populations is being affected by traditional fishing methods, leaving some breeding aggregations untouched and able to replenish affected areas. However, with the increased use of SCUBA and compressors (hookah) and the demise of shallow-water stocks, the deep water breeding aggregations now face the same fate

Over-exploitation of queen conch reproductive stocks may result in dramatic changes in population dynamics, as the per capita reproductive success declines at low population abundance. Ecological theory would predict that populations have multiple equilibria and may suddenly shift from one equilibrium to another (Myers et al. 1995). The temporal and spatial scale of these shifts can help resolve the definition of local populations and larger metapopulations. Understanding the dynamics of local populations and applying that information to management actions is essential for sustainable resource use.

METHODS

The methods used to assess living conch populations in PNE during this study followed that of procedures discussed in Delgado (1999). Based on the extent of habitats suspected of supporting juvenile and adult conch, a stratified, systematic survey design was used (Berg et al. 1992a). Between 160 (2000) and 350 (1996 and 1997) transects were surveyed in the marine lagoon (Canal de Catuano) of PNE. The total sample size was partitioned based upon the extent (coverage) of different benthic community types (Vega et al. 1997). Single or multiple transects measuring

50m x 5m (250m^2) were surveyed in different benthic community types in a systematic fashion, so as to increase the likelihood of sampling juvenile aggregations, if present (Figure 1). Surveys were primarily conducted within the Canal de Catuano and to the northwest of the lagoon (western shelf) in depths less than 10 m.

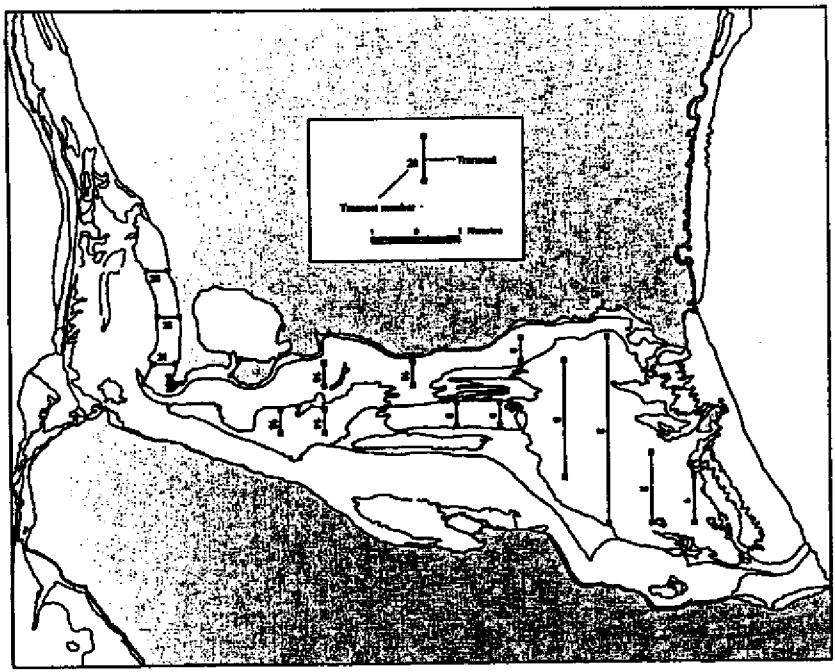


Figure 1. Map of the Canal de Catuano in Parque Nacional del Este showing the permanent queen conch stock assessment transects. Each transect is composed of many 5 m by 50 m continuous sampling units.

Queen conch were identified, counted, and measured to the nearest millimeter for total shell length and lip thickness along transects. Size measurements were taken with plastic calipers to the nearest 0.1 mm. Lip thickness was measured at the area of greatest thickness or roughly two-thirds of the distance from the end of the siphonal groove. At least three snorkelers were used to survey each transect. Observers searched 2.5 m perpendicularly from each side of the transect. It should be noted that visual estimates selectively under-sample conch less than 10 cm in shell length, because most of these individuals are buried during the day (Appeldoorn 1985a, Iversen et al. 1987).

Information collected from the transects was used to determine mean densities (no. per ha) for each community type. A Kruskal-Wallis test was used to evaluate differences in density among the community types sampled during March 2000. A Kolmogorov-Smirnov test was used to evaluate differences in the size-frequency distributions of queen conch found only in the sparse seagrass in sand (SSGS) and

the sparse seagrass in sand-mud (SGSM) community types, due to very low numbers of individuals found in the other community types.

RESULTS

Conch Densities and Size Frequency Distributions

During March of 2000, only four community types in PNE were surveyed for queen conch due to the lack of SCUBA support: sparse seagrass in sand (SSGS), sparse seagrass in sand-mud (SGSM), mixed algal canopy (MAC), and seagrass patches on a matrix of soft sediment (SGP). The majority of juvenile queen conchs in the park were found in SGSM during all years (1996, 1997, and 2000). Adults were most abundant in SGSM during 1996 and 1997, but had greater densities in SSGS during 2000 (Table 1). Relative to 1996 and 1997, surveys completed in 2000 showed continued declines in both juvenile and adult densities.

Table 1. Annual estimates of mean juvenile (A) and adult (B) conch density (1 SD) in Parque Nacional del Este, Dominican Republic. SGP = seagrass patches on a matrix of soft sediment; SSGS = sparse seagrass in sand; SGSM = sparse seagrass in sand mud; MAC = Mixed algal canopy; MDSG = moderate to dense seagrass. Total number of transects were: 1996 = 350, 1997 = 350, and 2000 = 160. Data from 1996 and 1997 are as reported by Delgado (1999).

A. Juvenile Conch

Community	1996	1997	2000
SGP	0.0(0.0)	0.0(0.0)	0.0(0.0)
SSGS	2.0(2.6)	0.0(0.0)	1.0(1.9)
SGSM	707.4(2,386.1)	46.8(149.0)	26.8(25.6)
MAC	1.3(2.1)	4.0(14.2)	0.3(0.7)
MDSG	64.7(94.1)	14.2(37.4)	N/A
Total	283(1,488.1)	22.5(95.1)	14.4(4.93)

B. Adult Conch

Community	1996	1997	2000
SGP	0.0(0.0)	0.0(0.0)	0.0(0.0)
SSGS	0.0(0.0)	0.0(0.0)	1.2(2.2)
SGSM	5.9(18.5)	2.8(10.2)	0.03(0.12)
MAC	0.7(1.6)	0.7(1.6)	0.0(0.0)
MDSG	6.9(6.7)	1.5(7.5)	N/A
Total	4.5(14.3)	1.6(7.9)	0.62(1.51)

Delgado (1999) reported a significant difference in both juvenile and adult conch density among five community types from March 1996 surveys. He also reported similar results for juvenile conch, but not for adults, in 1997. During March of 2000, we observed a significant difference in juvenile conch densities among the community types sampled ($p < 0.05$). However, there was no significant difference in adult conch density among community types ($p > 0.05$) (Figure 2).

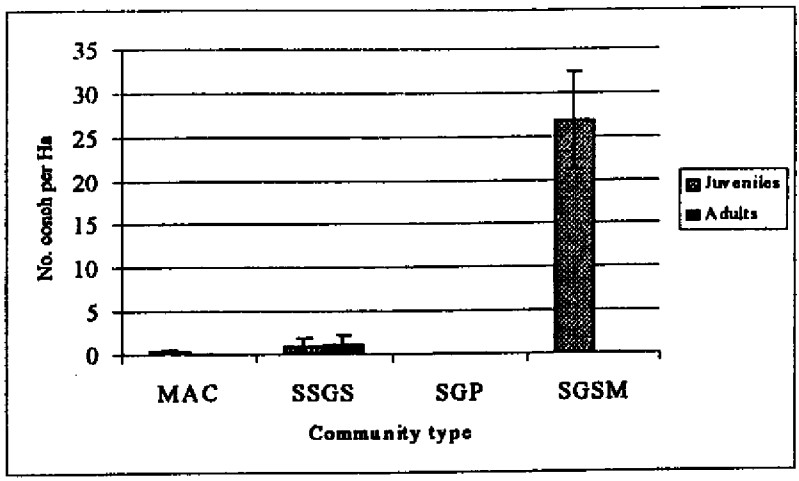


Figure 2. Mean juvenile and adults queen conch (*Strombus gigas*) densities for the community types surveyed during March 2000 in Parque Nacional del Este. (95% confidence intervals are shown as error bars). MAC = mixed algal canopy, SSGS = sparse seagrass in sand, SGP = seagrass patches on a matrix of soft sediment, SGSM = sparse seagrass in sand mud.

Size-frequency distributions for juvenile conch were significantly different in 1996 and 1997 as well, but adult size frequency distribution was not significantly different among SGSM and MDSG community types (Delgado 1999) in both 1996 and 1997. Due to depth limitations of the 2000 surveys, size-frequency distributions were compared between the communities with the greatest conch densities (SSGS and SGSM). While the size distributions of adults were found to be different ($p < 0.05$) (Figure 3A), juveniles were not significantly different ($p > 0.05$) (Figure 3B).

DISCUSSION

It is well known that seagrass beds are highly variable in attributes other than seagrass biomass or shoot count, and that many of the less obvious characteristics of seagrass habitats have a strong impact on the large-scale distribution of fishes and invertebrates (Stoner et al. 1995). From previous studies in PNE (Delgado 1999; Vega et al. 1997, Chiappone et al. in press), it is known that conch are distributed differently among several benthic community types, and that there is clear evidence of declining densities in the shallow-water areas of the park. The majority of juveniles showed a marked preference for moderate to dense seagrass habitats. This type of

habitat possesses required characteristics for juvenile conch to settle and survive from natural predators, and clearly serves an important nursery function for this species.

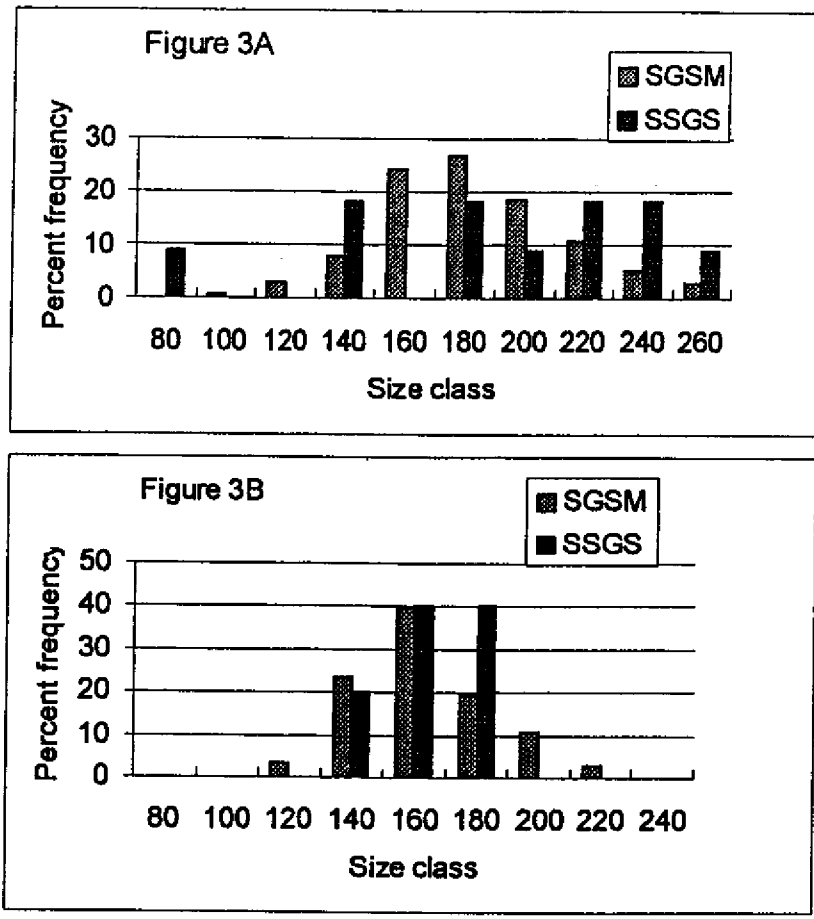


Figure 3. Size relative frequency distribution for juvenile (3A) and adult (3B) queen conch (*Strombus gigas*) for sparse seagrass in sand mud (SGSM) and sparse seagrass in sand (SSGS) during March 2000 in Parque Nacional del Este, Dominican Republic.

From a similar study of conch population in Jaragua National Park (southwestern Dominican Republic) Posada et al. (1999) estimated overall conch densities of 53.0 individuals per hectare. These results are substantially higher than

estimates for PNE, possibly indicating substantial recruitment from up-current sources to the large shelf area on the southwestern Dominican coast. Although the Dominican government recently declared (1999) the Canal de Catuano as a closed area for conch fishing and implemented a countrywide, seasonal closure during the breeding season (1 July – 31 October), this has not been adequately implemented (R.E. Torres, pers. observations).

Annual surveys have been of sufficient spatial scale to detect changes in conch densities among community types. A continuation of these surveys will be necessary to evaluate possible recovery of the queen conch population PNE, or the degree to which management implementation is working. Because of the uncertainty of the effects of this reduction in densities, the restoration of this important fishery remains problematic. Fishermen have been targeting queen conch intensively for hundreds of years on the southeastern Dominican shelf. As queen conch decline from this area, there may be population changes that may prevent the recovery of the species, even if fishing pressure declines or is halted.

LITERATURE CITED

Appeldoorn, R.S. 1985a. Growth, mortality and dispersion of juvenile laboratory-reared conchs (*Strombus gigas* Linne and *S. costatus*, released at an offshore site. *Bulletin of Marine Science* 37:785-793.

Appeldoorn, R.S., G.D. Dennis, and O. Monterrosa-Lopez. 1987. Review of shared demersal resources of Puerto Rico and the Lesser Antilles region. *FAO Fisheries Report.* 383:36-106.

Begon, M., J.L. Harper and C.R. Towsend. 1996. *Ecology*. Blackwell. Oxford, England.

Berg, C.J., Jr., F. Couper, K. Nisbet, and J. Ward. 1992a. Stock assessment of queen conch, *Strombus gigas*, and harbour conch, *S. costatus*, in Bermuda. *Proceedings of the Gulf abd Caribbean Fisheries Institute* 41:433-438.

Chiappone, M. (ed.) [In press]. *Fisheries investigations and management implications in marine protected areas of the Caribbean: A case study of Parque Nacional del Este, Dominican Republic*. American Verde. Arlington, Virginia USA.

Delgado, G.A. 1999. Influence of habitat on queen conch abundance and size distribution in soft-sediment marine communities in Parque Nacional del Este, Dominican Republic. M.S. Thesis, RSMAS-University of Miami, Florida USA.

Environmental Protection Agency (EPA). 1992. *Biological Populations as Indicators of Environmental Change*. Vol 1. U.S. Environmental Protection Agency 230/R-92/011. Washington, D.C. USA. 146 pp.

Frankel, O.H. and M.E. Soulé. 1981. *Conservation and Evolution*. Cambridge University Press. Cambridge, England.

Franklin, I.A. 1980. Evolutionary change in small populations. In: M.E. Soule and B.A. Wilcox (eds.), *Conservation Biology: An Evolutionary-ecological Perspective*. Sinauer Associates. Sunderland, MA. 135 pp.

Gibson, J., S. Strasdine and K. Gonzalez. 1983. The status of the conch industry in Belize. *Proceedings of the Gulf abd Caribbean Fisheries Institute* **35**:99-107.

Goodwin, M.H. 1983. Overview of conch fishery and culture. *Proceedings of the Gulf and Caribbean Fisheries Institute* **35**:43-45.

Hanski, I. 1999. *Metapopulation Ecology*. Oxford series in ecology and evolution. Oxford University Press. NewYork, New York USA. 313 pp.

Iversen, E.S., E.S. Rutherford, S.P. Bannerot and D.E. Jory. 1987. Biological data on Berry Islands (Bahamas) queen conchs, *Strombus gigas*, with mariculture and fisheries management implications. *U.S. Fisheries Bulletin* **85**:299-310.

Keegan, W.F. 1989. The Columbus Chronicles. Pages 47-55 in:. The Sciences, January/February. Columbus, OH USA.

Krebs, C.J. 1994. *Ecology. The Experimental Analysis of Distributions and Abundance*. Harper and Row, New York, New York USA.

Lovejoy, T.E. 1980. Discontinuous wilderness: Minimum areas for conservation. *Parks* **5(2)**:13-15.

Moore, N.W. 1962. The health of Dorset and their conservation. *Journal of Ecology* **50**: 369-391.

Mostafa, T. 1989. Our biological heritage under siege. *Bioscience* **39**:725-728.

Myers, R.A., N.J. Barrowman, J.A. Hutchinson and A.A. Rosenberg. 1995. Population dynamics of exploited fish stocks at low population levels. *Science* **269**: 1106-xxxx.

Posada, J.M., I. Mateo and M. Nemeth. 1999. Occurrence, abundance and length frequency distribution of queen conch, *Strombus gigas* (Gastropoda) in shallow waters of the Jaragua National Park, Dominican Republic. *Caribbean Journal of Science* **35(1-2)**:70-82.

Ricklefs, R.E. 1990. *Ecology*. Freeman, New York, New York USA.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. *Bioscience* **31**:131-134.

Stoner, A.W., M. Ray and J.M. Waite. 1995. Effects of a large herbivorous gastropod on macrofaunal communities in tropical seagrass meadows. *Marine Ecological Progress Series* **121**:125-137.

Torres, R.E., K. M. Sullivan 2002. Shell midden surveys as source of information about fished Queen conch (*S. gigas*) populations: A case study in Parque Nacional del Este, Dominican Republic. *Proceedings of the Gulf and Caribbean Fisheries Institute* 53:144-155.

Vega, B. 1987. *Santos Shamanes y Zemies*. Fundacion Cultural Dominicana, Santo Domingo, Dominican Republic. 185 pp.

Vega, M., M. Chiappone, G. Delgado, R. Wright, K. Sullivan. 1997. Evaluacion ecological integral, Parque Nacional del Este, Republic Dominicana. Tomoe 2: Recourses marinas. The Nature Conservancy. Arlington, Virginia USA.

Distribution, Density and Abundance of the Queen Conch, *Strombus gigas*, in the Los Roques Archipelago National Park, Venezuela

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ABSTRACT

In Venezuela, the populations of the queen conch , *Strombus gigas*, were submitted to very high levels of exploitation which resulted in the national closure of the fishery in 1991. The present study determined the distribution, density, and abundance of the queen conch in the Los Roques Archipelago. A visual assessment, conducted by SCUBA divers swimming transects, was carried out between July and September 1999. It involved a first random sampling, comprising the entire insular platform and a second stratified, random sampling, in the two blocks (northeast and south-southwest) where, according to the first field sampling, there was a greater abundance of queen conch. A total of 45.46 hectares were covered during the samplings, at a mean area per transect of 2,859 m^2. Individuals were found in 42 and 44 of the 78 and 56 localities visited in each phase of the sampling, respectively. A total of 641 conchs were observed, comprised primarily of adults (60%).

The overall density was estimated as 18.78 conch/ha (S.D.= 44.48), with an approximate abundance of 1,374,640 conchs (C.L. = 640,474 - 2,023,897) for the 73,197 ha of the platform. The density of juveniles and subadults was of 1.76 conch/ha (S.D.= 4.85), with an abundance of 128,827 conchs (C.L. = 49,042 – 205,684). On the northeast block, the overall density estimated was 34.74 conch/ha (S.D.=77.46) and on the south-southwest block 52.34 conch/ha (S.D.= 92.15), with an abundance of 428,970 conchs (C.L. = 206,706 - 795,952) and 332,097 conchs (C.L. = 138,892 - 555,314) in the northeast and south-southwest areas, respectively. The confidence limits of the abundance estimates were calculated using a Bootstrap technique. The northeast block showed the highest density of young conchs, 7.54 conchs/ha (S.D.= 12.88), representing a zone with potential breeding areas. The highest densities of juvenile (18.31 conchs/ha) were found on seagrass beds, at no more than 10 m depth. Significant populations of adults and older individuals, actively mating, were found on sand plains at depths greater than 16 m.

KEY WORDS: Population density, *Strombus gigas*, Los Roques, Venezuela

INTRODUCTION

The queen conch, *Strombus gigas* Linnaeus, 1758, is a large marine gastropod mollusk in the family Strombidae, which is broadly distributed in the

Caribbean Sea (Randall 1964). In its entire distribution range, this specie has been highly valued as a fishing resource, especially due to the delicious taste and nutritional value of its meat, which has acquired very high prices on the market. Due to exploitation of queen conch populations throughout its range, the Convention on the International Trade of Endangered Species (CITES) decided to include it in the appendix II of its protocol as a strategy to manage the fishery.

In Venezuela, the commercial fishery of the queen conch has been carried out almost exclusively in the insular region, constituting the archipelagos of Las Aves, Los Roques and Los Testigos, the areas accounting for the most important populations of this gastropod. The increasing demand for this resource resulted in intense fishing activity and the consequent decrease of its population (Posada y Alvarez 1988, Rodríguez y Posada 1994).

Evidence of overexploitation, detected in the Los Roques Archipelago, by Weil and Laughlin (1984), Rodríguez and Posada (1994) and Bastidas and Rada (1998), resulted in a national closure of the queen conch fishery. This regulation began in 1991 and has been extended until the present year 2000, when the Fishing and Aquaculture Resources Autonomous Service published the regulations for the reopening of the queen conch fishery, although lacking current scientific evidence on the population levels of the resource.

Therefore, the aim of the present study was to provide actualized information on the distribution, density and abundance of the queen conch in the Los Roques Archipelago National Park, which can be used to evaluate the effectiveness of the closure imposed. Also, the study includes areas of the archipelago that had not been previously sampled and the use of a practical methodology specifically designed for the assessment of gregarious populations.

MATERIALS AND METHODS

Study Area

The Los Roques Archipelago National Park is an insular reef platform located 160 km North off the central coast of Venezuela (11° 48 - 11° 58′ N and 66° 32′ - 66° 57′ W) (Figure 1), comprising an area of 1250 Km^2 and a maximum depth of 50 meters. It is conformed by 42 islands and 200 sand banks, distributed in an irregular oval, surrounding an inner lagoon with an average depth of 5 m (Amend 1992).

Field Work

Two field surveys were conducted between July and August, 1999. During the first survey (general sampling), a random stratified sampling was carried out, comprising the platform, over 40 meters depth, of the archipelago. In the second field survey, a random stratified sampling was done according to the areas where a higher density of individuals was found in the first survey. The sampling areas were located inside two blocks designated as northeast block and south-southwest

block (Figure 1). At each station two SCUBA divers carried out the visual censuses, swimming over a transect of fixed width. The transects were of variable length, but a fixed time of 20 minutes.

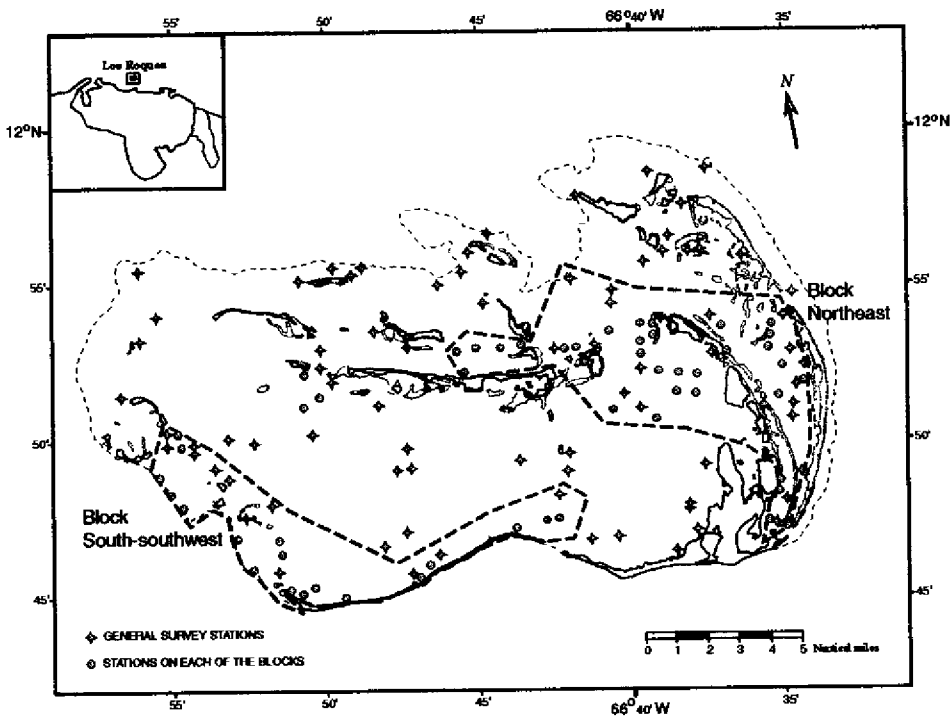


Figure 1. Location of different sampling stations visited on each of the surveys conducted in the Los Roques Archipelago National Park

During the transect swims, data on the total length and the lip width of all conch encountered was registered. They were classified into one of the following size/age categories: juvenile, subadults, adults and old, according to descriptions made by Appeldoorn (1995). At the same time, information including bottom type, depth and time at which an individual was found, was collected. The bottom types were classified in one of the following categories: fine mud, sand, algae plain, soft corals, hard bottom and seagrass (*Thalassia testudinum* and *Syringodium filiforme*) meadows. Combinations of the previous categories were

used to define mixed habitats (e.g. mixed sand, mixed meadows). The depths were registered into the intervals: 0 - 5 m, 6 - 10 m, 11 - 15 m, 16 - 25 m, over 26 m.

Two estimates of abundance were carried out. First, the overall density obtained in the general sampling and the total area occupied by the archipelago platform (over 40 m depth) were used. The second estimate was made for the area occupied by the blocks (northeast and south-southwest); this was made in order to reduce the confidence limits in the estimates due to the aggregated distribution of the queen conch. Because the density estimates were not normally distributed, the confidence limits of trust were determined using a Bootstrap method (Sokal and Rohlf, 1995). The density obtained for each size/age category was compared, through the analysis of contingency tables and preference indexes (applied by Appeldoorn and Rolke 1996), between bottom types and depth ranges. In the preference index a positive result indicates preference. On the opposite, if the result is negative it indicates that there is rejection.

RESULTS

During the general sampling, a total of 78 stations were completed, covering an area of 22.2 hectares. A total of 250 conchs were counted within 42 of the transects. The population was composed mainly of adults (55.6%), followed by the old class (22.9%) (Figure 2).

In the northeast block, a total of 52 transects were carried out, comprising an area of 15.7 hectares. While in the south-southwest block., 29 transects were completed over an area of 7.6 hectares. Individuals were found in 40 and 23 of the localities visited on the northeast and south-southwest blocks, respectively. A total of 287 conchs and 222 conchs were counted in each block, most of them belonging to the adult age class (Figure 2). The mean area of a transect was 2859 m^2.

The correlation between the observations carried out by each pair of divers was high r = 0.89), indicating that they lacked independence. Therefore, the data collected by each diver were analyzed together to estimate the values of density and abundance.

From the overall density for the general sampling of 18.78 conch/ha (S.D.= 44.48) total abundance of 1,374,640 conch over the 73,197 ha of the insular platform was estimated (Table 1). The density estimated for each size/age category showed that the adult and old classes present the highest densities with 17.02 conchs/ha (S.D.= 44.05). On the other hand, the densities of the juvenile and subadults categories were significantly lower with 1.76 conchs/ha (S.D. = 4.85) ($p < 0.0001$) (Table 1).

In the blocks, which correspond to the areas where more conch aggregations were found, the overall queen conch densities and abundance were 34.74 conchs/ha (S.D. = 77.46) and 428,970 individuals in the northeast, and 52.34 conchs/ha (S.D. = 92.15) and 332,097 individuals in the south-southwest. As

showed in table 1, in both blocks the adult and old categories presented the highest density and abundance. Nevertheless, in the northeast block the densities for the juvenile and subadults were significantly higher than in the south-southwest block, with 7.54 conchs/ha (S.D.= 12.88) and an abundance of 93,104 individuals versus 3.73 conchs/ha (S.D.= 7.60) and 23,667 individuals ($p < 0.05$) (Table 1). The confident limits in the blocks decreased by 63% compared with that in the general survey.

Most of the localities visited in both the general sampling area and in the blocks, were located at depths greater than 16 meters, as these depth strata contained the highest densities of individuals observed (Table 2). The individuals belonging to the adult and old categories showed a significant preference for the deep strata ($p < 0.005$) (Table 3). In almost all the deep stations it was usual to find solitary eggs masses, or individuals copulating or laying eggs.

A significant preference of the individuals belonging to the juvenile and subadult size/age categories for shallow depth ranges (between 0 and 10 m) was found in all surveys (Table 3). The presence of these size/age categories diminishes rapidly as depth increases.

At the general sampling site and on the blocks, a significant relationship between the densities of conchs of each size/age category and the bottom type ($p < 0.005$) (Table 4). The juvenile class showed a strong preference for the areas partially or completely covered by seagrass meadows. On the other hand, the adult and old size/age categories preferred the deep, sandy substrate (Table 5).

Table 1. Abundance of queen conch, grouped by size/age category, estimated on each of the surveys conducted in the Los Roques Archipelago National Park. The confidence limits (CL) came from a bootstrap analysis (J = Juvenile, SA = Subadult, A = Adult and O = Old).

	Age	Density		Area	Abundance	CL (95%)	
	class	Range	(conch / ha)	(m^2)	(No. ind)	Lower	Higher
General	J+SA	0-23.74	1.76 (±4.85)		128827	49042	205684
	A+O	0-	17.02 (±44.05)	7319	1245813	639742	2143208
	Total	0-	18.78 (±44.48)		1374640	640474	2023897
Northeast	J+S	0-65.99	7.54 (±12.88)	1234	93104	50874	147806
	A+O	0-	27.20 (±76.98)		335866	148176	652221
	Total	0-	34.74 (±77.46)		428970	206706	795952
South -	J+S	0-32.78	3.73 (±7.60)		23667	6218	43527
southwest	A+O	0-	48.60 (±90.15)	6345	308367	119350	547954
	Total	0-	52.34 (±92.15)		332097	138892	555314

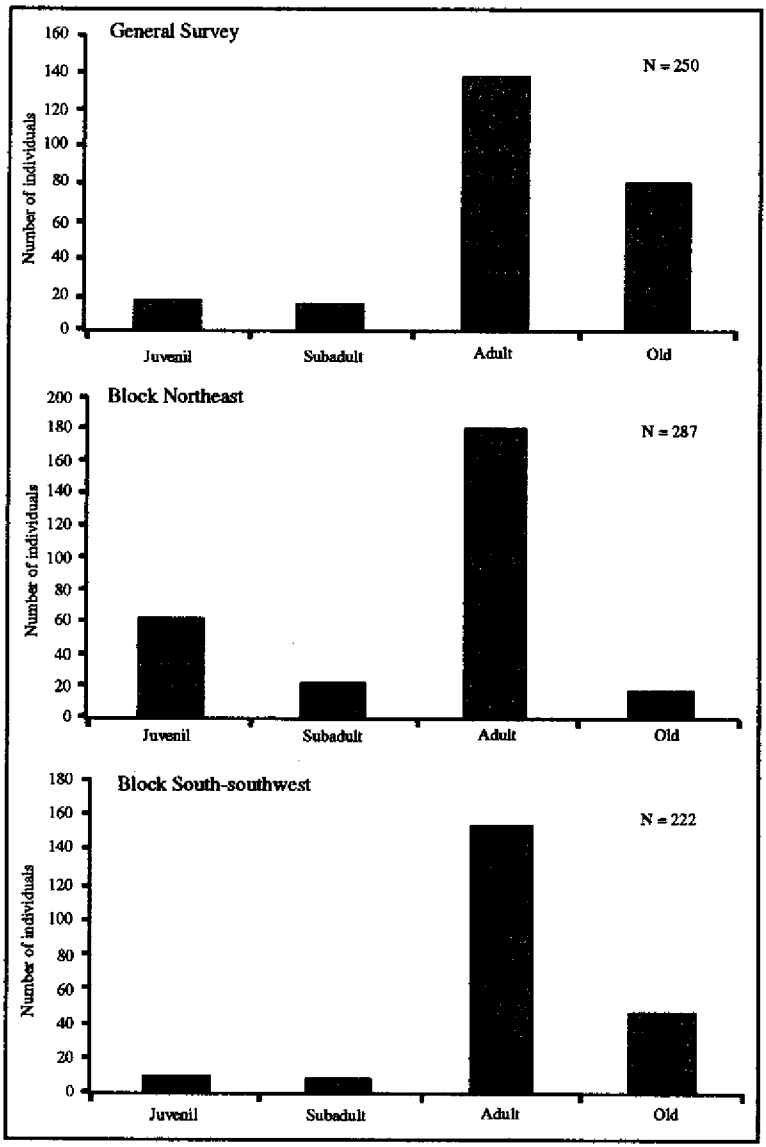


Figure 2. Age class distribution of the queen conch population on each of the surveys conducted in the Los Roques Archipelago National Park.

Table 2. Distribution and density of queen conch by depth strata and size/age classes, observed on each of the surveys conducted in the Los Roques Archipelago National Park (J = Juvenile, SA = Subadult, A = Adult, O = Old).

	Area	Percentage	Number of conch				Density (conch/ha)			
Depth (m)	(ha)	area	J	SA	A	O	J	SA	A	O
General Survey										
0-5	8.50	38.28	10	8	16	1	1.18	0.94	1.90	0.12
6-10	4.02	18.10	4	5	22	2	1.00	1.24	5.47	0.50
11-15	3.24	14.58	2	2	25	4	0.62	0.62	7.72	1.24
16-25	5.34	24.06	0	0	61	66	0	0	11.42	12.35
> 26	1.11	5.00	0	0	15	7	0	0	13.54	6.32
Total	22.2	100	16	15	139	80	0.72	0.68	5.59	3.28
Northeast										
0-5	8.21	52.31	52	14	40	2	6.33	1.71	4.87	0.24
6-10	1.73	11.01	5	9	28	0	2.89	5.21	16.20	0.00
11-15	2.62	16.69	6	1	30	3	2.29	0.38	11.45	1.15
16-25	2.77	17.63	1	0	69	13	0.36	0.00	24.93	4.70
> 26	0.37	2.36	0	0	14	0	0.00	0.00	37.80	0.00
Total	15.7	100.00	64	24	181	18	4.08	1.53	11.53	1.15
South-southwest										
0-5	4.25	56.17	7	3	47	3	1.65	0.71	11.07	0.71
6-10	1.59	21.05	4	4	4	16	2.51	2.51	25.77	10.06
11-15	0.78	10.37	0	2	39	7	0.00	2.55	49.72	8.92
16-25	0.93	12.28	0	0	27	22	0.00	0.00	29.08	23.69
> 26	0.01	0.04	0	0	0	0	0.00	0.00	0.00	0.00
Total	7.56	99.91	11	9	154	48	1.45	1.19	20.37	6.35

DISCUSSION

The methodology of visual data collection by SCUBA divers over transects of variable length applied in the present study was a very practical tool to assess heterogeneously distributed benthic organisms, such as the queen conch, *Strombus gigas*. The use of GPS to estimate the length of the transect, despite the small error in the calculation of positions, eliminates the complications and time consuming measurements involved using metric tapes (Tewfik et al. 1998). GPS also allows to make longer transects in less time, thus covering greater areas over a diversity of bottom types and depths.

Nevertheless, the gregarious behavior of the queen conch, together with the proximity of the divers during the visual censuses, created high correlations among their observations (no independent data), reducing the effectiveness of the method by not being able to duplicate the samples (Mateo 1997).

Table 3. Preference Index, by depth strata and queen conch size/age classes, observed on each of the surveys conducted in the Los Roques Archipelago National Park. The Preference Index is calculated as: % area - % of individuals (J = Juvenile, SA = Subadult, A = Adult and O = Old).

Depth (meters)	Area (ha)	Number of conch					Area (ha)	Percentage					Preference Index			
		J	SA	A	O	Total		J	SA	A	S	Total	J	SA	A	S
General Survey																
0-5	8.50	10	8	16	1	35	38.28	62.50	53.33	11.51	1.25	14	24.22	15.06	-26.77	-37.03
6-10	4.02	4	5	22	2	33	18.10	25.00	33.33	15.83	2.50	13.2	6.90	15.24	-2.27	-15.60
11-15	3.24	2	2	25	4	33	14.58	12.50	13.33	17.99	5.00	13.2	-2.08	-1.24	3.41	-9.58
16-25	5.34	0	0	61	66	127	24.06	0	0	43.86	82.50	50.8	-24.06	-24.06	19.83	58.44
> 26	1.11	0	0	15	7	22	4.99	0	0	10.79	8.75	8.80	-4.99	-4.99	5.80	3.76
Total	22.21	16	15	139	80	250	100	100	100	100	100	100				
Northeast																
0-5	8.21	52	14	40	2	108	52.31	81.25	58.33	22.10	11.11	37.63	28.94	6.03	-30.21	-41.19
6-10	1.73	5	9	28	0	42	11.01	7.81	37.50	15.47	0	14.63	-3.20	26.49	4.46	-11.01
11-15	2.62	6	1	30	3	40	16.69	9.38	4.17	16.57	16.67	13.94	-7.31	-12.52	-0.11	-0.02
16-25	2.77	1	0	69	13	83	17.63	1.56	0	38.12	72.22	28.92	-16.07	-17.63	20.49	54.59
> 26	0.37	0	0	14	0	14	2.36	0	0	7.73	0	4.88	-2.36	-2.36	5.37	-2.36
Total	15.70	64	24	181	18	287	100	100	100	100	100	100				
South-southwest																
0-5	4.25	7	3	47	3	60	56.17	63.64	33.33	30.52	6.25	27.03	7.47	-22.83	-25.65	-49.92
6-10	1.59	4	4	41	16	65	21.05	36.36	44.44	26.62	33.33	29.28	15.32	23.40	5.58	12.29
11-15	0.78	0	2	39	7	48	10.37	0	22.22	25.32	14.58	21.62	-10.37	11.85	14.95	4.21
16-25	0.93	0	0	27	22	49	12.28	0	0	17.53	45.83	22.07	-12.28	-12.28	5.25	33.55
> 26	0.01	0	0	0	0	0	0.13	0	0	0	0	0	-0.13	-0.13	-0.13	-0.13
Total	7.56	11	9	154	48	222	100	100	100	100	100	100				

Table 4. Distribution and density of queen conch by bottom type and size/age category, observed on each of the surveys conducted in the Los Roques Archipelago National Park.

Location/ Depth	Habitat	Area (ha)	Juveniles No	Juveniles Ind/ha	Subadults No.	Subadults Ind/ha	Adults No.	Adults Ind/ha	Olds No.	Olds Ind/ha
General	Fine Mud	0.06	0	0	0	0	0	0	0	0
Shallow	Sand	4.14	7	1.69	8	1.93	28	6.76	2	0.48
	Algae	2.98	0	0	1	0.34	6	2.01	1	0.34
	Soft corals	0.67	0	0	0	0	0	0	0	0
	Hard	0.13	0	0	0	0	1	7.55	0	0
	Thalassia	2.61	4	1.53	2	0.77	1	0.38	0	0
	Mixed sand	1.19	4	3.37	2	1.68	3	2.53	0	0
	Mixed	0.78	0	0	0	0	0	0	0	0
Deep	Fine mud	1.10	0	0	0	0	2	1.82	0	0
	Sand	2.97	1	0.34	1	0.34	63	21.23	47	15.84
	Algae	2.09	0	0	1	0.48	13	6.23	12	5.75
	Soft corals	1.60	0	0	0	0	4	2.50	10	6.25
	Hard	0.94	0	0	0	0	9	9.62	7	7.48
	Mixed sand	0.96	0	0	0	0	9	9.36	1	1.04
Totals		22.2	16	0.72	15	0.68	139	6.26	80	3.60N
North	Fine Mud	0.03	0	0	0	0	0	0	0	0
East	Sand	5.36	19	19	8	1.49	36	6.72	1	0.19
Shallow	Algae	0.87	2	2	4	4.61	11	12.68	0	0
	Soft corals	0.12	0	0	0	0	0	0	0	0
	Hard	0.60	0	0	2	3.35	5	8.37	1	1.67
	Thalassia	1.04	19	19	4	3.86	4	3.86	0	0
	Mixed sand	1.59	15	15	4	2.52	11	6.93	0	0
	Mixed	0.33	2	2	1	3.03	1	3.03	0	0
Deep	Fine mud	0.66	0	0	0	0	13	19.68	1	1.51
	Sand	3.19	5	5	0	0	85	26.64	13	4.08
	Algae	0.48	1	1	1	2.09	9	18.80	2	4.18
	Soft corals	0.80	1	1	0	0	3	3.75	0	0
	Hard	0.09	0	0	0	0	1	11.03	0	0
	Mixed sand	0.55	0	0	0	0	2	3.65	0	0
Totals		15.7	64	64	24	1.53	181	11.53	18	1.15
South	Fine Mud	0.02	0	0	1	59.64	0	0	2	119.29
S E	Sand	1.83	1	0.55	1	0.55	25	13.69	1	0.55
Shallow	Algae	1.54	0	0	2	1.30	18	11.72	5	3.26
	Soft corals	0.21	0	0	0	0	0	0	0	0
	Hard	0.01	0	0	0	0	0	0	0	0
	Thalassia	0.65	1	1.55	2	3.09	6	9.28	0	0
	Mixed sand	0.63	4	6.32	0	0	24	37.89	10	15.79
	Mixed	0.95	5	5.26	1	1.05	15	15.79	1	1.05
Deep	Fine mud	0.30	0	0	0	0	0	0	0	0
	Sand	0.76	0	0	1	1.32	63	83.31	29	38.35
	Algae	0.50	0	0	1	2.02	2	4.04	0	0
	Soft corals	0.10	0	0	0	0	0	0	0	0
	Hard	0.07	0	0	0	0	1	14.82	0	0
	Mixed sand	0.07	0	0	0	0	1	14.82	0	0
Totals		7.63	11	1.44	9	1.18	155	20.32	48	6.29

Table 5. Preference Index, by bottom type and queen conch size/age classes, observed on each of the surveys conducted in the Los Roques Archipelago National Park. The Preference Index is calculated as: % area - % of individuals (J = Juvenile, SA = Subadult, A = Adult, O = Old).

HABITAT	Area	Number of conchs					Area	Percentage					Preference Index			
	(ha)	J	SA	A	O	Total	(ha)	J	SA	A	O	Total	J	SA	A	O
General Survey																
Fine mud	1.16	0	0	2	0	2	5.22	0.00	0.00	1.44	0.00	0.80	-5.22	-5.22	-3.78	-5.22
Sand	7.11	8	9	92	49	158	32.00	50.00	60.00	66.19	61.25	63.20	18.00	28.00	34.19	29.25
Algae	5.07	0	2	19	13	34	22.82	0.00	13.33	13.67	16.25	13.60	-22.82	-9.48	-9.15	-6.57
Soft corals	2.27	0	0	3	10	13	10.22	0.00	0.00	2.16	12.50	5.20	-10.22	-10.22	-8.06	2.28
Hard bottom	1.07	0	0	10	7	17	4.82	0.00	0.00	7.19	8.75	6.80	-4.82	-4.82	2.38	3.93
Thalassia	2.61	4	2	1	0	7	11.75	25.00	13.33	0.72	0.00	2.80	13.25	1.59	-11.03	-11.75
Mixed sand	2.15	4	2	12	1	19	9.68	25.00	13.33	8.63	1.25	7.60	15.32	3.66	-1.04	-8.43
Mixed seagrass	0.78	0	0	0	0	0	3.51	0.00	0.00	0.00	0.00	0.00	-3.51	-3.51	-3.51	-3.51
Totals	22.22	16	15	139	80	250	100	100	100	100	100	100				
Northeast																
Fine mud	0.69	0	0	13	1	14	4.39	0.00	0.00	7.18	5.56	4.88	-4.39	-4.39	2.79	1.16
Sand	8.55	23	8	121	14	166	54.46	35.94	33.33	66.85	77.78	57.84	-18.52	-21.13	12.39	23.32
Algae	1.35	3	5	20	2	30	8.60	4.69	20.83	11.05	11.11	10.45	-3.91	12.23	2.45	2.51
Soft corals	0.92	2	0	2	0	4	5.86	3.13	0.00	1.10	0.00	1.39	-2.73	-5.86	-4.75	-5.86
Hard bottom	0.69	0	2	6	1	9	4.39	0.00	8.33	3.31	5.56	3.14	-4.39	3.94	-1.08	1.16
Thalassia	1.04	19	4	4	0	27	6.62	29.69	16.67	2.21	0.00	9.41	23.06	10.04	-4.41	-6.62
Mixed sand	2.14	15	4	14	0	33	13.63	23.44	16.67	7.73	0.00	11.50	9.81	3.04	-5.90	-13.63
Mixed seagrass	0.33	2	1	1	0	4	2.10	3.13	4.17	0.55	0.00	1.39	1.02	2.07	-1.55	-2.10
Totals	15.70	64	24	181	18	287	100	100	100	100	100	100				
South-southwest																
Fine mud	0.32	0	1	0	2	3	4.23	0.00	11.11	0.00	4.17	1.35	-4.23	6.88	-4.23	-0.07
Sand	2.59	1	2	88	30	121	34.26	9.09	22.22	57.14	62.50	54.50	-25.17	-12.04	22.89	28.24
Algae	2.04	0	3	20	5	28	26.98	0.00	33.33	12.99	10.42	12.61	-26.98	6.35	-14.00	-16.57
Soft corals	0.31	0	0	0	0	0	4.10	0.00	0.00	0.00	0.00	0.00	-4.10	-4.10	-4.10	-4.10
Hard bottom	0.01	0	0	0	0	0	0.19	0.00	0.00	0.00	0.00	0.00	-0.19	-0.19	-0.19	-0.19
Thalassia	0.65	1	2	6	0	9	8.60	9.09	22.22	3.90	0.00	4.05	0.49	13.62	-4.70	-8.60
Mixed sand	0.70	4	0	25	10	39	9.26	36.36	0.00	16.23	20.83	17.57	27.10	-9.26	6.97	11.57
Mixed seagrass	0.95	5	1	15	1	22	12.56	45.45	11.11	9.74	2.08	9.91	32.69	-1.45	-2.82	-10.48
Totals	7.56	11	9	154	48	222	100	100	100	100	100	100				

A revision of the average queen conch densities obtained in previous studies made in the archipelago and in other Caribbean regions suggests that the use of different methodologies in population assessments hinders comparative analysis (Table 6). However, when comparing those studies in which a data collection method over transects of variable length has been applied, it can be observed that the average density found in the Los Roques Archipelago (18.78 conch/ha) is closer to the values registered in overfished areas of Belize (14.6 conch/ha) and St. Thomas/St John (12.25 conch/ha), but below the density estimates of protected areas of Bahamas (53.60 and 96.00 conch/ha) (Table 6).

The presence in the general sampling of numerous localities (36 stations of 78) with zero individuals and some where the densities were very high (up to 247.01 conch/ha), is a consequence of the clumped behavior of queen conch populations. This behavior generates high variances in the density estimates and thus, wide confidence limits associated with the calculation of population abundance (Stoner and Ray 1996, Friedlander et al. 1994, Mateo 1997). For this reason, the current total abundance of 1,374,640 conch (C.L.= 640,474 – 2,023,897) found for the archipelago, should be taken with caution, since it assumes that the queen conch is distributed homogeneously in the 73,197 hectares of its platform.

Nevertheless, the general sampling allowed us to stratify the area appropriately to carry out a second field sampling in those areas where greater aggregations were found. This resulted in higher density values, even when the estimates of abundance were lower, since a smaller area was considered. The stratification in blocks reduced by 63% the confidence limits in the estimation of abundance.

According to the density estimates obtained in the blocks, it seemed that there is a recovery of queen conch populations in certain areas of the park. The presence of important populations of adults and older individuals in deep waters (> 16m) suggests that the protection strategy has allowed the migration of individuals from shallow waters toward deep waters, a natural process in the life cycle of this specie (Stoner and Sandt 1992). These aggregations represent an important larvae source for the archipelago, since reproductive activity was common between them. Similar observations have been documented in other areas of the Caribbean (Stoner et al. 1996, Stoner and Ray 1996, Stoner and Schwarte 1994, Stoner and Sandt 1992).

However, the low overall density of juvenile and sub-adults found in the present study is worrying. The same observation found in previous evaluations, made in the Los Roques Archipelago (Weil and Laughlin, 1984) and in other regions of the Caribbean (Stoner and Schwarte 1994, Stoner and Ray 1996, Mateo 1997) has been associated with a diverse of factors, among this the juveniles burring behavior, the lack of significant recruitment events (Tewfik et al. 1998) and the high mortality rate among the individuals of the juvenile age class (Appeldoorn 1988).

Table 6. Average densities of queen conch estimated in various locations in the Caribbean region.

Locality	Density (conch/ha)	Methodology	Status of the Fishery	Reference
Puerto Rico			Overfished	
West coast	8.49	Variable length transects	Recruitment of	Mateo, 1997
East coast	7.49	Variable length transects	juveniles observed	Mateo, 1997
Jamaica (Pedro's Bank)				
Artisanal zone (0-10m)	89.09	Quadrates over transects	Not sustainable	Appeldoorn, 1995
Commercial zonel (10-20)	144.46	Quadrates over transects	fishing levels	Appeldoorn, 1995
External zone (20-30m)	276.97	Quadrates over transects		Appeldoorn, 1995
Belize	14.6	Variable length transects	Overfished	Appeldoorn and Rolke,
Honduras (Cayos Cochinos)	14.6	Variable length transects	Overfished	Tewfik et al., 1998
Florida			Overfished	
High density period	4.08	Towed diver	Fishery closed	Glazer and Berg, 1994
Low density period	0.44	Towed diver	in 1985	Glazer and Berg, 1994
US Virgin Islands				
St. Thomas/St. John	9.7	Towedd diver	Overfished	Wood y Olsen, 1983
St. Thomas/St. John	12.25	Scooter diver		Friedlander et al., 1994
Venezuela (Los Roques)				
Protected zone	2130	Quadrates		Weil and Laughlin, 1984
Fished zone	900	Quadrates	Overfished	Weil and Laughlin, 1984
General	1210	Fixed length transects (3x60m)	Total closure	Bastidas and Rada, 1998
General	18.78	Variable length transects		Present study
Northeast block	34.74	Variable length transects		Present study
South-southwest block	52.34	Variable length transects		Present study
Bahamas (Exuma Cays)			Overfished	
Protected bank	53.6	Variable length transects	in specific areas	Stoner and Ray, 1996
Protected shelf	96	Towed diver		Stoner and Ray, 1996

The limited distribution of juvenile individuals in depths beyond 10 meters can be explained by the limited distribution of seagrass meadows in these depth strata. According to studies carried out by Stoner et al. (1994), the juvenile aggregations are closely related to seagrass communities with a high biomass of macroalgae, which constitutes the main source of carbon for this age class (Stoner et al. 1994).

The clear preference of adult and old individuals for sand plains observed during the present evaluation, is similar to that found by Stoner and Sandt (1992), coinciding both studies with the peaks of reproductive activity. Those authors point out that, during the reproductive season spawning individuals migrate from the feeding areas over seagrass and algae meadows to sand beds, which provides a favorable substrate for producing egg masses

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LITERATURE CITED

Amend, T. 1992. Los habitantes del Archipiélago de los Roques, en el pasado y en el presente. Paginas 1-42 en: T. Amend (ed.) *Parques Nacionales y Conservación Ambiental. Parque Nacional Archipiélago de los Roques.* N° 3. Caracas, Venezuela.

Appeldoorn, R.S. 1988. Age determination, growth, mortality, and age of first reproduction in adult queen conch, *Strombus gigas*, off Puerto Rico. *Fisheries Resources* 6:363-378.

Appeldoorn, R.S. [1995]. Stock abundance and potential yield of queen conch of Pedro Bank. Technical Report. Fisheries Division, Ministry of Agriculture, Kingston, Jamaica. 31 pp.

Appeldoorn, R.S. and W. Rolke. [1996]. Stock abundance and potential yield of queen conch resource in Belize. Technical Report CARICOM Fisheries Research Assessment and Management Program (CFRAMP) and Belize Fisheries Department. Belize City, Belize. 7 pp.

Bastidas, C. and M. Rada. 1998. Evaluación de las densidades de botuto, *Strombus gigas,* en zonas específicas del Parque Nacional Archipiélago de Los Roques. Pages 284-287 in: I. Novo (ed.) *Ciencia y Conservación en el Sistema de Parques Nacionales de Venezuela.* Caracas, Venezuela.

Friedlander, A., R.S. Appeldoorn, and J. Beets. 1994. Spatial and temporal variations in stock abundance of queen conch, *Strombus gigas*, in the U.S. Virgin Islands. Pages 51-60 in: R.S. Appeldoorn and B. Rodríguez (eds.) *Biología, pesquería y cultivo del caracol Strombus gigas.* Fundación Científica Los Roques. Caracas, Venezuela.

Glazer, R.A. and C.J. Berg. 1994. Queen conch research in Florida: An overview. Pages 79-95 in: R.S Appeldoorn and B. Rodríguez (eds.) *Biología, pesquería y cultivo del caracol Strombus gigas.* Fundación Científica Los Roques, Caracas, Venezuela.

Mateo, I. 1997. Spatial variations in stock abundance of queen conch, *Strombus gigas*, (Gastropoda: Strombidae) in the West and East coast of Puerto

Rico. M.S. Thesis, University of Puerto Rico; Mayaguez, PR. 75 pp.

Posada, J.M. and B. Alvarez. 1988. Análisis del sistema pesquero del Parque Nacional Archipiélago de los Roques, IV.- La pesqueria del botuto, *Strombus gigas*. 1985-1987. *Memoria de la Sociedad de Ciencias Naturales de La Salle*. **48** (3):435-443.

Randall, J.E. 1964. Contributions to the biology of the queen conch, *Strombus gigas*. *Bulletin of Marine Science* **14**:247-295.

Rodríguez, B. and J. Posada. 1994. Revisión histórica de la pesquería del botuto o guarura (*Strombus gigas*) y el alcance de su programa de manejo en el Parque Nacional Archipiélago de Los Roques, Venezuela. Pages.13-24 in: R. Appeldoorn and B. Rodríguez (eds.) *Biología, pesquería y cultivo del caracol Strombus gigas*. Fundación Científica Los Roques. Caracas, Venezuela.

Sokal, R. and J. Rohlf. 1995. *Biometry*. Third Edition. Freeman Publishers. New York, New York USA. 887 pp.

Stoner, A.W. and M. Ray. 1996. Queen conch, *Strombus gigas*, in fished and unfished locations of the Bahamas: effects of a marine fishery reserve on adults, juveniles, and larval production. *Fishery Bulletin* **94**:551-565.

Stoner, A.W. and V. Sandt. 1992. Population structure, seasonal movements and feeding of queen conch, *Strombus gigas*, in deep-water habitats of the Bahamas. *Bulletin of Marine Science* **5** (3):287-300.

Stoner, A.W., P.A. Pitts and R.A. Armstrong. 1996. Interaction of physical and biological factors in the large-scale distribution of juvenile queen conch in seagrass meadows. *Bulletin of Marine Science* **58** (1):217-233.

Stoner, A.W. and K.C. Schwarte. 1994. Queen conch, *Strombus gigas*, reproductive stocks in the central Bahamas: distribution and probable sources. *Fisheries Bulletin* **92**:171-179

Tewfik, A., H. Guzmán and G. Jácome. 1998. Assessment of the queen conch, *Strombus gigas* (Gastropoda: Strombidae) population in Cayos Cochinos, Honduras. *Revista de Biología Tropical* **46**(4):137-150.

Weil, E. and R. Laughlin. 1984. Biology, population dynamics, and reproduction of the Queen Conch, *Strombus gigas*, in the Archipiélago de Los Roques National Park. *Journal of Shellfish Research* **4**(1):45-62.

Wood, R.S. and D. Olsen. 1983. Application of biological knowledge to the management of the Virgin Islands conch fishery. *Proceedings of the Gulf and Caribbean Fisheries Institute* **35**:111-121.

Shell Midden Surveys as Source of Information about Fished Queen Conch (*Strombus gigas*) Populations: A Case Study in Parque Nacional Del Este, Dominican Republic

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ABSTRACT

Queen conch (*Strombus gigas*) populations are in decline throughout their range in the tropical western Atlantic, due to a combination of intense fishing, habitat loss and water quality degradation. The dramatic decline in abundance of queen conch has led to commercial extinction throughout much of its range. Life history features such as their slow movements, aggregational behavior, and dependence on shallow-water habitats make them vulnerable to over-exploitation by humans. A better understanding of how population dynamics have reacted to long-term fishing pressure is critical for future restoration and management efforts. From the beginning of conch fishing in the area, fishermen have left evidence of past fishing efforts in the form of shell middens. It is our objective to determine the characteristics of fished populations by surveying undisturbed middens that have been found on the shores of a marine lagoon in Parque Nacional del Este (PNE), Dominican Republic. Some of the middens date to pre-Columbian fishing times and provide a historical context for evaluating recent fishing intensity.

Two conch shell middens were thoroughly surveyed by excavating a 2m x 2m area from top to ground level during March and April 2000. Nearly 10,000 queen conch shells were mapped within the middens and measured for shell length, shell width, spine length, and lip thickness when a flared lip was present. The type of opening used to extract the animal was also recorded. One of the middens dates approximately to 1400 $\pm$ 70 years, suggested first by Taino artifacts found with the shells and later confirmed by carbon-14 isotopic analysis. The second midden was presumed to be modern based on anecdotal accounts, the pink coloration of shells, and the modern artifacts found at the base of the midden. Results from these excavations revealed that there is a long history of conch fishing in PNE. Shells from the older midden were found to be dominated by smaller shells than the modern midden (probably suggesting different fishing practices or target preferences by Tainos). As we excavated from the top to the bottom of the recent midden, a significant increase in mean shell length of queen conch shells was apparent. The further analysis and dating of these shell middens may help to reconstruct the history of *S. gigas* fishing and better understand how such activities have affected population dynamics in terms of size frequency distribution and shell morphology.

KEY WORDS: Carbon dating, Parque Nacional del Este, shell midden, *Strombus gigas*.

INTRODUCTION

The status of queen conch (*Strombus gigas*) populations is well documented throughout the wider Caribbean, but historical population abundance and size frequency distribution patterns are known only from anecdotal accounts and shell midden records. Queen conch fishermen left evidence of fishing practices in the form of shell middens that probably date back to pre-Columbian occupation of the Caribbean, especially in remote areas where only the meat was transported to a distant market. A marine lagoon in Parque Nacional del Este (PNE), in the southeastern corner of the island of Hispaniola, has been an area of conch fishing over the centuries of human occupation in the Caribbean Basin. The analysis and dating of these shell middens may help us to elucidate the structure of fished populations once present in the lagoon. Long-term population dynamics of a tropical marine invertebrate are influenced both by climatic factors and biological factors such as high fishing mortality. Queen conch have been utilized as a food and shell source in the Caribbean Basin for well over 1,500 years. Through this time, climatic cycles and changes have impacted growth, reproduction and recruitment of populations. Changes in population dynamics related to climate are only now possible to study with the construction of new climate records for the past 1,000 years. Segregating the impacts of climate from intensive fishing pressure requires a study site with a long-term fishing history.

Queen conch have persisted in many coastal systems, because the fishing techniques exploited only part of the depth range of adults breeding aggregation. Commercial fisheries were once important in the southeastern Dominican Republic (DR). The southeastern coast has the largest platform area (722 km^2) in the country (Secretaría de Estado de Agricultura 1995). Historically, important fisheries ports were located in San Rafael de Yuma (northeast of PNE) and La Romana (west of PNE) (Bonnelly de Calventi 1975). These fisheries supported a relatively large export market to the U.S., Virgin Islands, and Puerto Rico. More recently, however, small-scale artisanal fisheries exist for local consumption. Presently, fishermen are allowed to fish in the areas surrounding the park, with the exception of Canal de Catuano. The degree to which the Canal de Catuano has been protected from poaching is unknown.

PNE was designated as a national park by the Dominican government on 16 September 1975 (Act No. 1311) and it is the second largest in the country (Figure 1). A large, mostly shallow (< 10 m depth) marine lagoon (Canal de Catuano) separates Isla Saona from the mainland. Because of the lagoon's nursery function for queen conch, it was declared a no-fishing zone for conch in 1999. Additionally, a seasonal closure has been implemented from 1 July to 31 October throughout the country. PNE is located in an area where one of five major Taino provinces occurred. Just north of San Rafael de Yuma (northeast of PNE) was located Villa Salvaleon, where Ponce de Leon once lived. This area was governed by the Cacique Cayacoa, who was one of the last to be killed by the Spaniards, leaving Caizcimu as the last area of Hispaniola where Taino people ever lived. Taino fished queen conch for food and used the shells for tools (Vega 1990).

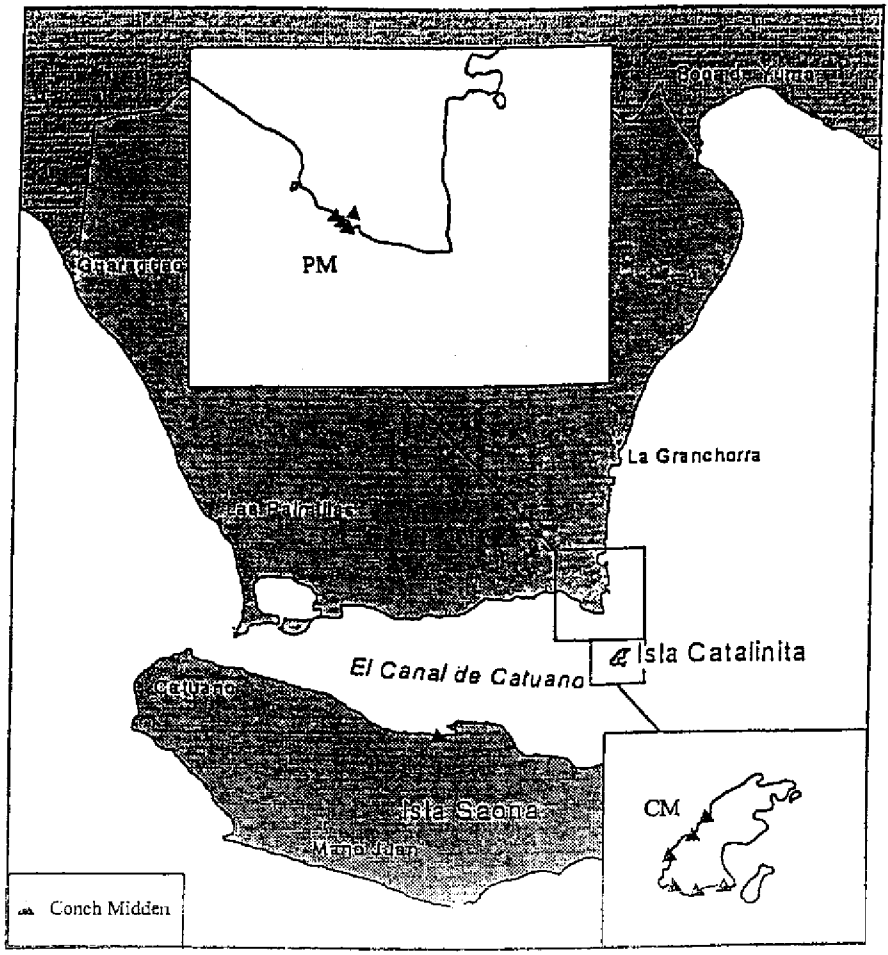


Figure 1. Map of Parque Nacional del Este, southeastern Dominican Republic. Midden sites: Peninsula Middens (PM) and Catalinita Middens (CM) are indicated.

An evaluation of historical queen conch populations in PNE will be an important issue in the DR, as PNE plays an important role in conservation efforts in the country's protected areas system. Although most of the marine habitats around the park are not legally protected, they have the potential to serve as a source of replenishment for many marine organisms. Nursery grounds for many marine organisms are located within the park and these areas may be a potential source of larvae that could seed adjacent coastal habitats of the Dominican Republic and other countries in the wider Caribbean.

METHODS

Previous expeditions to Parque Nacional del Este (PNE) led to the discovery of several shell middens. From these, two were selected based on how undisturbed they were and by their estimated age. Catalinita Midden #1 (CM1), an ancient midden, is located on the western shore of Isla Catalinita, while a modern midden, Peninsula Midden #5 (PM5), is located on the southeastern extent of the PNE peninsula (Figure 1). Shells were also collected from other middens (CM2, CM3, CM4 and CM5) for carbon-14 dating to identify possible future excavation sites. Volunteers from Earthwatch were used in the midden excavation work, all staff and volunteers received training in shell measurement. An exercise measuring a set of 35 conch shells was performed prior to the excavations to test for differences in error in shell measuring between surveyors prior to the midden survey. A Kendall's coefficient of concordance was obtained from this exercise to compare how surveyors ranked by size the 35 conch shells and to determine if there was any association between them or if there was any similarity or difference in the measurements that each surveyor was obtaining.

At the midden sites, we first mapped the middens by laying parallel measuring tapes with a meter of separation between them over the midden to record the elevation of every meter increment within these grid lines using an electronic builder's level (Compulevel by Stanley Tools). This provided a three-dimensional profile of the midden and an estimate of the volume of shells per cubic meter. The grid lines later served for placement of 2 m x 2 m PVC quadrants at the highest point of the midden (Figure 2).

At the site of what was believed to be an intensive commercial fishery between 1955 and 1970, a serives of nine middens were mapped and the total volume of shells estimated. The mapping was accomplished by placing a central survey line parallel to shore and making distance and altitude measurements off that line (Figure 3). The PM5 was in the center of this midden line. Total volume of the middens was estimated by calculating the volume of an elipsoid cut in half by the slope of the shoreline.

Within quadrants, information on the location and measurement of every other queen conch shell was recorded as follows. Using string, each quadrant was equally divided into sixteen 50cm x 50 cm areas. These areas represent the horizontal location of the shells within the midden, as the sides of the unit (X and Y axes) are divided into four segments (0 = 0-49cm, 1 = 50-99cm, 2 = 100-149cm, and 3 = 150-200cm). This was used to record X and Y coordinates. The third coordinate was recorded from the relative altitude of the shell within the midden. For this an electronic engineer level was used to measure the difference in elevation from a previously set reference point, in this case, ground level on one side of the midden. Also within the units (and only in PM5), several layers were pre-determined to later look for differences in shell sizes between layer or through time (based on the superposition effect). Layers were chosen to be as a 50-cm difference in elevation starting from the lowest corner of the unit, and later from the base of each previous layer. Shell samples were collected from the different middens and layers for

carbon-14 isotope analysis.

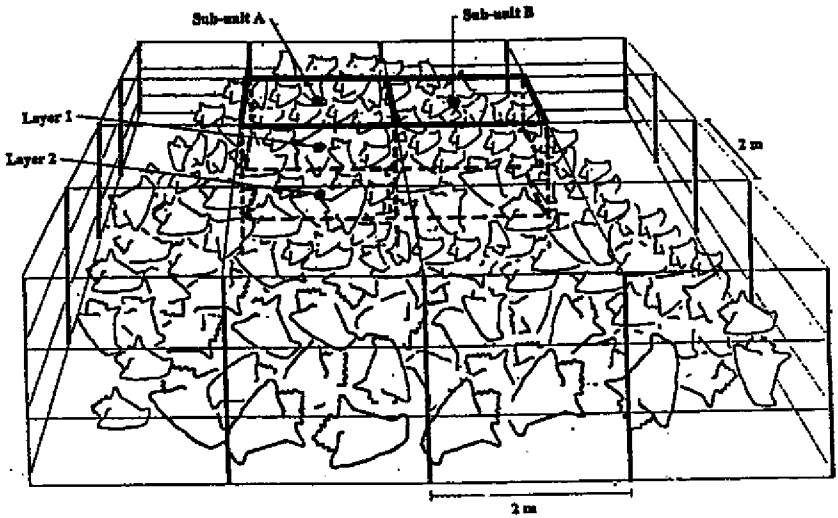


Figure 2. Midden excavation grid used to map and later excavate the middens. Sub-units are 2 m x 2 m areas, Layers are determined to be a 50 cm vertical difference in elevation.

Every other shell was mapped (X,Y, Z coordinates) and then measured in mm by tossing one shell and selecting another as randomly as possible for shell length, body whorl width, lip thickness, and length of the shell spines. When a flared lip was present in a shell, lip thickness was measured about two-thirds of the distance from the end of the siphonal groove. Information on the shape of the opening used to extract the animal out of the shell was also recorded. A standard fish board was used to measure the shell length, while body whorl, lip thickness and spine length was measured using plastic calipers. While the midden surveys yielded a wealth of information, we limit our discussion herein to patterns of species composition, proportion of juvenile to adults and shell length. Further excavations and analyses will be carried out during 2001.

A Kolmogorov-Smirnoff test was used to test for differences in shell length frequency distribution between the CM1 and PM5 middens. Due to the heterogeneity of variances of shell lengths found using Bartlett's test between the

different layers of PM5, a Kruskall-Wallis test was perfomed in lieu of a one-way ANOVA to test for differences in mean shell length between the layers. Both these tests as well as the Kendall's coefficient of concordance for the volunteer practice were performed as described in Zar (1999) and Sokal and Rolf (1995).

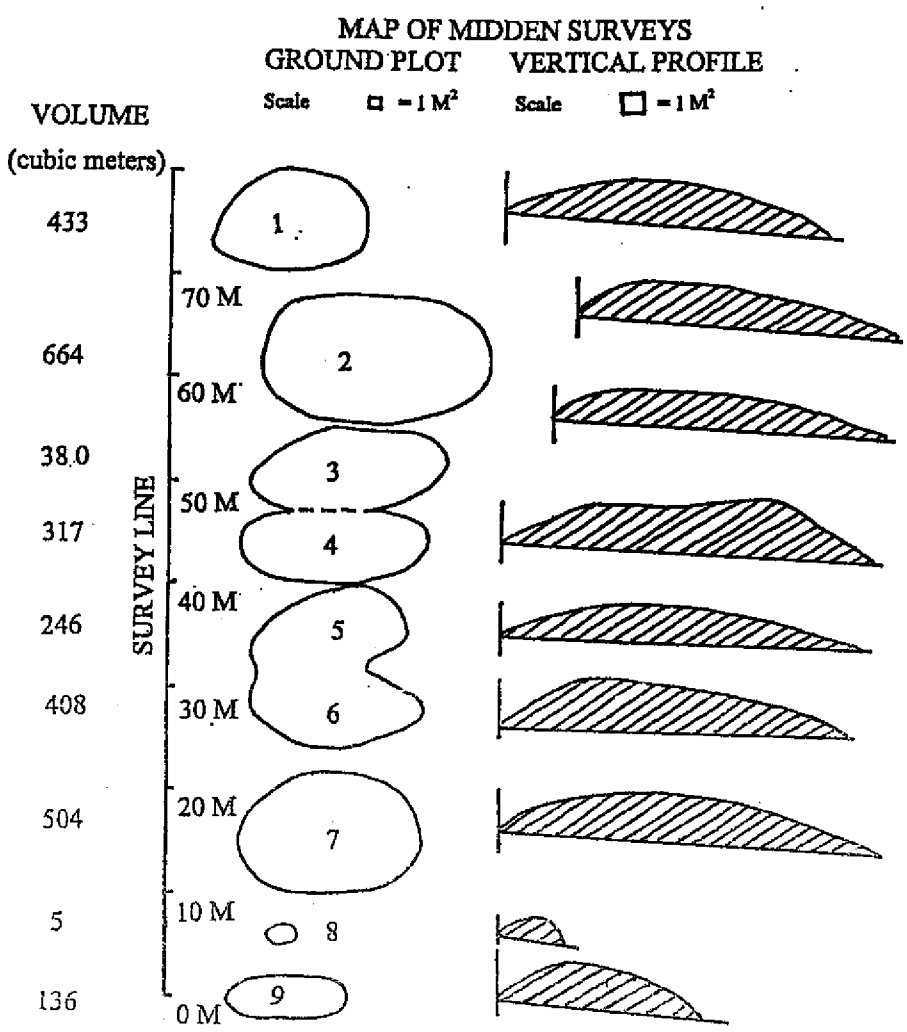


Figure 3. Map of the nine shell middens found at the Peninsula site. This graphs shows each middens' area and elevation along the survey line. Also the volume (in cubic meters) is indicated for each.

RESULTS

Shell Measuring Error

Results from the Kendall's coefficient of concordance from the shell length data produced by 14 different surveyors measuring 35 known shells, showed that there was an association on the way the surveyors ranked the shells from smallest to largest. This result indicates that these 14 surveyors would measure conch shells with very similar results.

Older Conch Shell Midden (CM1)

Detailed information on the middens can be found in Table 1. CM1 is located on the northwestern side of Isla Catalinita (Figure 1). Radiocarbon dating analysis performed with samples taken from CM1 indicated that this midden was formed with shells approximately 1,400 years old (± 70 years). This later date (year 600 or so) was also suggested by the finding of several pieces of Taino pottery found within the midden. In CM1, 2,175 conch shells were mapped and measured, yielding a mean (SD) shell length of 121.8 (26.0) mm. Most shells (98%) were *Strombus gigas*, less than 2% were *Cittarium pica*, and less than 1% from other species (*Cassiss sp.*, *Murex sp.*, and *S. pugilis)*. We determined that 99% of the *S. gigas* shells were juveniles.

Table 1. Information on the volume of shells, mean shell length (SD in parenthesis), species composition and proportion of juveniles to adults of middens CM1 and PM5 (Top, middle and bottom layers from PM5 are also described).

	Density (shells/m^3)	Shell Length (mm)	Species proportions	% Juveniles
CM1	1391	121.80 (26)	98% *S. gigas* <2% *C. pica* <1% other	99%
PM5				
Total	1139	147.99 (33.08)	98% *S. gigas* <2% *S. costatus* <1% other	85%
Layer 1	1298	131.49 (26.97)		
Layer 2	1079	154.30 (25.92)		
Layer 3	860	177.12 (30.51)		

Recent Conch Shell Midden (PM5)

PM5 is located on Punta Algibe, and it is presumed to have been formed in recent decades due to several modern artifacts (e.g. broken bottles and piece of sandal) found at the base of this midden. Several local fishermen indicated that this midden, along with others in the same general locale, were a product of commercial fishery in the 1960s and 1970s. PM5 is larger than CM1, and it forms part of a group of middens with similar sizes and shapes. In total, we mapped and measured 4,868 *S. gigas* shells that had a mean (SD) shell length of 147.99 (33.08) mm, with a range of 45 mm to 267 mm. The species composition of PM5 was similar to CM1

in terms of the predominance (98%) of *S. gigas*. Less abundant species were represented by *S. costatus* (2%), *S. pugilis* < 1%) and *C. pica* (< 1%). A larger proportion of adult queen conch (15%) were found at PM5.

Figure 4 shows a relative shell length frequency distribution for both CM1 and PM5. Results indicate that there is some difference in the size structure (shell length) between the middens. PM5 has a larger mean shell length when compared to CM1, and frequency distributions were found to differ ($p < 0.001$), as determined by a Kolmogorov-Smirnoff test.

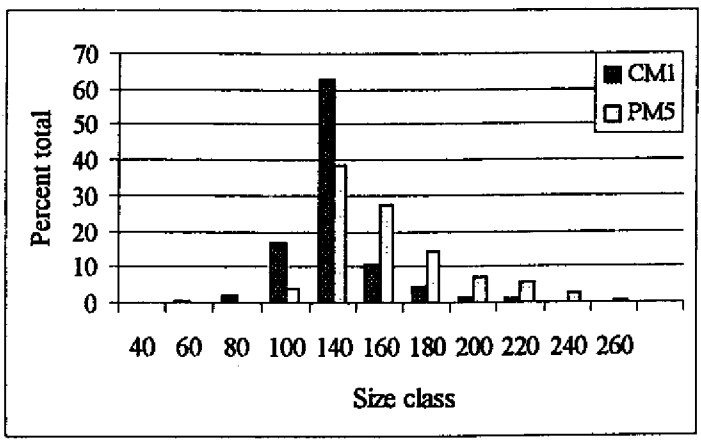


Figure 4. Shell length frequency distribution of CM1 and PM5 middens.

Stratigraphy Within PM5

Given the large size of PM5 compared to CM1, it was possible to subdivide PM5 into three different layers to determine if there was any significant difference in shell length of conchs deposited at the bottom of the midden (ealier in time) than from the top (later in time). Figure 5 shows a relative shell length frequency distribution of layers 1 (top), 2 (middle), and 3 (bottom) for midden PM5. Mean shell length increases from the top to the bottom of the midden. Mean length from layers 1, 2 and 3 was 131.49 (26.97) mm, 154.30 (25.92) mm, and 177.14 (30.51) mm, respectively (Table 1). A Kruskall-Wallis test showed that there was a significant difference ($p < 0.001$) in mean shell length among the three layers.

Midden Ages

Queen conch shells shells from the two excavated middens and other locations in the vicinity of CM1 were dated using radiocarbon isotope analysis. These data will help to determine the approximate time when the middens were formed (and hence when

fishing occurred). Radiocarbon data will also be used to locate future excavation sites that will target different periods of time in conch fishery history in the area. Table 2 summarizes the dates from these middens.

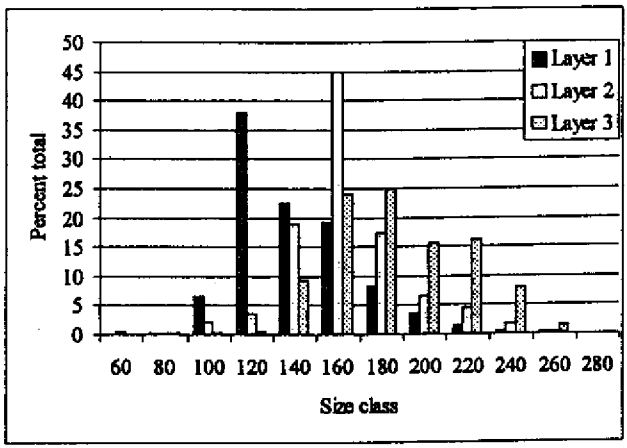


Figure 5. Shell length frequency distribution of the top, middle and bottom layers within PM5.

Table 2. Radiocarbon dating analysis performed on several shell samples collected from different middens in Parque Nacional del Este. PM5 is located at the southeastern tip of the mainland peninsula while CM1-5 middens are located on Isla Catalinita (Figure 1).

Sample	Material	Age (years)	Date (year AD)
CM1	*S. gigas* shell	1,400 (± 70)	600 (± 70)
CM2	*S. gigas* shell	1,390 (±60)	1,800 (±70)
CM3	*S. gigas* shell	1,010 (±60)	1,420 (±60)
CM4	*S. gigas* shell	460 (±60)	870 (±60)
CM5	*S. gigas* shell	1,170(±70)	1,590 (±70)
PM5	*S. gigas* shell	Recent	1960's ??

From this range of dates found at other middens, future midden surveys will be conducted at middens CM2, CM3 and CM5. This will give us an adequate range to compare to collected data from the year 600 (± 70) and recent decades.

DISCUSSION

Stoner and Ray (1996) concluded that shell remains provide useful information about marine mollusks over ecologically relevant time scales, and that important insights about the long-term distribution and exploitation of some species can be drawn from shell middens. Besides being a very labor-intensive exercise (excavating shell middens), this study has shown that many ancient (and fished) and recent conch shell parameters can be accessed from shell middens.

Older middens (CM1-5) in Parque Nacional del Este are definitively a product of a conch fishing activities that occurred hundreds of years ago when the area was first inhabited by the Taino people. Not having the most appropriate fishing gear (mask, fins, scuba, etc), they seemed to have targeted mostly juvenile conch in very shallow water and other species found on the rocky inter tidal coasts of Isla Catalinita (Table 1). Vega (1987) found large piles of shells on the shores of Isla Catalinita and Isla Saona, indicating the importance of conch in the diet of early inhabitants.

Stoner (1997) found that shell middens at several sites in the Bahamas probably indicate a historically significant abundance of conch in that area. Many shell middens have been reported by Vega (1987) and this study on Isla Catalinita island that appear (and now confimed by carbon dating) to have been formed in pre-Columbian time. These findings indicate that there is a long-term occurrence of conch, possibly indicative of a steady or high recruitment rate. This latter assumption is based upon the long history of fishing pressure. Conch aggregations still occur in shallow-water habitats on the southeastern coast, albeit at reduced densities (Delgado 1999, Torres and Sullivan Sealey, in prep.).

Shell midden analysis has to be conducted with a good knowledge of resource use by human populations. Fishermen, ancient or contemporary, may target specific sizes of conch given the relative access to the resource, and by their personal preference for a type of conch. The smaller mean shell length found in the older midden (CM1) can be viewed from different perspectives. The fact that the Taino people were limited in their fishing gear when compared to modern fishermen may indicate that they only had access to juvenile conch in shallower water. It is also possible that Tainos had a preference for conch that were easier to "open" (i.e. thinner shells), or perhaps the meat from juveniles was more tender.

The recent midden (PM5) showed a larger proportion of adult conch shells, mostly found at the base of the midden. There are several possible conclusion that can be drawn from this pattern. Given more advanced fishing gear (SCUBA or hookah), modern fishermen are able to reach adult conch aggregations in deeper water. This midden was part of a large group of 9 middens with a total shell volume of over 3,095 cubic meters, representing an estimated 3.2 million shells. These middens are very similar in size, shape and apparent age. Mangroves trees growing in between most of these recent middens may indicate that this site was a beach used by fishermen only targeting queen conch that beached their boats on shore and cleaned the shells on-site, throwing empty shells to either side and forming the middens we see today.

The midden information combined with local interviews allow us to make some important observations of the commercial fishery:

i) the fishery was intensive, and at least 3 million conch shells were deposited over a relatively short period of time, (2 to 3 conch generations),

ii) the fishery preferentially exploited adult conch first, as evidenced by the large conch at the bottom of the midden, then proceeded to fish sub-adults then smaller and smaller juveniles.

Towel (1973) reported that by the early 1970s, the creation of PNE was not controversial because the commercial fisheries in the area had already collapsed. Presumably it was no longer profitable – the density and size of conch available making it more expensive to collect conch meat than it would sell for in the export market. It is unlikely that this 1955 - 1970 commercial fishery used hookah. The operation of the commercial fishery was intensive and not intended to be sustainable. This high mortality over such a short period of time would likely require a long (tens of years) recover time, but the depth range and habitats not accessible to this earlier fishery are now open to present-day fishers.

LITERATURE CITED

Bonnelly de Calventi, I. 1975. Informe sobre la pesca en la República Dominicana. Colleción Ciencia y Tecnología No. 2, Publicaciones de la Universidad Autónoma de Santo Domingo, República Dominicana. 87 pp.

Delgado, G.A. 1999. Influence of habitat on queen conch abundance and size distribution in soft-sediment marine communities in Parque Nacional del Este, Dominican Republic. M.S. Thesis. RSMAS-University of Miami. Miami, Florida USA.

Secretaría de Estado de Agricultura. 1995. Proyecto de promoción de la pesca costera artesenal del litoral Sur. Volume II. Reportes del PROPESCAR-SUR: Contribuciones al conocimiento de las pesquerías en la República Domincana. PROPESCAR-SUR, Barahona, República Dominicana. 103 pp.

Sokal, R.R and F.J. Rohlf. 1995. *Biometry, Third edition.* W.H. Freeman and Company. New York, New York USA. 887 p.

Stoner, A.W. 1997. Shell middens as indicators of long-term distributional patters in *Strombus gigas*, a heavily exploited marine gastropod. *Bulletin of Marine Science* **61**(3): 559-572.

Stoner, A.W. and M. Ray. 1996. Shell remains provide clues to historical distribution and abundance patterns in a large seagrass-associated gastropod (*Strombus gigas*). *Marine Ecology Progress Series* **135**:101-108.

Vega, B. 1987. *Santos Shamanes y Zemies.* Fundacion Cultural Dominicana, Santo Domingo, Dominican Republic. 185 pp.

Vega, B. 1990. *Los caciazgos de la Hispaniola.* Fundacion cultural Dominicana, Santo Domingo, Republica Dominicana. 89 pp.

Zar, J.H. 1999. *Biostatistical Analysis.,Fourth edition.* Prentice Hall. Princeton, New Jersey USA. 663 pp.

Signalling Processes Involved in Queen Conch Metamorphosis

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ABSTRACT

Chemical cues are important in the exogenous and endogenous control of metamorphosis in many marine larvae. In most cases, the exact nature of the cue is unknown, and the manner in which larvae receive and transduce cues is not well understood. In order to understand theses process in the queen conch, *Strombus gigas*, the role of second messenger pathways in larval metamorphosis were examined. Past work with an artificial inducer of conch metamorphosis, H_2O_2 pointed to the importance of the phosphatidyl inositol signal transduction pathway. The current work focused on this pathway, examining the involvement of tyrosine kinases (TKs), protein kinase C (PKC), and arachidonic acid (AA). Activators of PKC induce queen conch metamorphosis, as does AA. Inhibitors of TKs, PKC, and AA block metamorphosis. These results were used to develop a model for signalling processes involved in the induction of conch metamorphosis and allowed for comparisons with other recognition based systems.

KEY WORDS: Larval metamorphosis, signalling, *Strombus gigas*

INTRODUCTION

In the queen conch, *Strombus gigas*, larval metamorphosis is induced by low molecular weight compounds associated with dominant species of red algae found in conch nursery grounds (Davis 1994, Davis and Stoner 1994, Boettcher and Target 1996, 1998, Stoner et al. 1996). The free amino acids valine and isoleucine mimic the effects of the natural inducer, and may be recognized at the same sites as the algal cues (Boettcher and Targett 1998). Examinations of the effects of neuroactive compounds and manipulations of external ion concentrations suggest that metamorphosis may be triggered through second messengers, specifically those involved in the phosphatidyl inositol (PI) pathway (Davis et al. 1990, Boettcher et al. 1997, Boettcher and Targett 1998). In this study the role of this pathway in conch metamorphosis was examined by testing the responses of larvae to various blockers and activators of the PI pathway. Changes in the expression and phosphorylation of specific components of the signalling pathway during metamorphosis were also examined. The involvement of tyrosine kinases (TKs), protein kinase C (PKC), arachidonic acid (AA) and Ca^{2+} were specifically addressed

RESULTS AND DISCUSSION

Models for processes controlling the transduction of larval metamorphogenic signals have drawn on those developed for olfactory responses involving primarily the adenylate cyclase/cAMP (AC/cAMP) pathway and the PI pathway (see Morse 1990 and Leitz 1997 for reviews). Preliminary experiments with *S. gigas* indicated that the AC/cAMP pathway was not directly involved in the induction of metamorphosis for this species (Boettcher, unpublished data). These studies along with experiments examining the effects of hydrogen peroxide (Boettcher et al. 1997, Boettcher and Targett 1998) pointed to a role of the PI pathway. In the current study, activators of PKC, including phorbol esters and 1,2 dioctanoyl sn glycerol, were shown to induce queen conch metamorphosis, as was AA. Inhibitors of TKs (genistein and AG82), PKC (chelerythrine chloride and phloretin), and AA (lipoxygenase inhibitors) blocked metamorphosis. Manipulation of calcium concentrations and calcium channel blockers gave mixed results that suggest changes in internal calcium concentrations may influence the induction processes. Using the information provided by these experiments and models applied to other marine invertebrate larval systems (Leitz 1997), a model was developed for signalling during conch metamorphosis.

LITERATURE CITED

Boettcher, A.A. and N.M. Targett. 1996. Induction of metamorphosis in queen conch, *Strombus gigas* Linnaeus, larvae by cues associated with red algae from their nursery grounds. *Journal of Experimental Marine Biology and Ecology* **196**:29-52.

Boettcher, A.A. and N.M. Targett. 1998. Role of chemical inducers in larval metamorphosis of queen conch, *Strombus gigas* Linnaeus: relationship to other marine invertebrate systems. *Biological Bulletin* **194**:132-142.

Boettcher, A.A., C. Dyer, J. Casey, and N.M. Targett. 1997. Hydrogen peroxide induced metamorphosis of queen conch, *Strombus gigas*: tests at the commercial scale. *Aquaculture* **148**:247-258.

Davis, M.A. 1994. Mariculture techniques for queen conch (*Strombus gigas* Linne) eggmass to juvenile stage. Pages 231-252 in: R.S. Appeldoorn and B. Rodriguez, (eds.) *The Biology, Fisheries, Mariculture and Management of the Queen Conch*,. Fundación Científica Los Roques. Caracas, Venezuela.

Davis, M. and A.W. Stoner. 1994. Trophic cues induce metamorphosis of queen conch larvae (*Strombus gigas* Linnaeus). *Journal of Experimental Marine Biology and Ecology* **180**:83-102.

Davis, M., W. D. Heyman, W. Harvey, and C. A. Withstandley. 1990. A comparison of two inducers, KCL and *Laurencia* extracts, and techniques for the commercial scale induction of metamorphosis in queen conch, *Strombus gigas* Linnaeus, 1758, larvae. *Journal of Shellfish Research* **9**:67-73.

Leitz, T. 1997. Induction of settlement and metamorphosis of Cnidarian larvae: signals and signal transduction. *Invertebrate Reproductive Development*

31:109-122.

Morse, D.E. 1990. Recent progress in larval settlement and metamorphosis: closing the gap between molecular biology and ecology. *Bulletin of Marine Science* 46:465-483.

NOTE: This is an expanded abstract and is not meant for citation purposes.

Preliminary Assessment of Nearshore Fishable Resources of Jamaica's Largest Bay, Portland Bight

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ABSTRACT

Sampling of mangrove, seagrass (*Thalassia, Syringodium* and *Halodule*) and nearshore sandy habitats over 13 months in Jamaica's largest bay, adjoining the country's largest landing site, yielded 98 species, comprising 92 finfish species from 41 families, including three elasmobranchs families, plus eight crustacean species from six families, and two molluscan species. Adult, sub-adult and juvenile fishes were captured with two types of seines nets deployed in shallow waters of not more than 2m depth. A total of 18.16 kg of fishable species were taken comprising 2,389 individuals, confirming the small sizes taken. Most (69%) of the 92 finfish species came from mangrove-seagrass habitats, and were represented entirely by juveniles. The five most abundant fish species numerically were *Anchoa lyolepis* (dusky anchovy), *Eucinostomus gula* (silver jenny), *Sardinella anchovia* (Spanish sardine), *Diapterus rhombeus* (caipita mojarra), and *Haemulon sciurus* (bluestriped grunt).Crustaceans comprised 7.1% with *Callinectes* spp. (blue swimming crab) the most abundant species, with molluscs contributing 2% of all species taken.

Species richness for the total area is high (SR = 98), and not unlike that (SR = 87) found in the Florida Everglades by Thayer et al. (1987). Similarity in diversity between sample stations and areas were measured using Jaccard's coefficient of similarity, and preliminary results suggest diversity in adjoining bays was sometimes different from each other. Mangrove-seagrass complexes in eastern Portland Bight had higher species diversity than western, despite nearly identical ecology and physico-chemical characteristics. Portland Bight and the area just west of it was shown to possess important juvenile fishable resources which occupied shallow nearshore zones as well as deeper areas that are fished commercially. Two commercially important marine shrimp species (*Penaeus schmitti* and *P. notialis*, southern white and southern pink shrimps) were caught.

Despite limited sampling, it was apparent that some areas functioned as critical nursery areas for many species and that the entire area as a whole, appeared to function as a giant nursery for many useful species. These fishable resources are inextricably linked with the larger body of resources landed at Old Harbour Bay beach, Jamaica's largest fish landing site, through movement from the Portland Bight area into deeper, exploited reef areas and through directly supporting the commercially fished reef species by providing forage species. The economic value of the fishable resources is thought to be so great that loss of these nursery areas through poorly planned development or other means, would affect the livelihoods

of several thousand fishers, as well as equal numbers of directly dependent vendors and their respective families in adjoining parishes. This study was limited to very shallow waters, and thus, sampling of waters deeper than 2 m would be necessary for a more complete assessment.

KEYWORDS: Community structure, biodiversity, ecology, fishable resources, protected areas.

INTRODUCTION

The Jamaica Wetlands Resources Management Project determined that an assessment of the relationship between the wetlands and fishable resources of the large bay called Portland Bight or Old Harbour Bay, would be a very important project output (SCCF 1996). Because of study area size and various limitations, selected areas in the bay were studied.

It is generally taken as "an article of faith" (Boesch and Turner 1984) among estuarine scientists that coastal wetlands, such as mangrove and adjacent seagrass beds function as important nursery areas for juvenile fish and crustaceans. But, despite a great volume of literature on the subject (Austin 1971, Lindall et al. 193, Odum and Heald 1975, Blaber 1980, Staples 1980,Yanez-Arencibia et al. 1980, Robertson and Duke 1987) it has been suggested that the nursery ground value of mangroves up to recentl, was unclear (Robertson and Duke 1987). However, one very recent study, (Nagelkerken 2000) appears to prove conclusively that this assumption may be correct after all. The present study (conducted before Nagelkerken 2000) was thus intended to describe the nearshore fishable species in this largely unstudied area and to determine the extent and values of such resources. The areas investigated by limited sampling over 13 months April 1997 to April, 1998 were mainly mangrove-seagrass habitats, but also included a few alluvial beach sand sites west of Portland Bight.

Our objectives were to determine fishable species compositions and their spatial and temporal distributions, the importance of selected areas as nurseries and/or spawning areas, and seasonal variation in species composition and abundance, as well as the relative, actual, and potential economic importance of the species found. Further, our objective was to identify how existing and potential threats to wetlands and associated ecosystems could affect the actual and potential economic importance. Another goal was to develop area-specific management recommendations, and overall management recommendations for Portland Bight wetlands (Aiken 1996).

The areas sampled are indicated on Figure 1. These areas were, a). East Portland Bight (i.e. Manatee Bay, Coquar Bay, Walker Bay, Galleon Harbour), b). Central Portland Bight (Goat Island, Big Pelican Cay, Pigeon Island), c). Western Portland Bight (Port Esquivel, Salt river, Rocky Point, West Harbour, Miller Bay, Little Miller Bay), and lastly, d). West of Portland Point (Carlisle Bay and Macarry Bay).

Sample sites were all in very shallow nearshore areas with substrate conditions ranging from fine biogenic calcareous sand, soft grey mud, seagrasses, to coarse alluvial sand. Basic sample site characteristics are summarised in Table 1. In summary, sea surface temperature varies from 30 - 45°C. (the high 45°C. reading was caused by a power plant).

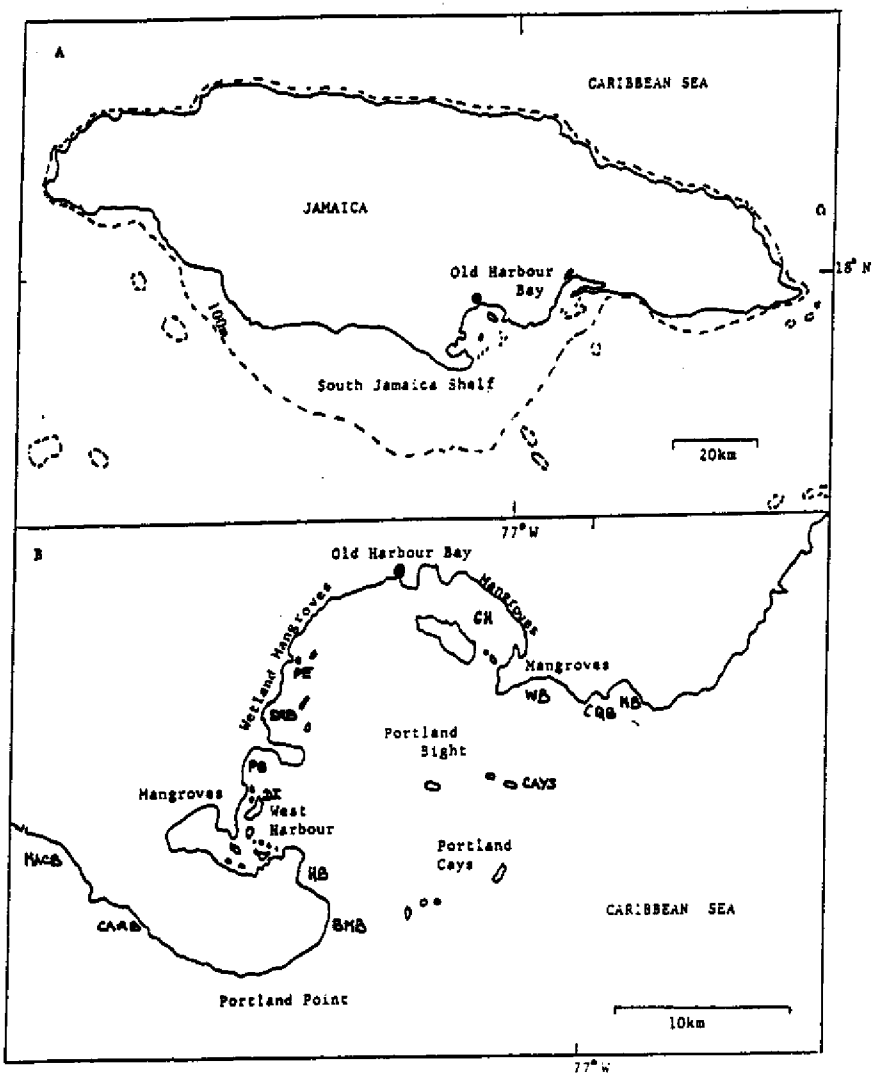


Figure 1. A. Map of Jamaica showing 100m depth contour and proximal oceanic bands; B. Portland Bight and Old Harbour Bay Sampling sites.

Table 1. Characteristics of sample sites

Site and Code Number	Main Characteristics (depth m)
Manatee Bay MB 1-8	Red mangrove prop roots, *Thalassia* beds, MB 1 - 8 scattered *Syringodium*, soft ooze and mud (0.2 -1.5 m)
MB 9-11	*Thalassia* beds, some *Syringodium* over firm white sand, surf. B11 at mangrove-seagrass junction (mean depth 1.5 m).
Coquar Bay CB 12-13	Red mangrove-*Thalassia* junction, *Syringodium*, fine white carbonate sand. Surf zone at west, many dead.*Thalassia* blades (1.0 - 1.5 m)
Walker Bay WB 14-16	Mangrove-dense *Thalassia* junction, with some *Halodule* (manatee grass), soft H_2S- rich mud and ooze (1.5 -1.75 m)
Galleon Harbour GH17-19	'Red mangrove-seagrass junction, soft, deep H2S-rich mud. Salt Island Creek mouth, (GH18) very rich detritus, and red mangrove with *Isognomon alatus* (false oyster) on roots (1.5 - 1.75 m)
Holmes Bay HB20/22	Red mangrove-*Thalassia* junction, deep organic ooze, with nearby *Halimeda* beds (1.0 -1.75 m)
(Big) Miller's Bay BMB 21	*Thalassia* and white carbonate sand, Millipore (fire) coral, encrusting algae accumulated *Thalassia* blades (0.5 - 1.5 m)
Dolphin Island DI 23	Mangrove-*Thalassia* junction, soft, deep organic ooze, with *Cassiopeia xamachan* (upsidedown jellyfish) on mud (1.0 -1.8 m)
Peake Bay PB 24-25	*Thalassia & Halimeda*, strong surf in centre, hard white sand (0.5 -1.5m). Salt River Bay
Salt River Bay SRB26-29	Mangrove-seagrass interface, soft ooze, (1.5 - 2.0 m)
Rolling Bay RB30	At mouth of wetland creek, *Thalassia*, much dead seagrass, very soft ooze, and quicksand (0.5 - 1.8 m)
Port Esquivel PE31-32	Pebbles, shingle, scattered *Thalassia, Syringodium, Padina*, near creek mouth green urchins (*Lytechinus*) (0.5 - 1.5 m)
Big Pelican Cay/ Pigeon Island BPC33-34	*Thalassia*, fine white sand and red Pigeon Island alga (*Neogoniolithon spectabile*) (1.0 - 1.75 m)
Rocky Point Lagoons RP35 -36	Soft white sand, ooze, lagoon nearby, reduced salinity water, mangroves, murky (1.00 - 2.0 m)
Macarry Bay MB37-38	Alluvial sand, murky water, surf, open ground, lagoons, *Gracilaria* spp. (1.5 - 2.0 m), black mangroves.

METHODS

All sampling was done with seine nets. For areas near mangrove roots, a small meshed seine net with dimensions 5 m long, 2 m deep with 3 mm diameter mesh, fitted with two 2 m wooden poles, deployed by two persons. The distance sampled

each time was 10 paces. Over seagrass beds, a larger seine net with dimensions 20 m long, 2 m deep with 15 mm diameter mesh, fitted with two wooden poles, was deployed for 20 paces each time. All catches were placed in labelled plastic bags and immediately fixed in 10-20% formalin. Samplings were executed once per month and this minimum frequency was generally met throughout the 13 month study. In some months, it was possible to do up to three trips. Generally, it was not possible to repeat sampling at each sampling site, except for three sites and therefore the data are for one set of samples per site. All sampling was done in daytime (between 1000 and 1600 hrs.).

All sample sites were sampled with both nets, with not less than three replicate settings of each net (small and large mesh). All catches were labelled and kept separately. Thus three samples were obtained for each net/habitat combination. Two-way analyses of variance with habitats (sort sites by habitats) and daytime as fixed factors were used to compare the equality of mean numbers of fish or crustaceans per netting. For small meshed nettings, catches were always standardized to numbers of fish per 10-pace netting. Not every site had mangrove-seagrass, although most did. Therefore, similar sites were grouped and analyzed together. One-way Analysis of Variance (ANOVA), with site (mangrove-seagrass) as a factor, were used to compare mean catch rates after appropriate transformation of the raw catch data. Similarity between sample areas was measured using the Jaccard (1902) *Coefficient of Similarity (C): C = a/(a+b+c)* where:

a = the number of species common to both areas or stations sampled

b = the number of species found at area/station b only, and

c = the number of species found at C only.

This index compares species on the basis of their presence or absence. Sites were compared in groups of three (triplets).

RESULTS

Species Composition

Some 2,389 fishable organisms comprising 98 species of finfish, crustaceans and molluscs, were taken during sampling from all the study sites. Fin fish comprised 92% of the species. Eight species of crustaceans from 6 families were captured, along with two molluscan species. Table 2 lists species as first encountered from roughly east to west. These fishable species all comprised 18.16 kg weight of total catch. From this total weight it can be deduced that all fishable resources were relatively very small in size and of low weight. Table 3 lists the 10 most numerically abundant species (both finfish and crustaceans) with information on their respective feeding guilds.

Table 2. Fishable species

Species (family)	Common Name	Total Number	Total Weight (gm)
Haemulon aurolineatum (Haemulidae)	Tomtate grunt	61	66
Sparisoma chrysopteum (Scaridae)	Redtil parrotfish	39	873
Stegastes dorsopunicans (Pomacentridae)	Dusky damselfish	36	176
Larisoma guppi (Blennidae)	Mimic blenny	1	-
Lutjanus apodus (Lutjanidae)	Schoolmaster snapper	63	1384
Caranx bartholamaei (Carangidae)	Yellow jack	3	100
Selene vomer (Carangidae)	Lookdown jack	27	41
Eucinostomus gula (Gerreidae)	Silver jenny	452	2692
Umbrina coroides (Scaenidae)	Sand drum	31	247
Callinectes spp. (Portunidae) C	Swimming crab	113	647
Stellifer rastrifer (Scaenidae)	Red Star drum	-	53
Polydactylus spp. (Polynemidae)	Threadfins	13	177
Hemirhamphus balao (Hemirhamphidae)	Balao	9	228
Harengula humeralis (Clupeidae)	Red ear sarine	13	88
Trachinotus goodei (Carangidae)	Palometa	1	41
Chloroscomberus chrysurus (Carangidae)	Leatherjacket	5	4
Chaetodipterus faber (Ephippidae)	Spadefish	1	28
Penaeidae spp. C	Roughneck shrimp	-	1
Sygnathus rousseau (Sygnathidae)	Pipefish	1	-
Lutjanus synagris (Lutjanidae)	Lane snapper	27	332
Unid Blenny (blennidae)	Blenny	2	19
Panulirus argus (Palinuridae) C	Spiny lobster	4	139
Penaeus spp. (Penaeidae) D	Marine shrimp	44	62
Abudefduf saxatalis (Pomacentridae)	Sergeant major	1	1
Unident. Species (Gerridae)	Mojarra	1	1
Gerres cinereus (Gerridae)	Yellowfin mojarra	4	127
Caranx latus (Carangidae)	Horse-eye jack	40	112
Syacium micrurum (Pleuronectidae)	Channel flounder	1	2
Sphyraena barracuda (Sphyraenidae)	Great barracuda	12	756
Scarus croisensis (Sparidae)	Striped parrot	43	56
Synodus foetens *(Synodontidae)*	*Inshore lizardfish*	*5*	*154*
Blennidae	Unidentified blenny		
Mithrax spinossissimus (Mithracidae) C	Spider crab	1	1
Archosargus rhomboidalis (Sparidae)	Sea bream	36	1581
Acanthurus bahianus (Acanthuridae)	Ocean surgeonfish	4	5
Haemulon sciurus (Haemulidae)	Bluestriped grunt	100	654
Odontoscion dentex (Sciaenidae)	Reef croaker	43	32
Jenkinsia lamprotaenia (Clupeidae)	Dwarf herring	95	45
Sparisoma rubripinne (Scaridae)	Yellowtail parrotfish	35	1091
Haemulon flavolineatum (Haemulidae)	French grunt	10	110
Haemulon plumieri (Haemulidae)	White grunt	22	125
Calamus spp. (Sparidae)	Porgy	7	26
Eucinostomus lefroyi (Gerridae)	Mottle mojarra	1	6
Scorpaena brasiliensis (Scorpaenidae)	Plumed scorpionfish	2	62
Sphoeroides spengleri (Tetraodontidae)	Bandtail pufferfish	36	609
Bothus lunatus (Bothidae)	Peacock flounder	7	18

Table 2 continued:

Species (family)	Common Name	Total Number	Total Weight (gm)
Siconyia spp. (Siconyidae) C	Grass shrimp	3	3
Diapterus rhombeus (Gerridae)	Caipita mojarra	157	970
Lutjanus griseus (Lutjanidae)	Grey snapper	9	115
Ripticus maculatus (Serranidae)	Whitespotted soapfish	2	18
Anchoa lyolepis (Engraulidae)	Dusky anchovy	371	193
Strongylura notata (Belonidae)	Redfin needlefish	2	5
Ocyurus chrysurus (Lutanidae0	Yellowtail snapper	48	354
Chilomycterus antillarum (Diodontidae)	Web burrfish	4	100
Lactophrys triqueter (Ostraciidae)	Smooth trunkfish	1	16
Urotuphus jamaicensis (Dasyatidae)	Yellowspotted stingray	2	452
Acanthurus chirurgus (Acanthuridae)	Doctorfish	5	9.5
Acanthurus coeruleus (Acanthuridae)	Blue tang	1	7
Stegastes variabilis (Pomacentridae)	Cocoa damsel	1	7
Monacanthus ciliatus (Monacanthidae)	Fringed filefish	5	13
Monacanthus hispidus (Monacanthidae)	Planehead filefish	1	1
Diodon holacanthus (Diodontidae)	Balloonfish	11	1995
Hemiramphus brasiliensis (Hemiraphidae)	Ballyhoo	23	211
Synodus intermedius (Synodontidae)	Sand diver	2	10
Symphurus arawak (Cynoglossidae)	Tonguefish	2	9
Haemulon bonairiense (Haemulidae)	Black grunt	4	44
Lachnolaimus maximus (Labridae)	Hogfish	1	4
Monacanthus tuckeri (Monacanthidae)	Slender filefish	1	1
Stegastes leucostictus (Pomacanthidae)	Beaugregory damsel 3	7	
Squilla spp. (Squillidae) C	Mantis shrimp	1	5
Gobionella saepepallens (Gobiidae)	Dash goby	1	0.25
Abudefduf saxitalis (Pomacentridae)	Sergeant major	3	2
Mulloidichthys martinicus (Mullidae)	Yellow goatfish	1	16
Hyporamphus unifasciatus (Belonidae)	Needlefish	1	18
Sphoeriodes testudineus (Tetraodontidae)	Checkered puffer	5	60
Dasyatus americana (Dasyatidae)	Southern stingray	3	1248
Balistes vetula (Ballstidae)	Queen triggerfish	1	9
Leptocephalus larvae (Elopidae)	Tarpon or ladyfish	2	<1
Harengula jaguana (Clupeidae)	False pilchard	2	16
Lactophrys polygonius (Ostraciidae)	Honeycomb cowfish	1	10
Labrisoma nuchipinnis (Blennidae)	Hairy blenny	2	24
Bothus ocellatus (Bothidae)	Eyed flounder	1	13
Scorpaena plumieri (Scorpaenidae)	Spotted scorpionfish	3	101
Sparisoma aurofrenatum (Scaridae)	Redband parrotfish	1	5
Sardinella anchovia (Clupeidae)	Spanish sardinge	263	146
Hippocampus reidii (Syngathidae)	Reid's seahorse	1	2
Bairdiella sanctaluciae (Sciaenidae)	Striped croaker	2	18
Trachinotus falcatus (Carangidae)	Permit	12	298
Strombus gigas (Strombidae)	Queen conch	1	20

Table 2 continued:

Species (family)	Common Name	Total Number	Total Weight (gm)
Acanthostracion quadricornis (Ostraciidae)		Cowfish	120
Centropomus spp. (Centropomidae)	Snook	2	50
Rhinobatus lentiginosus (Rhinobatidae)	Atlantic guitarfish	1	128
Achirus lineatus (Soleidae)	Lined sole	6	52
Penaeus schmittii (Penaeidae)	Southern white shrimp	3	13
Trichiurus lepturus (Trichiuridae)	Largehead hairtail	2	77
Anchoa spp. (Engraulidae)	Unidentified anchovy	2	6
Penaeus notialis (Penaeidae)	Southern pink shrimp	3	10
Alectis crinitus (Carangidae)	African pompano	1	0.5
Isognomon alatus (Bivalvia) M	False or flat oyster	Unknown	
Total		**2439**	**18057**

Table 3. Ranked numerical abundance of top ten species indicating feeding guilds.

Species	Common Name	Food Guild	Number
Anchoa lyolepis	Diusky anchovy	Zooplanktivore	367
Eucinostomus gula	Silver jenny	Zoobenthivore	349
Sardinella anchovia	Spanish sardine	Zooplanktivore	264
Diapterus rhombeus	Caipita mojarra	Zoobenthivore	155
Callinectes spp.	Swimming crab	Zoobenthivore	116
Haemulon sciurus	Bluestripved grunt	Zoobenthivore	102
Jenkinsia lamprotaenia	Dwarf herring	Zooplanktivore	99
Umbrina coroides	Sand drum	Zoobenthivore	75
Lutjanus apodus	Schoolmaster snapper	Piscivore	71
H. aurolineatum	Tomtate grunt	Zoobenthivore	70

Spatial Distribution of Species Between Habitats, Species Diversity and Species Richness

It shows that the number of species found was greater per site in the eastern portion of the Bight than the west. Manatee Bay westward through to Galleon Harbour (four bays) had a mean species number of 32 (± 2.4) species, while in contrast the Cays (2 sites) had only 8 species in the same shallow depth (0.5 - 2 m) sampled at all sites. Carlisle and Macarry Bays on the extreme west had a mean of 15 (± 3.1) species present or were roughly 50% less diverse than eastern sites. The Diversity Index estimate for the whole of Portland Bight and immediately adjacent areas is Species Richness = 98, which is relatively high for an estuarine/coastal lagoon environment (Colinvaux 1986).

Table 4 provides a comparison of relative Species Richness by site, and suggests that eastern sites were more diverse than western ones.

Table 4. Species found at Manatee, Coquar, and Galleon Harbour 12 months apart, indicating nursery role

Species	Common Name
Anchoa lyolepis	Dusky anchovy
Archosargus rhomboidalis	Sea bream
Sparisoma chrysopterum	Redtail parrot
Eucinostomus gula	Silver jenny
Selene vomer	Lookdown jack
Gerres cinereus	Yellowfin mojarra
Caranx latus	Horse-eye jack
Ocyurus chrysurus	Yellowtail snapper
Haemulon sciurus	Bluestriped grunt
Sphyraena barracuda	Great barracuda
Lutjanus apodus	Schoolmaster snapper
Odontoscion dentex	Reef croaker
Bothus lunatus	Peacock flounder
Lutjanus synagris	Lane snapper
Acanthurus chirurgus	Doctorfish
Sphoeroides spengleri	Bandtail puffer
Penaeus spp	Marine shrimp

Comparisons of Guilds Between Biotopes (Habitats)

Densities of zooplanktivorous fishes (herrings and sardines) were higher in the red mangrove prop-root biotopes than the seagrass beds, and these densities and abundances were probably higher there due to structural complexity of the red mangrove prop roots. This complexity was lowest over open muddy ground.

Over seagrass beds the abundance and densities of diurnally active zoobenthivores and herbivores was greater than for mangroves. However, it must be noted that depths greater than 2 m were not sampled and also that other biotopes, such as patch reefs, open sandy areas, and coral rubble were not sampled. Such sampling needs to be executed in future for complete guild structure assessment. Table 3 compares the various major feeding guilds found.

Comparisons of Guilds Within Biotopes

The shallow nearshore area sampled was dominated by zoobenthivores (mainly *Eucinostomus gula* and *Diapterus rhombeus*), and zooplanktivores, principally *Anchoa lyolepis* and *Sardinella anchovia*), (See Figure 5 finfish families by occurence). Zoobenthivores comprised 36.7% (Gerreidae, Haemulidae and Sciaenidae) and zooplanktivores 32.1%. Diurnal herbivores (Scaridae and Pomacentridae) comprised 6.7% of fishes taken (Figure 2).

Habitat Dominance

Table 1 summarizes the major features of the habitats which were sampled in the study. The dominant habitat sampled was the red mangrove prop root-seagrass interface. The Cays that were sampled (Big Pelican Cay and Pigeon Island only) were characterised by sandy shore-seagrass habitats. Many cays in the bay were not sampled due to limitations of this programme. The westernmost sites outside of

Portland Bight were characterised by black mangrove-lined lagoons and seagrass or muddy/alluvial sand substrates. Generally, as mentioned, eastern sites had more fishable species than western ones.

Single-species Comparisons

The 10 most abundant species consisted of three small pelagic (surface-dwelling planktivorous) coastal pelagic fishes (anchovies, sardines and herrings; see Table 3) and seven benthic (bottom-dwelling) species (including the swimming crabs). All of the 10 species are of commercial importance.

The dusky anchovy (*Anchoa lyolepis*) was the most numerous species (N = 367) taken. Size composition of this species is shown in Figure 3, and the mean size was 41.25 (± 3.3) mm TL and a mean weight of 0.53 g (± 0.09). Despite their small size they are vital in the food chain as a forage species for many larger commercial fishes. The largest dusky anchovy were found at Carlisle and Macarry Bays and one large specimen weighed 7.0 g and measured 87 mm FL. However, the mean size at Carlisle Bay was only 21.9 (± 3.1) mm TL, while on the eastern side of the Bight this species had a mean size of 34.8 (± 4.1) mm TL.

The silver jenny mojarra (*Eucinostomus gula*) was the second most abundant (N = 349) species (see Figure 4), the largest numbers found in Galleon harbour, Manatee Bay, and Port Esquivel, and it appears to be strongly associated with those areas near mangrove prop-roots and mud.

Spanish sardine (*Sardinella anchovia*) was the third most abundant (N = 264) species and was present only around the Cays sampled and the western side of the Bight, continuing into Carlisle Bay. The mean size for the species in the entire area was 33.2 mm TL (± 3.0) Mean size for this species in Carlisle Bay was 48.4 mm TL (± 3.9). At Big Pelican Cay, Spanish sardine had a mean size of 32.3 mm TL (± 4.1).

The most abundant invertebrate species was the swimming crab, *Callinectes* spp. (N = 89) and was found at most sites. Figure 4 indicates from their size distribution that they were generally small with a mean carapace width (MCW) of 41.3 mm (± 5.1).

Critical Habitats

There are at least four types of critical habitats for fishable species that were encountered in the area studied:

i) Coastal mangrove lagoons - (Manatee & Walker (Long) Bays, Rocky Point (Carlisle Bay), Macarry Bay)
ii) Red mangrove prop root-seagrass complexes - (Galleon Harbour & Goat Island, West Harbour)
iii) Coastal seagrass beds - (Portland Cays, Manatee & Walker Bays, Galleon Harbour)
iv) Wetland drainage-seagrass interfaces - Cockpit & Browers River areas.

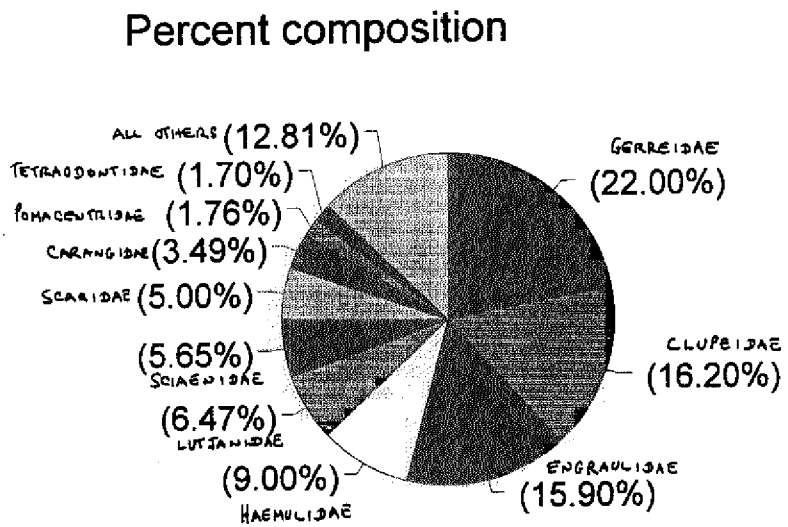


Figure 2. Percent composition of finfish families

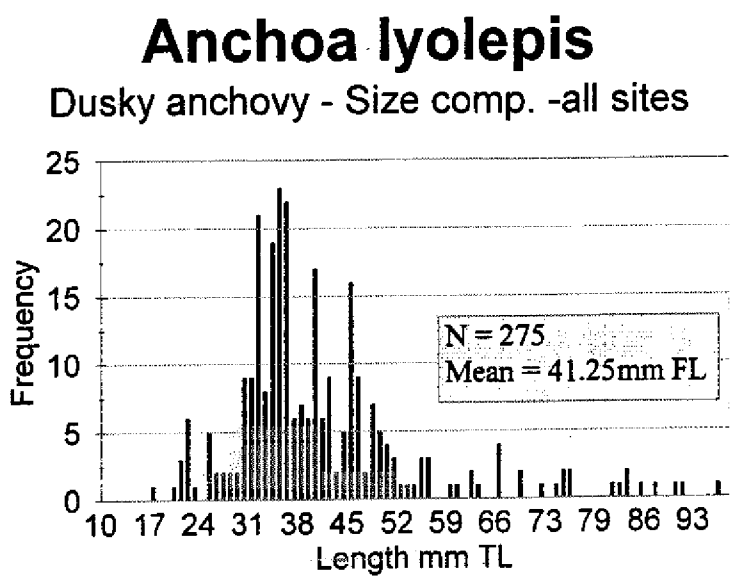


Figure 3. Size-frequency distribution for the dusky anchovy, *Anchoa lyolepis*, from all sites.

Similarity of Diversity Between Sites

Figure 6 shows the Jaccard's coefficient of Similarity for the sample sites. In summary, it appears that the most similar areas were Manatee bay and Galleon Harbour (eastern sites), while most of the western sites were very similar in diversity, with Carlisle Bay being most dissimilar to these westen sites.

Juveniles Versus Adults

A total of 68% of the 98 fishable species were found as juveniles, with only 7% as adults and 25% were a mix of juveniles with adults.

Spawning Areas

From the size of the juveniles caught, spawning probably occurs in deeper waters away from the areas sampled and that the habitats, such as the mangrove-seagrass complexes, are associated with spawning adult fishes. Note especially, that the muddy areas near Galleon Harbour and off Carlisle Bay and Macarry Bay had adult and juvenile marine commercial shrimp in numbers larger than elsewhere in this study. The previous section also shows that 93% of all the fishable species were found as juveniles or these mixed with adults.

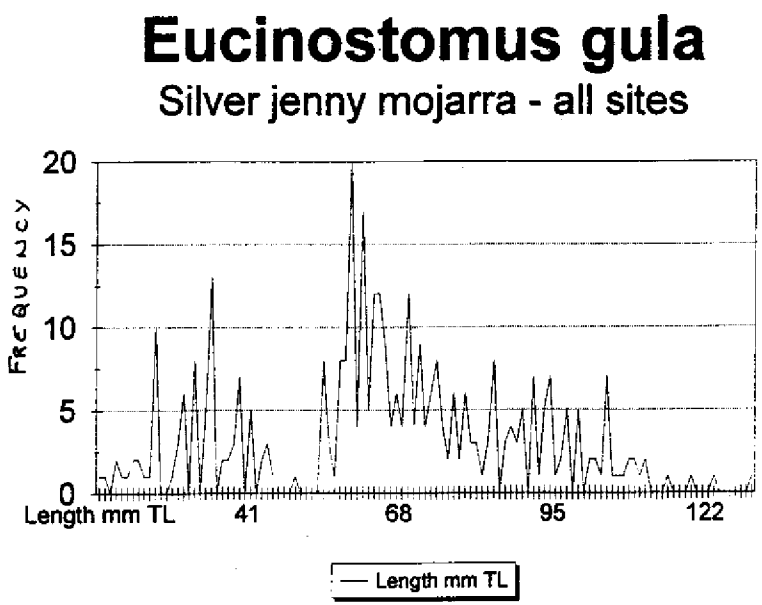


Figure 4. Size-frequency distribution for the silver jenny mojarra, *Eucinostomus gula*, at all sites.

Economic Importance of Fishable Resources

The economic importance was deduced from the following categories into which they may be placed:

i) Juveniles of commercial reef (pot fishery) finfish species,
ii) Juveniles of commercial crustacean (lobster) species (to be later caught in traps and by divers),
iii) Juveniles of marine shrimp species.
iv) Many abundant small pelagic fishes form the forage or prey species on which the commercial fishes thrive and without which they would have to move away and/or die.
v) There are socio-economic considerations. For instance, the large fisher communities, including the largest fish landing site in Jamaica at Old Harbour Bay with over 150 boats and 400 fishers and at least four other landing sites, all directly depend on the availability of fishable resources in and around Portland Bight.
vi) A large fish vending community directly depends on the success of fishers and the availablity of fishes.
vii) A large body of fresh fish product distributors and mobile retailers, directly depend on the fishers and vendors for their supply.

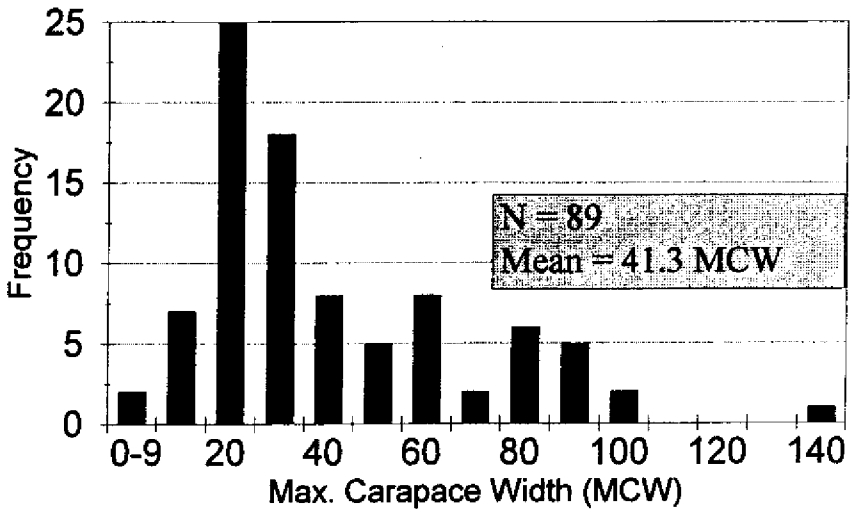


Figure 5. Size-frequency distribution of *Callinectes* spp. crabs from all sites.

Regarding fishes, of the ten most abundant families, eight are of prime commercial importance in their own right, with no less than 33 commercial species (or 29.6% of fish species). The major fish families in Portland Bight are represented in Figure 2. Four of the 10 families are of value to the trap pot) fishery, two to the seine and tangle net fisheries, and two to the hook-and-line fishery as bait. The two baitfish families (the anchovies and herrings) made up nearly 32% or about one third of all finfish species caught numerically.

We suggest that the demise of the fishable resources in Portland Bight will have serious consequences for persons residing in the geographic area, both of and surrounding, Portland Bight.

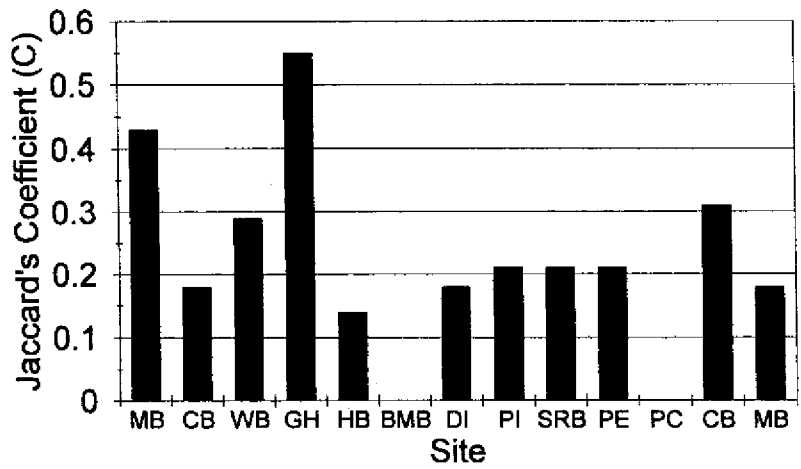


Figure 6. Jaccard's Coefficient of Similarity. Comparisons of fish species, divided by sampling site.

Existing and Potential Threats to Wetlands and Associated Ecosystems

The existing threats to wetlands as they applied to fishable resources, which were identified are as follows:

i) Dynamiting over coralline and seagrass habitats,
ii) Cutting of mangroves, and
iii) Waterborne pollution of rivers draining into Portland Bight and the Caribbean Coastal Area Management Foundation's management area.

Temporal Distribution of Species

Insufficient repeat sampling was done to allow this type of comparison but it showed that the following species could be repeatedly found in the same location up to one year later (see Table 4) At least 17 fishable species apparently repeatedly use the above sites as nurseries. There were another 10 species that were found only once.

DISCUSSION

The entire area can be considered a giant estuarine wetland complex. Such area are indispensable in the life cycles of many marine fishes and crustaceans (Salm and Clark 1987, Clark 1977, Geyer 1970, Nagelkerken 2000).

Community Structure (fishable resources)

Examination of the species list, the total numbers and weights of organisms, and the feeding guilds to which they belong, suggest that small, zooplanktivorous inshore or coastal pelagic fishes numerically dominated (three of 10 most abundant species or 39.7% of 10 numerically most abundant species). It is accepted that fishes may show ontogenetic differences in food utilisation, and of differences in food utilisation according to food availablity (Nagelkerken 2000).

Seagrass habitats yielded less fish and fewer species than expected. This may be due to disturbance of the fish fauna by the sampling boat (noise factor) and by the samplers who operated in relatively clear water and were easily observed by the fish. Normally, one would expect at similar sites and depths, an abundance of small scaridae (parrotfishes) and other young herbivores over seagrass in the shallows. Of note is the observation that normal high water clarity is probably a factor in the relatively low catches over seagrass. Thus, when occasional rough weather produced cloudy water, catches over such habitats were consistently higher.

Catches were numerically dominated by anchovies, sardines and herrings. Juvenile grunts measured from 21-35 mm TL only, though many eventually could attain 300 mm TL or more. This shows that the shallow mangrove-seagrass interface all around the Bight, serves as a nursery. We note that the presence of juveniles at all times during a 12 month period defines that area as a nursery.

The three small pelagic species are valued as baitfish by the hook-and-line fishery, while the others species comprise the fish trap (pot) and the chinese (tangle) seine net fisheries. All these fisheries take place in and around the Portland Bight management area.

Some 81% of finfish came from mangrove-seagrass habitats, and 19% from sandy substrate sites west of Portland Point. Most of the 89 finfish species were represented entirely by juveniles. The top five finfish species numerically were anchovies, mojarras, grunts and swimming crabs. The 10 most abundant fish species comprised 69.8% by number and 39.7% by weight of all catches. Three of these 10 species are important as baitfish and serve as forage fish for large commercial

carnivores such as snapper and groupers. The 10 most abundant finfish families comprised 87.1% by number of all finfish. Four of the eight crustacean species found are commercially important and included three types of marine shrimp (*Penaeus* spp.) and the spiny lobster (*Panulirus argus*). The most abundant crustacean captured in the study was the edible swimming crab species (*Callinectes* spp.). The two molluscan species were of commercial importance (conch and flat or false oyster). Densities of small juveniles and sub-adult fishes were significantly higher in mangrove-seagrass than over open sandy ground. Fishable resources were relatively more abundant and in eastern Portland Bight mangrove-seagrass than western habitats. Diversity was also higher in the eastern Bight. West of Portland Bight (past Portland Point) diversity was lowest.

In comparison, Robertson and Duke (1987) investigating mangrove and seagrass habitats in Australia, found 103 fish species in mangroves and another 20 species in seagrasses. The present study found 92 fish species, with 58% being commercial versus 18.6% commercial species of 102 species in Australian mangrove estuaries (Robertson and Duke 1987). The Australian study found distinct mangrove and seagrass fish and crustacean faunas, whereas the present study did not. Similar to the Australian study, we found post-larval, juvenile and small (sub-adult) fish in the mangrove habitat. Small crustaceans were significantly more abundant on the western edge of the management area (i.e. in the muddy parts of Carlisle and Macarry Bays) than in Portland Bight sites.

The mangrove-seagrass complexes in the western portions of Portland Bight had relatively less diversity than those on the eastern boundary (see Table 4). This was despite their outward near identical appearance with the same mangrove and seagrass species, and physico-chemical factors.

Of special note was the observation that nearly all the species collected west of Jackson's Bay were larger and heavier than their relatives in the Bight itself. This may be due to the roles of the large western complex of shallow coastal lagoons and the adjoining black mangrove (*Laguncularia racemosa*) forests immediately behind Carlisle and Macarry Bays, the presence of the Rio Minho river and the different type of substrate (muddy seafloor) there.

Galleon Harbour (eastern edge of Portland Bight), is the most important area both in terms of critical habitat and as a nursery area. We suggest there is a nutrient-supplying role and linkage between the wetlands of the Cockpit River and Browers River and the relatively rich fishable resources near the mouths of these small tidal creeks.

The vital roles, as put by Salm and Clark (1987) of the renewable resources of coastal lagoons and estuaries, such as those that dominate the ecology of Portland Bight, should not be overlooked. The total yield of Portland Bight fisheries was estimated by Cesar et al. (2000) at 1,088 tons in 1997 or a unit yield of 0.8 $t/km^2/yr^1$ This yield is approximately 7.7% of the annual national catch (14,000 tons in 1996). Further, they estimated that fishers could make US$6.8 million for whole Portland Bight Area at a mean price of US$2.8 /kg. Thus, the study area has quite valuable resources which need to be managed in a sustainable manner.

This short study of the fishable resources of Portland Bight is the first ever

conducted there and is only a preliminary assessment. The overall study (wetlands, socioeconomics, etc.) is an attempt to have a first look at this unique area of Jamaica which is part of the last remaining relatively undeveloped part of the central south coast, with the island's largest bay. It may also be the opportunity to protect some of Jamaica's valuable marine nurseries from the impacts of coastal development.

Any conclusions are necessarily preliminary. Manatee Bay and Coquar Bay, are previously known to serve as nursery grounds in the shallows near the centre of the bay, especially for rays (Ann Sutton, pers. comm. and pers. observ.). It appears that red mangroves and shallow nearshore seagrass beds shelter and nurture juvenile fishes and crustaceans. These juveniles and sub-adults dominated the fishable fauna here and at all sites sampled. Therefore, all of these shallow areas could function as fish and crustacean nurseries. Thus, bearing this in mind, Manatee Bay and Coquar Bays should be included in any plan for the sustainable development of the overall area.

MANAGEMENT RECOMMENDATIONS

Based on the foregoing, we suggested the there should be *area-specific and overall management recommendations.*

Based on their roles as nurseries and critical habitats, *protected areas/fish sanctuaries* should include:

i) Manatee and Coquar Bays and the adjoing mangrove lagoons behind the beach berms and also the seagreass beds offshore for distance of not less than 1.6 km
ii) Walker (Long) Bay and adjoining lagoon and seagrass beds (as in 1)
iii) Galleon Harbour and adjoining lagoon and seagrass beds (as in 1 above)
iv) Salt Island Creek for its entire length be protected
v) The Goat Islands and its inextricable linkage with the Galleon Harbour habitats also be included (note that Big and Little Goat Islands have now merged due to the sediment-accretion role of the mangroves over approximately 20 years since the printing of the Survey Departments 1:250,000 Jamaica topographic chart for 1977).
vi) Inner West Harbour mangroves (nursery roles and potential touristic value)

Since the time of this study, the above areas have been made protected areas (CCAM 1998). These area are policed by the fishers groups in the area who are memebers of the Portland Bight Fishers Management Council (PBFMC).

Since this study, the Caribbean Coastal Area Management Foundation has made several of these areas fish sanctuaries (Figure 7) within the Portland Bight Sustainable Devoplment Area (CCAM 1998)

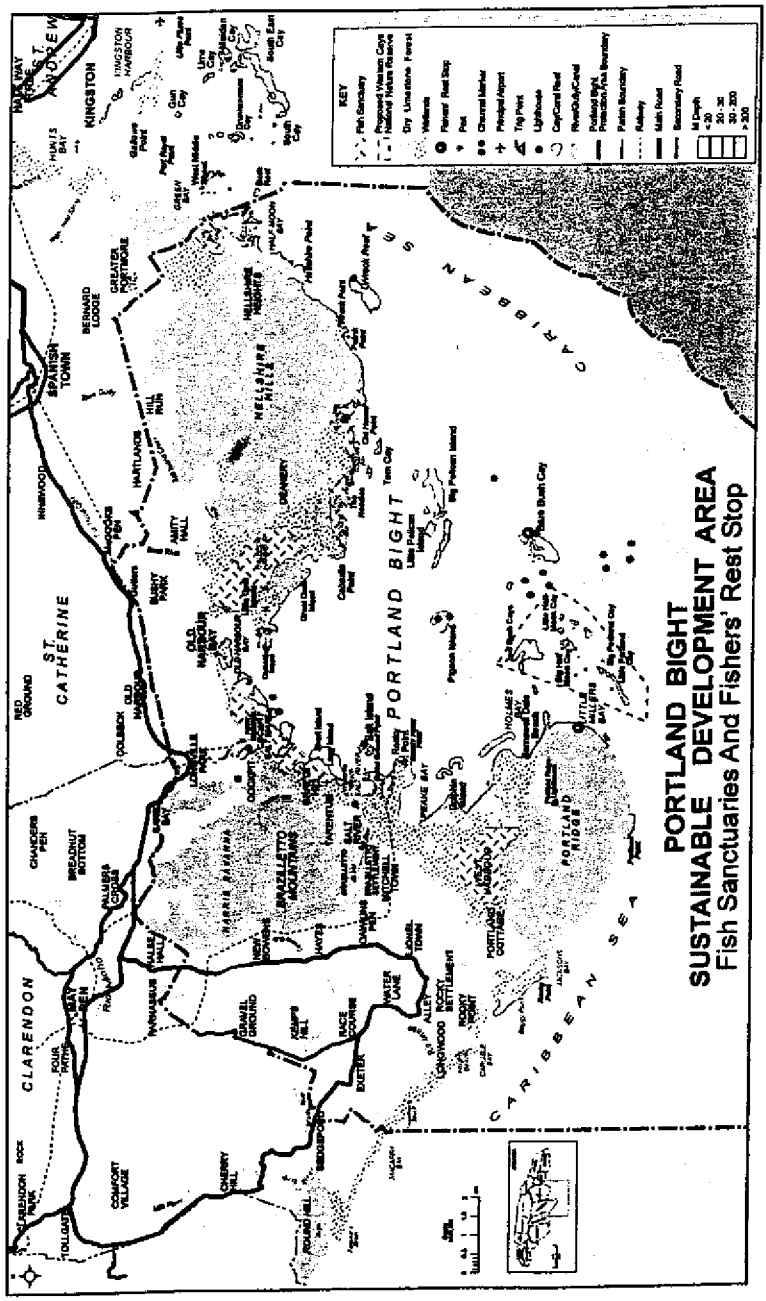


Figure 7. Portland Bight Sustainable Development Area: Fish Sancturaries and Fisher's Rest Stop

FUTURE RESEARCH

The present study examined only the shallow edges of the bay to only 2 m depth. This omitted, for various reasons, the middle and deeper parts of the Bight as well as the coral reef areas near the mouth of the Bay. Also, we recommend that the virtually unknown large coastal lagoons behind Carlisle Bay and Macarry Bay, in partitcular, be closely studied with regard to their role as fish nurseries and/or critical habitats. A first economic valuation of the entire area of Portland Bight is put at over US$52 million dollars (Cesar et al. 2000), and thus, sustainable management of the fisheries resources will contribute to the maintenance and enhancement of this value.

ACKNOWLEDGEMENTS

Fishers from Old Harbour Bay, St. Catherine, and Salt River, Portland Cottage and Rocky Point, Clarendon, gave assistance. Dr. Ann Sutton assisted in preliminary planning tours, provided maps and charts, amd much useful advice. Some of these data were first published by the South Coast Conservation Foundation (Aiken, 1998).

LITERATURE CITED

Aiken, K.A. 1996. Proposal for the investigation of the role of portions of the South Coast Conservation Foundation (SCCF) Management Area, as fish nurseries. South Coast Conservation Foundation. Kingston, Jamaica. 4 pp.

Aiken, K.A. 1998. Report on survey of fishable resources of Portland Bight and adjacent areas. South Coast Conservation Foundation. Kingston, Jamaica. 51 pp.

Austin, H.M. 1971. A study of the ichthyofauna of the mangroves of western Puerto Rico during December, 1967-August, 1968. *Caribbean Journal of Science* **11**:27-39.

Blaber, S.J.M. 1980. Fish of the Trinity Inlet System of North Queensland with notes on the ecology of tropical Indo-Pacific estuaries. *Australian Journal of Marine and Freshwater Research* **31**:137-146.

Boesch, D.F.and R.E.Turner. 1984. Dependency of fishery species on salt marshes: the role of food and refuge. *Estuaries* 7:460-468.

Caribbean Coastal Area Management (CCAM) Foundation. 1998. Portland Bight sustainable development area, Jamaica, Management Plan 1998-2003. Kingston, Jamaica. 129pp.

Cesar, H.S.J., M.C. Ohman, P. Espeut, and M. Honkanen. 2000. An economic valuation of Portland Bight, Jamaica: An integrated terrestrial and marine protected area. Vrije Universitiet, Inst. for Envir. Studies, Amsterdam. 36pp.

Clark, J.L. 1977. *Coastal Ecosystem Management: A Technical Manual for the Conservation of Coastal Zone Resources.* John Wiley & Sons. New York, New York USA. 928 pp.

Colinvaux, P. 1986. *Ecology.* Wiley & Sons. New York, New York, USA. 725pp

Geyer, R.A. 1970. The multi-user zone of the Gulf of Mexico: Its promise and problems. *Water Research Bulletin* **6(4).**

Lethbridge, J., G. Harvey, and D. Carter. 1996. *A Yachtsman's Guide to Jamaica.* Zone Publishing. Kingston, Jamaica. 176 pp.

Lindall, W.N., J.R. Hall, W.A. Fable, and L.A. Collins. 1973. *A Survey of Fishes and Commercial Invertebrates of the Shore and Estuarine Zone Between Cape Romano and Cape Sable, Florida.* (PB-235 215 NTIS) National Marine Fisheries Service, US Dept. of Commerce. 62 pp.

Nagelkerken, I. 2000. *Importance of Shallow-water Bay Biotopes as Nurseries for Caribbean Reef Fishes.* PhD dissertation, Univ. of Nijmegen, The Netherlands. 168 pp.

Odum, W.R. and E.J. Heald. 1975. The detritus-based food web of an estuarine mangrove community. Pages 265-286 in: L.E. Cronin. (ed.) *Estuarine Research.* Academic Press, Inc. New York, New York USA.

Salm, R.V. and J.R. Clark. 1987. Marine and protected areas: a guide for planners and managers. IUCN, Gland, Switzerland. 302 pp.

Survey Department. 1977. *Topographic Chart of Jamaica, 1:250,000.* Survey & Lands Department, Charles St., Kingston, Jamaica.

Sutton, A. 1996. Map of Portland Bight. South Coast Conservation Foundation. Kingston, Jamaica.

Perspectives de Développement de la Pêche Associée aux DCP Ancrés dans la Caraïbe

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ABSTRACT

Le DCP (Dispositif de Concentration de Poissons) ancré est un moyen pour les pêcheurs artisans côtiers d'exploiter les ressources pélagiques du large généralement peu accessibles aux embarcations à faible rayon d'action.

Les principales difficultés rencontrées pour le développement de la pêche à l'aide de DCP ont pu être identifiées. Elles portent sur la conception des DCP, leur localisation ainsi que sur leur mode de gestion et d'exploitation. Au cours de la phase initiale du développement des DCP, des difficultés particulières sont mentionnées : détériorations volontaires des dispositifs, mévente des prises, ...

L'exploitation des DCP dans la région peut être optimisée. L'effet de la densité des DCP et de leur localisation (profondeur, distance à la côte, ...), sur les concentrations de poissons ou sur les prises des professionnels, n'est pas connu. L'impact environnemental des DCP est encore mal apprécié.

L'objectif de cette présentation est de proposer la mise en place d'un groupe de travail destiné à faciliter les échanges de données et la coordination de programmes de recherche entre pays.

MOTS CLÉS : DCP, Pélagique, Caraïbe

Prospects for the Development of Fishing with Anchored Fads in the Caribbean

Deployment of anchored FADs has opened large pelagic resources to small-scale fisheries, which usually operate nearshore. The main difficulties in using FADs for fishing have now been identified. It concerns principally the design of FADs, their location, and also the type of management and exploitation. During the initial phase of FAD development, particular problems are mentioned, namely voluntary deterioration of the devices, marketing of the catches...

FADs exploitation in the area can still be optimised. The impact of FADs

densities and locations (depth, distance from shore) on the concentration of fish resources or on fishery production is not established. Environmental impact of FADs is not well evaluated either.

We would like to implement a workshop to facilitate data exchanges and coordination of research programs between nearby countries.

KEY WORDS: FAD, Pelagic, Caribbean

INTRODUCTION

De nombreuses tentatives de développement de la pêche des grands poissons pélagiques ont été faites dans la région Caraïbe depuis les années 1960. Des campagnes de prospections ont mis en évidence la faible abondance apparente des grands poissons pélagiques dans le secteur des petites Antilles. Les concentrations observées sont constituées de petits groupes agrégés autour d'épaves à la dérive, laissant peu d'espoir quant aux possibilités de développer l'exploitation de ces ressources à partir des techniques traditionnelles (Farrugio et al. 1988).

Parmi les moyens retenus pour développer la pêche sur ces ressources du large, figure le DCP ancré (Dispositif de Concentration de Poissons). Les expérimentations les plus anciennes de DCP dans la région caraïbe ont été faites dans le cadre du projet de développement de la pêche caribéenne PNUD/FAO entre 1965 et 1971 (Wolf et Rathjen 1974). Douze radeaux de bambou ont été ancrés à proximité de Curaçao, Bonaire, Barbade et Anguilla, entre février 1968 et juin 1971. La plus grande partie des DCP a été perdue peu de temps après leur mise à l'eau. Il avait été conclu, à l'issue de ces essais, que les DCP ne constituaient pas un réel potentiel pour la pêche.

En 1983, au 36eme congrès du GCFI (Gulf and Caribbean Fisheries Institute) réuni à Trinidad, les participants des pays de la Caraïbe Est ont demandé une assistance pour développer les DCP ancrés dans la région. Leur demande était fondée sur le fait que la région était importatrice de produits de la mer et que la demande, tant de la population locale que de l'industrie du tourisme, allait en augmentant. Par ailleurs, les ressources des plateaux étaient jugées fortement exploitées. Les ressources pélagiques paraissaient être les seules à offrir un potentiel suffisant pour augmenter les débarquements des petits pays insulaires et réduire le déficit de leurs échanges extérieurs. Une première opération pilote a été réalisée à St Kitts. Les objectifs étaient d'évaluer l'utilité des DCP pour l'amélioration des pêcheries artisanales de la région, d'adapter et de développer des mouillages appropriés et d'apporter une assistance technique aux utilisateurs de DCP de la région (McIntosh 1984).

Depuis, la volonté de développer la pêche des poissons pélagiques du large, à l'aide des DCP, est manifeste dans pratiquement toutes les îles de la Caraïbe. De nombreuses expérimentations ont été réalisées sur des périodes plus ou moins longues, pendant plus de 30 ans. Les DCP expérimentés ont été souvent mouillés

près de la côte, par des fonds peu importants et de ce fait ne concentraient que les petits pélagiques côtiers ou les espèces rencontrées sur le plateau insulaire. La technique de pêche mise en œuvre pour évaluer l'effet des DCP sur les prises des professionnels était pratiquement toujours la ligne de traîne. Les prises autour des DCP étaient données pour supérieures à celles des pêches effectuées sans dispositif. Au cours des expérimentations, la durée de vie des DCP était généralement un objet de préoccupation et conditionnait parfois leur emplacement. Les conclusions des études présentaient invariablement les DCP comme un moyen intéressant de développer la pêche professionnelle côtière et la pêche de loisir.

Mais, malgré ces résultats encourageants, la pêche des grands poissons pélagiques ne s'est pas développée comme espéré. Si la production totale de grands poissons pélagiques capturés dans l'Atlantique Centre Ouest a progressé depuis les années 1950 (elle est passée de 20 000 t à près de 100 000 t dans les années 1990), ce sont essentiellement les pêcheries continentales qui sont à l'origine de cette augmentation (Figure 1). Les grandes et petites Antilles ont vu leurs prises à partir de la zone progresser très faiblement en près de 50 ans (Reynal et al. 2000).

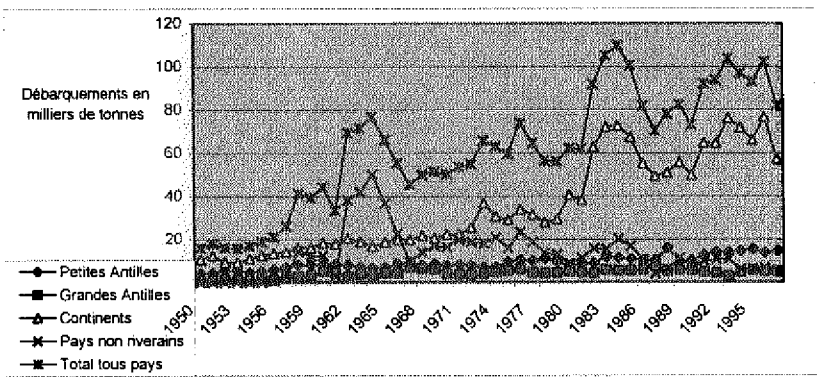


Figure 1. Evolution des débarquements de poissons pélagiques hauturiers de l'Atlantique Centre Ouest

LE DÉVELOPPEMENT DES DCP ANCRÉS AUX ANTILLES FRANÇAISES

C'est à la suite d'une évaluation des pêcheries qu'il a été décidé de déployer l'activité de pêche sur les ressources du large. En effet, plus de 60 % des sorties de pêche se faisaient sur le plateau insulaire et les ressources benthiques et démersales donnaient des signes de forte exploitation. Les revenus relativement faibles des

professionnels et la forte mobilité des équipages, bien souvent non-inscrits auprès de l'Administration, rendaient difficile une mise en adéquation de l'effort de pêche avec les ressources exploitées. La demande importante en produit de la mer du marché intérieur (environ trois fois la production locale) et la progression du chômage entraînant un repli vers la pêche, contribuaient à aggraver la situation des ressources côtières. La recherche de voies de diversification a été entreprise sur les ressources peu ou pas exploitées, accessibles aux pêcheurs (ressources profondes, bancs du Nord de la Guadeloupe ...). C'est en priorité sur les ressources de grands poissons pélagiques hauturiers qu'il a été choisi de redéployer la pêche.

Atouts des Ressources de Grands Poissons Pélagiques Hauturiers

Les grands poissons pélagiques hauturiers sont des espèces à aire de répartition très large. Ils sont faiblement exploités par les Antilles françaises dont les marchés et la capacité des flottilles sont à priori relativement faibles au regard de l'importance des stocks. Ces espèces trouvent facilement leur place sur les marchés locaux qui sont très demandeurs en produits frais et tout particulièrement en poissons. De plus, leur exploitation se développe naturellement en raison des revenus jugés intéressants par les professionnels. A la période de pêche des pélagiques (décembre à juin), le nombre de pêcheurs passe de 2100 à 3800 (Failler 1996).

Mais, la pêche traditionnelle des grands poissons pélagiques est essentiellement une pêche de surface qui nécessite de parcourir de grandes distances (les pêcheurs vont parfois à plus de 60 milles des côtes) à la recherche de bancs de poissons en déplacement ou de concentrations se formant sur des bois dérivants. La flottille de pêche évolue vers une motorisation de plus en plus importante des embarcations dont les dimensions augmentent, afin de parcourir des distances plus grandes au cours de la journée. Il en résulte une consommation croissante de carburant qui représente plus de 30 % du chiffre d'affaires des entreprises (Daniel 1995).

Quant aux techniques traditionnelles de pêche des Antilles françaises (lignes de traîne de surface), elles ne peuvent certainement pas accéder à toutes les ressources présentes dans les eaux de la région. La profondeur insuffisante des engins, la saison et les heures de pêche (de jour) ainsi que les lieux fréquentés par les pêcheurs (exclusivement la façade atlantique), laissent supposer que toutes les ressources en poissons pélagiques hauturiers autour de ces îles ne sont pas pleinement exploitées.

Ces observations laissent espérer des possibilités de développement de la pêche des grands poissons pélagiques à proximité de la Guadeloupe et de la Martinique, à partir de petites unités faisant des sorties à la journée. A priori, un tel développement ne constitue pas une menace pour les ressources ciblées, compte tenu des faibles prises réalisées par ces unités et de l'importance relativement faible des marchés locaux au regard de celle des stocks. Toutefois, un suivi du développement reste indispensable car il n'est pas possible de prévoir les espèces et les quantités qui seront réellement capturées par une nouvelle activité de pêche.

Atouts des DCP Ancrés

Plusieurs techniques ont été testées pour favoriser la pêche des poissons pélagiques hauturiers, mais c'est le DCP ancré qui paraît présenter le plus d'atouts pour favoriser le redéploiement de l'activité sur les ressources du large, dans le contexte antillais. En effet, le DCP devrait présenter a priori les avantages suivants :

i) il est facilement transférable car il ne nécessite pas de changement d'outil de production (l'exploitation des DCP peut se faire à l'aide des mêmes embarcations et techniques de pêche que celles utilisées traditionnellement)
ii) il facilite le passage des professionnels, de l'exploitation du plateau insulaire à celle des poissons pélagiques en rendant ceux-ci plus accessibles et les prises moins aléatoires
iii) il évite l'extension des zones de pêche en particulier dans les ZEE (Zones Economiques Exclusives) des pays voisins
iv) il permet l'exploitation de nouvelles espèces non rentables jusqu'ici car insuffisamment concentrées et rend la pêche des pélagiques moins saisonnière
v) il est probable qu'il entraîne une réduction de la consommation de carburant et de la puissance motrice
vi) il devrait permettre d'augmenter les revenus des pêcheurs

Difficultés Rencontrées pour le Développement des DCP Ancrés

Au cours des différentes expérimentations de DCP réalisées aux Antilles françaises, plusieurs difficultés ont dû être surmontées avant que les dispositifs ne puissent faire partie intégrante de la pêche.

La Réaction des Pêcheurs Face à ce Nouvel Équipement — A la suite des premières mises à l'eau de DCP, se sont développés des conflits se traduisant par la détérioration volontaire du matériel. Ces conflits ont été le fait de certains pêcheurs qui se sont appropriés la zone de pêche autour du dispositif, parce qu'ils l'avaient acheté (dispositif privé) ou simplement entretenu (dispositif financé sur fond public). Dans ce cas, les pêcheurs considèrent que leur investissement leur donne le droit d'imposer des conditions d'accès ou d'exploitation. Dans d'autres cas, des pratiques de pêche incompatibles entre elles ont pu générer des conflits.

Il est par conséquent important de définir dès le début les conditions d'accès à la ressource située à proximité des DCP (qui a le droit de pêcher autour des DCP et quand ?) ainsi que les modes d'exploitation (engins autorisés, mise en œuvre). La zone d'influence des DCP n'étant pas connue, la réglementation de la pêche autour des DCP ne peut se faire pour l'instant que sur un espace défini arbitrairement (rayon de ½ ou 1 mille) autour de la bouée.

La Définition d'un Mode de Gestion des DCP — Afin de régler les conflits, il est nécessaire de définir au préalable le mode de gestion des DCP. Plusieurs modes de gestion existent aux Antilles françaises : des DCP privés sont utilisés en Guadeloupe, des dispositifs gérés collectivement par les professionnels sont imposés en Martinique. Il faut noter qu'à Curaçao les DCP sont la propriété du gouvernement et qu'ils sont entretenus par le Département de l'Agriculture et des Pêches (Dienst L.V.V.), (Reynal et al. 2000). Il n'y a *a priori* pas de système qui ne soit opérationnel parmi ceux développés dans la région. Selon le mode de gestion adopté, l'accès aux DCP est autorisé à des groupes sociaux différents. Il va de soi que si les DCP sont gérés par des professionnels ceux-ci n'accepteront pas que des plaisanciers les exploitent. Actuellement, les avantages et inconvénients des divers modes de gestion des DCP au cours des étapes successives du développement ou sur les résultats de la pêche sont mal connus.

La Localisation des DCP — En Martinique, au cours des premiers programmes d'expérimentation de DCP, la localisation de ceux-ci a été faite en premier lieu en fonction des passages connus de pélagiques, c'est à dire du côté atlantique. Ils étaient alors placés là où les professionnels pratiquaient déjà une pêche rentable de surface et ne les utilisaient que ponctuellement. Bien que de nombreuses expérimentations aient été menées sur cette façade de l'île, c'est d'abord du côté caraïbe que les DCP se sont développés alors que la pêche des grands poissons pélagiques y était pratiquement inexistante.

L'effet de la distance à la côte ou de la profondeur d'implantation des DCP sur les résultats de la pêche a dû également être abordé compte tenu des différences de rendements constatées entre les DCP. Mais aucune différence statistiquement significative n'a été mise en évidence à partir des données recueillies jusqu'ici. Il est cependant vraisemblable qu'il y ait une interaction entre DCP relativement proches de la côte et pêche côtière de pélagiques (bonites), car les pêcheurs à la senne se sont plaints d'une diminution de leur rendement lorsque les DCP ont été implantés. Il est probable également que les DCP les plus proches de la côte concentrent plus de juvéniles de certaines espèces que ceux placés plus au large.

Le positionnement des DCP peut également avoir de l'importance dans la gestion de certains conflits. Il semble en effet que, placés près de côte, ils génèrent plus de conflits du fait de la concentration des activités dans cette zone que lorsqu'ils sont plus éloignés. En Guadeloupe, les pêcheurs placent fréquemment des DCP à 40 ou 50 milles des côtes.

La Conception des DCP — Une des premières préoccupations a été de savoir comment monter les DCP. De nombreux modèles de DCP existent à travers le monde. Aux Antilles françaises, ils sont conçus de façon différente selon qu'ils soient privés ou financés sur des fonds publics. Les premiers sont de conception plus simple et de coût inférieur au second. Les études comparatives sur les coûts et la durée de vie des DCP sont encore insuffisantes pour qu'il soit possible de préconiser un ou quelques types de DCP. Toutefois, des avancées technologiques ont été faites

et ont permis d'identifier les principales causes de rupture des DCP et de formuler certaines recommandations pour leur fabrication, leur maintenance et leur protection (Guillou et al. 2000). Des modèles ont été élaborés pour décrire le comportement des DCP en fonction des mouvements de la mer. Mais leur usage reste limité en raison du manque de données sur les houles et les courants. De même, les caractéristiques du concentrateur sont très variables d'un DCP à l'autre. Les facteurs favorisant la concentration des poissons n'étant pas connus, il n'est actuellement pas possible de faire des recommandations sur le concentrateur à utiliser. L'utilité des concentrateurs n'est d'ailleurs pas prouvée ; il est possible que le cordage suffise à provoquer une concentration de poissons.

L'exploitation des DCP — La technique traditionnelle de pêche la plus répandue dans la région est la ligne de traîne. Celle-ci ne permet la prise que de poissons, en général juvéniles, se trouvant à proximité de la surface ; or les concentrations se trouvent également en profondeur. Aux Antilles françaises, l'engouement pour les DCP n'est apparu que lorsque les professionnels ont maîtrisé la technique de la pêche « au bidon ». Celle-ci consiste à appâter à l'aide de bonites vivantes une ligne verticale de 80 à 150 m environ mise en dérive autour des DCP. Grâce à cette technique, ce sont les gros poissons localisés préférentiellement en profondeur qui sont capturés : albacore adulte (*Thunnus albacares*), marlin bleu (*Makaira nigricans*). Il est donc indispensable de réaliser simultanément le transfert des DCP et celui de techniques de pêche « profonde » pour exploiter les concentrations autour des dispositifs.

La Commercialisation des Prises — Les pêcheurs se plaignent souvent de difficultés de commercialisation de leurs produits en particulier lors de la phase de démarrage des DCP. Cela tient à l'étroitesse des marchés insulaires d'une part, et à l'arrivée d'espèces nouvelles, en quantités parfois importantes, d'autre part. C'est le cas par exemple du marlin bleu qui était peu connu des consommateurs et qui en peu de temps est devenu une espèce commune. Le prix de vente de ces "nouvelles" espèces est relativement bas au début, puis augmente au fur et à mesure qu'elles se font connaître. La difficulté de conservation de tels produits, du fait de leur taille et du manque d'équipement frigorifique des pêcheurs, pénalise leur commercialisation.

Exploitation Actuelle des DCP Ancrés aux Antilles Françaises

Les DCP sont maintenant utilisés toute l'année par les pêcheurs de Guadeloupe et Martinique. Dans les deux îles, les techniques mises en œuvre sont les mêmes ; il s'agit principalement de lignes de traîne et de pêche « au bidon ».

La durée moyenne des sorties de pêche est de 7h14 en Guadeloupe (Lagin et Ledouble 1994), alors qu'en Martinique les sorties ne duraient en moyenne que 5h40 en 1999 . Cette différence entre les deux îles s'explique par le fait qu'en Martinique les DCP sont moins nombreux et plus près de la côte que dans l'île sœur. En contre partie, deux sorties peuvent être faites le même jour en Martinique. Alors que du

côté caraïbe, les sorties se font exclusivement sur DCP, sur la côte atlantique de la Martinique, des sorties mixtes (pêche sous et hors DCP) étaient d'abord pratiquées (Guillou et al. 1995). Actuellement, certains pêcheurs de la côte atlantique ne pêchent que sur DCP.

En Martinique, une comparaison a pu être faite, en 1999, entre la pêche traditionnelle des grands pélagiques et la pêche sous DCP. Si l'effectif moyen embarqué est le même (1,8 hommes par sortie), la consommation de carburant est deux fois moindre pour la pêche sous DCP (70 l par sortie au lieu de 140 l). Cette différence de consommation de carburant est due à la puissance motrice moindre des unités qui pratiquent la pêche sous DCP (91 ch au lieu de 117 ch), à la durée moyenne des sorties inférieure (5h30 pour la pêche sous DCP au lieu de 8h59) et à la vitesse moyenne plus élevée en pêche traditionnelle.

Les débarquements moyens par sortie sont plus faibles pour la pêche sous DCP que pour la pêche traditionnelle: 26,7 kg par sortie dans le premier cas, contre 59 kg par sortie pour le second. Cependant, la pêche sous DCP se pratique toute l'année alors que la pêche traditionnelle ne dure que de décembre à juin. Pendant cette période, les débarquements de la pêche autour de DCP ont été de 36 kg par sortie (Reynal et al. 2000).

La composition spécifique des prises sous DCP diffère de celle des prises de la pêche traditionnelle. Sous DCP, ce sont les thons noirs (*Thunnus atlanticus*) qui dominent (29 % du poids total débarqué), puis les albacores (27 %) et les marlins bleus avec 24 %. Dans les prises de la pêche traditionnelle, c'est la daurade coryphène (*Coryphaena hippurus*) qui constitue la part la plus importante (53 % du poids débarqué); viennent ensuite le thazard bâtard (*Acanthocybium solandri*) (28 %) et l'albacore (10 %). Les thons noirs ne représentent que 5 % en poids des captures de la pêche traditionnelle (Laurans *et al.*, 2000).

En Guadeloupe, des échantillonnages de débarquements ont été réalisés pendant quelques années. En 1992, les rendements moyens annuels ont été de 30 kg par sortie. Ils ont augmenté progressivement pour atteindre 43 kg en 1995. Dans le même temps, les rendements horaires sont passés de 6 kg en moyenne sur l'année 1992 à plus de 9 kg pour l'année 1995. La proportion des poissons porte-épée est passée de 30 % des débarquements en 1992 et 1993 à 38 % en 1994 et 50 % en 1995 (Le Guen et al. 1996). L'augmentation des captures d'une année sur l'autre, est donc fortement liée au développement des prises profondes de poissons de grandes tailles.

Les rendements moyens mensuels observés à partir des données recueillies sur la pêche associée aux DCP aux Antilles françaises montrent une saisonnalité des captures. Les rendements les plus faibles sont observés de juin à août et les chiffres les plus élevés de septembre à novembre. Ce sont essentiellement les petits thonidés qui sont capturés pendant la morte saison et les espèces de grandes tailles comme les poissons porte-épée ou les gros albacores qui constituent les prises des mois où les rendements sont les plus élevés. Cette saisonnalité des rendements résultent de la saisonnalité des migrations des espèces mais également du rythme des courants qui immergent fréquemment les DCP entre avril et juillet. La dorade coryphène est

surtout abondante entre mars et juin (maximum en mai) (Reynal et al. 2000).

Il faut noter que les prises sous DCP sont constituées de nombreux juvéniles de certaines espèces qui sont pour partie utilisés comme appât pour la pêche « au bidon ». Ces juvéniles sont pêchés en surface à la ligne de traîne. Leur proportion en nombre d'individus dans les captures est élevée pour les espèces comme le thon noir et l'albacore (supérieure à 70%). A l'inverse, ces juvéniles ne représentent qu'une faible part en poids des quantités débarquées (inférieure à 30%) (Laurans et al. 2000).

PERSPECTIVES DE DÉVELOPPEMENT DES DCP ANCRÉS DANS LA CARAÏBE ET NÉCESSAIRE ORGANISATION RÉGIONALE DE LA RECHERCHE

Les DCP ancrés constituent une alternative au développement de la pêche industrielle pour l'exploitation des poissons pélagiques hauturiers. L'expérience acquise et les résultats obtenus aux Antilles françaises montrent que les DCP constituent une solution techniquement et économiquement viable, pour permettre à la pêche artisanale côtière de mieux profiter des ressources de grands poissons pélagiques du large. Les difficultés rencontrées au cours des programmes de développement des DCP sont maintenant connues et ont été en grande partie surmontées. Des données existent également pour apprécier les retombées du développement de la pêche associée aux DCP.

Les Perspectives de Développement des DCP Ancrés

Le potentiel offert par les DCP ancrés n'est pas encore valorisé de façon optimale et leur exploitation peut être améliorée. Pour cela, il conviendrait de poursuivre les travaux de recherche notamment dans les trois domaines présentés ci-dessous.

L'amélioration de la Conception, de L'exploitation et de la Gestion des DCP Ancrés — Sur le plan technologique, des progrès restent à réaliser pour améliorer la tenue en mer des DCP et diminuer leur coût. L'effet des concentrateurs et leurs caractéristiques restent également à préciser. Si les poissons pélagiques de surface ne sont plus visibles ni exploités lorsque les DCP coulent à cause des courants ou sont coupés, le comportement des poissons en profondeur est encore inconnu. C'est en effet à partir des appâts constitués des poissons de surface que se font les pêches des individus en profondeur. Or, s'ils continuaient à agréger les poissons en profondeur, ces DCP ou restes de dispositifs permettraient, moyennant un changement de technique de pêche, d'éviter des interruptions d'exploitation pénalisantes pour les professionnels.

Les concentrations se formant à différentes profondeurs autour des DCP ne sont pas toutes valorisées et les juvéniles sont trop exploités. Des pêches expérimentales réalisées autour des DCP ont par exemple montré la présence d'espadon, de thon

noir adulte ou de thon obèse (*Thunnus obesus*) qui sont actuellement peu ou pas exploités par les professionnels (Taquet et al. 1998 et 2000 a). Une meilleure connaissance de la localisation spatio-temporelle des espèces et concentrations autour des DCP serait nécessaire à une exploitation plus rationnelle des ressources. La recherche de techniques de pêche sélectives est à poursuivre afin de préserver les juvéniles (Taquet et al. 2000 b).

Actuellement, la localisation, la densité et le taux d'exploitation optimale des DCP sont inconnus et les méthodes pour les évaluer n'existent pas. Une compréhension des mécanismes de l'agrégation des pélagiques sera probablement nécessaire pour parvenir à apporter des réponses à ces questions. Des suivis statistiques précis des pêcheries en fonction de la position des DCP et de leur nombre pourraient également contribuer à faire progresser les connaissances dans ce domaine.

La Gestion des Ressources — Comme toute forme d'exploitation des ressources halieutiques, la pérennisation de la pêche autour des DCP tient en grande partie à la capacité des stocks exploités à supporter cette nouvelle activité. Un suivi du niveau d'exploitation des ressources est d'autant plus nécessaire que les DCP accroissent la vulnérabilité de certaines espèces et par conséquent leur capture. Des statistiques de production et d'effort doivent donc être élaborées et la connaissance de la biologie des espèces affinée.

La connaissance des migrations et des facteurs qui les influencent à l'échelle régionale est nécessaire pour expliquer la variabilité inter-annuelle des débarquements de certaines espèces et identifier les pêcheries séquentielles.

L'évaluation de L'impact des DCP Ancrés — L'impact des DCP ancrés sur les ressources peut aller au-delà d'une augmentation de la vulnérabilité de certaines espèces. Lorsque leur nombre est élevé, les DCP pourraient entraver la migration de certaines espèces. Aucune preuve de l'existence d'un tel phénomène n'a été apportée jusqu'ici, mais il convient de s'en assurer par des recherches appropriées.

Les DCP ancrés peuvent favoriser un redéploiement de l'activité de pêche et ainsi soulager les ressources côtières fortement sollicitées par les populations du littoral. Une telle démarche a été proposée pour les pays insulaires de la Caraïbe. Mais il convient de garder à l'esprit que ce redéploiement peut s'opérer de façon différente d'un pays à l'autre et qu'il est nécessaire d'en assurer le suivi de façon à évaluer l'impact des mesures mises en œuvre.

L'impact social et économique des DCP ancrés a été peu examiné jusqu'ici. L'effet du développement d'une telle pêche sur les revenus des pêcheurs et sur l'emploi constitue une préoccupation des aménageurs.

L'impact des différents modes de gestion sur les étapes successives du développement des DCP mériterait d'être évalué et des études comparatives effectuées. Les premiers résultats obtenus en Guadeloupe et en Martinique montrent déjà des différences significatives entre les deux îles (tableau 1), tant au niveau de la rapidité du développement des DCP que de la maîtrise de celui-ci ou des

rendements des professionnels.

La Nécessaire Organisation Régionale de la Recherche

L'enjeu de la recherche actuelle est de répondre aux nouvelles questions posées par le développement des DCP. Ces questions sont l'objet des préoccupations de nombreuses équipes qui se sont réunies en 1999 en Martinique lors du colloque "Pêche thonière et DCP". A l'évidence, les DCP ancrés sont considérés dans beaucoup de régions du monde comme un outil de développement des pêches artisanales. Ils constituent une alternative à l'exploitation des ressources côtières. Leur développement paraît inéluctable notamment dans les pays insulaires où l'absence de pêche industrielle limite l'accès aux ressources du large.

Dans la région Caraïbe, les DCP ancrés se développent également, en raison de leur succès avéré et de la réponse qu'ils apportent à un besoin exprimé par de nombreux pays, depuis plusieurs décennies. Cependant, la recherche doit s'organiser pour accompagner ce développement et pouvoir répondre aux nombreuses questions posées. La connaissance des migrations ou de la biologie des espèces exploitées nécessite une approche régionale qui passe par la création d'un groupe de travail scientifique. De même la compréhension et l'évaluation des interactions entre les pêcheries régionales, dans un souci de partage équitable des ressources communes de pélagiques, nécessitent une organisation régionale de la collecte et des échanges de données statistiques. D'une manière générale, les échanges d'expériences et la confrontation des idées ne peut que contribuer à faciliter et harmoniser le développement de la pêche des pélagiques dans la Caraïbe et prévenir les risques de conflits.

Il est donc nécessaire de mettre en place un groupe de travail pour accompagner le développement des DCP ancrés. Son premier objectif doit être d'apporter un soutien scientifique pour le suivi des pêcheries. La normalisation de la collecte des données nécessaires aux évaluations des ressources ciblées et des impacts du développement des DCP, doit être rapidement entreprise. Cette normalisation doit prendre en compte les besoins des groupes de travail déjà constitués à un autre niveau, comme l'ICCAT (Commission Internationale pour la Conservation des Thonidés de l'Atlantique) pour la gestion des ressources de certaines espèces à l'échelle de l'Atlantique. L'élaboration d'outils pour la saisie et le traitement de ces données et la formation de personnels à leur utilisation, sont également à réaliser de façon à faciliter la mise en œuvre des recommandations qui seront faites.

C'est en priorité au niveau des petites Antilles qu'il conviendrait de mettre en place un tel groupe de travail, car c'est dans ces îles que les DCP ancrés se développent et que le besoin est exprimé. Compte tenu de la diversité des questions posées par ce développement, le soutien de scientifiques extérieurs à la zone s'avère indispensable, mais ne pourra être efficace que lorsqu'une base de données sur la pêche associée aux DCP aura été alimentée.

CONCLUSIONS

Les DCP ancrés constituent un moyen pour les pêcheries artisanales côtières d'accéder aux ressources du large sans nécessité de changement de l'outil de production. Ils répondent au besoin de diversification de l'activité des petites pêches, actuellement trop dépendantes de ressources benthiques et démersales côtières fortement exploitées.

C'est dans la Caraïbe insulaire que le besoin de développement de la pêche des grands poissons pélagiques du large à l'aide de DCP ancrés est le plus exprimé. C'est en effet, dans ces pays que les débarquements de ces pélagiques ont le moins progressé au cours de ces dernières décennies et que les flottes de pêche sont composées presque exclusivement d'unités de petites dimensions ne pouvant que difficilement accéder aux ressources du large. C'est également dans la Caraïbe insulaire qu'après près de trente années d'expérimentations les DCP ont commencé à se développer.

Tableau 1. Comparaison succincte des modes de gestion des DCP de Guadeloupe et Martinique

Critères de comparaison des modes de gestion	Martinique DCP collectifs	Guadeloupe DCP privés
Phase de développement	Lente, peu de DCP opérationnels (quelques dizaines)	Rapide, beaucoup de DCP en œuvre (plusieurs centaines)
Conflits pour l'utilisation des DCP	Gérés par le Comité des Pêches	Non gérés avec des dérives pouvant avoir des conséquences pour la sécurité
Danger pour la navigation	DCP bien balisés et signalés par AVURNAV	DCP non balisés afin de les cacher aux autres pêcheurs.
Coût pour la collectivité	Existe (financement de DCP)	Nul
Structuration de la profession	Organisation collective pour la mise à l'eau et la maintenance des DCP. Réglementation des pratiques de pêche.	Aucune
Phase de régulation	Probablement plus aisée	Risque d'être difficile
Suivi scientifique	Participation du Comité des Pêches	Difficile
Durée moyenne des sorties	5h30	7h14
Rendements moyens par sortie	Les rendements augmentent d'une année sur l'autre. L'effet nombre de DCP est masqué par l'effet maîtrise d'une nouvelle technique de pêche	
	26,7 kg en 1998-1999	30 kg en 1992
	32.6 kg en 1999-2000	43 kg en 1995

Les raisons des difficultés d'appropriation des DCP ancrés par les pêcheurs sont maintenant identifiées, ce qui a permis le développement d'une pêche associée à ces dispositifs dans plusieurs îles de la Caraïbe et en particulier aux Antilles françaises. Mais une optimisation de la pêche autour des DCP est possible et nécessite des travaux de recherche. De même, un suivi scientifique des ressources exploitées est indispensable car les DCP accroissent les prises de certaines espèces. Le développement des DCP ancrés apporte des changements dont les impacts doivent également être évalués, tant sur le plan biologique que socio-économique, afin de prévenir toute évolution indésirable.

Une organisation régionale de la recherche scientifique en soutien au développement durable des DCP ancrés devient indispensable afin de tenir compte des évolutions actuelles de la pêche et de la nécessité d'aborder certaines questions à une échelle géographique plus large. Elle devrait se constituer en priorité à partir des petites Antilles ou la demande est forte. Une standardisation des données nécessaires aux différents programmes scientifiques à conduire dans la région et aux évaluations de ressources par les groupes ad hoc, ainsi que l'élaboration des logiciels adéquats pour la saisie et le traitement de ces données est la première étape de cette organisation. La mise en place avec la FAO d'un groupe de travail régional pour la réalisation de ces travaux scientifiques paraît indispensable et devrait être entreprise dans un avenir proche.

LITERATURE CITED

Daniel P., 1995. Approche systémique des entreprises de pêche martiniquaises. Identification des points de blocage socio-économiques. Rapport d'étude, Contrat Ifremer/Région Martinique n° 90/1211221. Rapport Ifremer, Laboratoire RH Antilles. 79 pp.

Failler P., 1996. Système des relations de travail de la pêche martiniquaise. Impact du RMI et du non-enrôlement des matelots sur les relations de travail au sein de la pêche artisanale en Martinique. Rapport de synthèse, Convention n°94/1212042 Affaires maritimes/Comité des Pêches maritimes de la Martinique/Ifremer. 21 pp .

Farrugio H., F. Lantz , et J.L. Vallet. 1988. Compte rendu de mission aux Antilles du 11 au 24 avril 1988.Rapport interne Ifremer. N° : SS 218/88 – DRV/RH/H.F. 35 pp.

Guillou, A., F. Bruyère, A. Lagin. 1995. Activités nouvelles de pêche observées autour de DCP « profonds » à la Martinique : Comparaison des résultats obtenus avec ceux de la pêche au large traditionnelle « à Miquelon ». Rapport de contrat Région Martinique / Ifremer, Laboratoire RH Antilles. 58 pp.

Guillou A., A. Lagin, A. Lebeau, D. Priour, M. Repecaud, L. Reynal, J. Sacchi , et M. Taquet. [2000]. Démarche d'amélioration des DCP à la Martinique. In: Le Gall J.Y., Cayré P., Taquet M. (eds.) Pêche thonière et dispositifs de concentration de poissons, Caraïbe-Martinique, 15-19 oct. 1999. Ed. Ifremer, Actes Colloq., (sous presse).

Lagin, A. et O. Ledouble. 1994. Première analyse des informations fournies par les pêcheurs professionnels guadeloupéens sur leur activité de pêche autour des DCP en 1993. Rapport Ifremer, Laboratoire RH Antilles. 21 pp.

Laurans M., M. Taquet, L. Reynal, et A. Lagin. [2000]. Comparaison des captures des grands poissons pélagiques en Martinique avec ou sans dispositifs de concentration de poissons (DCP). In: Le Gall J.Y., Cayré P., Taquet M. (eds.), Pêche thonière et dispositifs de concentration de poissons, Caraïbe-Martinique, 15-19 oct. 1999. Ed. Ifremer, Actes Colloq., (sous presse).

Le Guen, R., A. Guillou, et A. Lagin. 1996. Résultats comparés de pêche autour de DCP en Guadeloupe en 1995 par rapport à ceux des trois années précédentes. Rapport Ifremer, Laboratoire RH Antilles. 14 pp.

McIntosh, S. 1984. Progress with the development of Fish Aggregating Devices in the Caribbean. *Proceedings of the Gulf and Caribbean Fisheries Institute* 37:64-66.

Reynal L., G. Van Buurt, et M. Taquet. [2000]. Perspectives de développement des DCP ancrés dans les petites Antilles. L'exemple de trois îles: Guadeloupe, Martinique et Curaçao. In: Le Gall J.Y., Cayré P., Taquet M. (eds), Pêche thonière et dispositifs de concentration de poissons, Caraïbe-Martinique, 15-19 oct. 1999. Ed. Ifremer, Actes Colloq., (sous presse).

Taquet M., A. Guillou, O. Rageot, C. Maguer, et A. Lagin. 1998. Grands pélagiques : biologie et optimisation de l'exploitation dans les eaux proches de la Martinique. Rapport final de convention Ifremer/Conseil Régional de la Martinique N°96-241. 82 pp.

Taquet M., L. Reynal, M. Laurans, et A. Lagin. Blackfin tuna (Thunnus atlanticus) fishing around FADs in Martinique (French West Indies). *Aquatic Living Resources*. (soumis).

Taquet M., M. Laurans, L. Reynal, et A. Lagin. [2000]. Proposition d'une nouvelle technique de pêche du thon noir (Thunnus atlanticus) sous les DCP en Martinique. In: Le Gall J.Y., P. Cayré, et M. Taquet (eds.) Pêche thonière et dispositifs de concentration de poissons, Caraïbe-Martinique, 15-19 oct. 1999. Ed. Ifremer, Actes Colloq., (sous presse).

Wolf, R.S. et W.F. Rathjen. 1974. Exploratory Fishing in the *Caribbean. Marine Fisheries Review* 36(9):septembre 1974.

Propuesta de Conservación y Desarrollo Sustentable del Complejo Arrecifal de Banco Chinchorro en el Caribe Mexicano

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RESUMEN

Banco Chinchorro es el arrecife oceánico más grande que tiene México; con sus 864 km^2 de área en la laguna arrecifal, soporta arrecifes prístinos, parches coralinos, extensos seibadales, camas de macroalgas y arenales donde se presentan especies de gran importancia comercial tales como el caracol rosado(*Strombus gigas*) y la langosta espinosa (*Palinurus argus*). Posee islas de mangle con grandes colonias de anidamiento de aves marinas, lagunetas con especies en peligro tales como el cocodrilo (*Crocodile acutus*). Los hábitats que soportan globalmente a las especies en peligro, son amenazados por un reciente florecimiento del turismo y un megadesarrollo en áreas costeras adyacentes. A pesar de su reciente declaración como reserva de la biosfera, la protección de este sistema arrecifal es un reto donde se incluye: una dependiente ayuda económica, infraestructura y personal entrenado limitado o inexistente; un incremento de presiones en sitios específicos (especialmente en sitios populares de buceo en el arrecife coralino), la pequeña escala de vigilancia y de servicio civil con que cuenta la reserva, la falta de conocimiento ambiental y biológico de esa zona y la sobrepesca de especies de importancia comercial. Se presenta en este trabajo, una descripción de elementos necesarios para realizar una propuesta de administración con sólidas bases ecológicas y que sirva como parte de una estrategia para el desarrollo sustentable con patrones de protección y monitoreo de áreas frágiles del ecosistema. A pesar de su gran importancia, este trabajo analiza globalmente las variables socio-económicas del área, donde se muestra la necesidad de integrar mayor información. La metodología de descripción y diagnóstico del sistema incluye estudios de: fisiografía, hidrografía, cartografía y comunidades arrecifales importantes, dando como resultado esquemas de uso tradicional y propuestas de zonificación en el arrecife. Se presentan también recomendaciones y estrategias que tienen implicaciones para muchos sistemas arrecifales costeros en el Caribe Mexicano.

PALABRAS CLAVE: Biodiversidad, Áreas protegidas, Banco Chinchorro, Caribe Mexicano.

Conservation and Sustainable Development Proposal for the Chinchorro Bank Reef Complex in the Mexican Caribbean

ABSTRACT

The Chinchorro Bank is the largest reef complex in Mexico, measuring 864 Km^2 in area. It contains hábitats such as a lagoon which support pristine reefs, coral patches, extensive *Thalassia testudinum* bed, macroalgae beds and sandy bottoms, and commercially important species such as queen conch (*Strombus gigas*) and spiny lobster (*Palinurus argus*). They are also mangrove islands with large marine bird breeding colonies, and small lagoons with species in danger of extintion, such as crocodiles (*Crocodile acutus*). These hábitats, which as a whole support the endangered species, are increasingly threatened by the growth of tourism and megadevelopments in nearby coastal áreas. In addition to its recent declaration as a biosphere reserve, the protection of this reef system requires: economic support, infraestructure, trained personnel (currently limited or nonexistent), establishment of popular diving sites, different security stages and civil service, implementation of regular control of the zone through environmental and biological research, and restructuring of the capture of commercially important species via fundamental controls. This study present a conservation and sustainable development proposal with solid ecological foundations, as well as protection and monitoring strategies for fragile áreas of the ecosystem. Socio-economics variables are analyzed as a whole. The descriptive and diagnostic methodology integrates physiographic, hydrographic, cartographic and ecological analyses of the system's reef communities, proving tradicional use schemes and reef zonation proposals. Recommendations and strategies are also presented for the administration of the system, as are the resulting implications for this mexican Caribbean reef system.

KEY WORDS: Biodiversity, protected areas, Chinchorro Bank, Mexican Caribbean.

INTRODUCCIÓN

Desde décadas pasadas se ha venido incrementando la pérdida de biodiversidad biológica en las zonas tropicales, la explotación humana de los recursos naturales bajo patrones no sustentables han contribuido a la degradación y destrucción de variados hábitats naturales tanto terrestres como acuáticos. A pesar de la creciente publicidad sobre la conciencia ecológica y la designación reciente de años mundiales del océano y los arrecifes coralinos, los impactos humanos originan amenazas potenciales sin precedentes a muchas especies marinas, pero sobre todo a las interacciones biológicas del océano. Los ecosistemas costeros en México y en particular los del Caribe mexicano, son parte de una preocupación general debido a su relación con amplios megadesarrollos y a que en esas áreas la pesquería artesanal y el ecoturismo son recursos importantes de empleo y obtención de divisas. Los arrecifes de coral en particular, son utilizados para subsistencia, generación de ingresos, investigación y recreación, en donde la mayor parte de la explotación que

se ejerce en ellos es de naturaleza extractiva.

Una estrategia inicial para contrarrestar estas amenazas es el establecimiento de áreas protegidas y su utilización sustentable. A pesar de que existen una gama amplia de tipos de áreas protegidas, las grandes áreas de uso múltiple en donde se acoplan la conservación de hábitats y las actividades socioeconómicas son los mayores retos, sobre todo porque generalmente revisten preocupaciones políticas, económicas y éticas. Un gobierno inadecuado, una administración ignorante, ineficaz e insuficiente, escasa supervisión, falta de personal adiestrado y exigente, fondos inadecuados y una percepción pública inexacta puede ser una obstrucción para preservar la diversidad biológica marina como ha ocurrido en otros países (Kelleher 1989, Sobel 1993, Mumby *et al.* 1995). Una administración y gestión exitosa debe demostrar con evidencia científica cuantitativa como los recursos son protegidos y utilizados sustentablemente bajo su marco de regulación.

En México, los procesos para la planificación de áreas protegidas empiezan a adoptar la tecnología de los Sistemas de Información Geográfica (SIG), ya que es necesario integrar datos de una amplia variedad de fuentes. Al incorporar datos de los Sistemas de Posicionamiento Global (GPS), el SIG se ha transformado en una poderosa herramienta multidisciplinaria de detección y en algunos casos de predicción para los acercamientos sectoriales y globales de la administración de recursos (Hildebrand y Norrena 1992). En el entorno marino, además permite mejorar el inadecuado control terrestre y la cartografía de baja resolución.

Coincidiendo en que una adecuada administración de un área natural debe estar sustentada en una cooperación estrecha entre gobierno, instituciones, organizaciones no gubernamentales y usuarios locales y potenciales (Ordoñez-Díaz y Flores-Villela 1995), el presente trabajo propone algunas estrategias para la conservación de Banco Chinchorro, arrecife coralino oceánico. Esta propuesta está limitada desde un punto de vista científico, sin considerar las complejas relaciones socioeconómicas que tiene el Banco y solo está enfocada a aspectos físicos y biológicos del Banco.

MATERIAL Y MÉTODOS

En 1993-94 la sociedad para la conservación de la vida silvestre (WCS), el Consejo Nacional de Ciencia y Tecnología (CONACYT) y la Unidad Mérida del Centro de Investigación y Estudios Avanzados del I.P.N. (CINVESTAV) condujeron a una evaluación ecológica de Banco Chinchorro. Este arrecife fue considerado por esas instituciones como un área que necesitaba esa evaluación para garantizar su protección a causa de presiones de turismo y pesca ilegal.

Área de Estudio — Banco chinchorro es un sistema arrecifal coralino ubicado entre las coordenadas geográficas 18°47'-18°23'N y 87°14'-78°27'W (Fig. 1). Se localiza fuera de la costa 24 Km al sureste de la Península de Yucatán, con un canal que lo separa de la costa con profundidades mayores a 1000 m. El arrecife tiene la forma de un atolón con 4 islas: dos en el norte, una en el centro y una en el sur, posee una gran variedad de hábitats incluyendo una intrincada red de islotes de mangle, un

somero microsistema lagunar en la isla más grande (Cayo Centro). La laguna arrecifal es poco profunda con un gradiente batimétrico sur-norte y arrecifes de borde topográficamente complejos. El arrecife es un pináculo con más de 500 m de profundidad en la pendiente externa y fuerte crecimiento de corales en la zona de barlovento sur. Con una área total de 814.2 km^2, es el complejo arrecifal más grande de México y es un punto importante de pesca comercial.

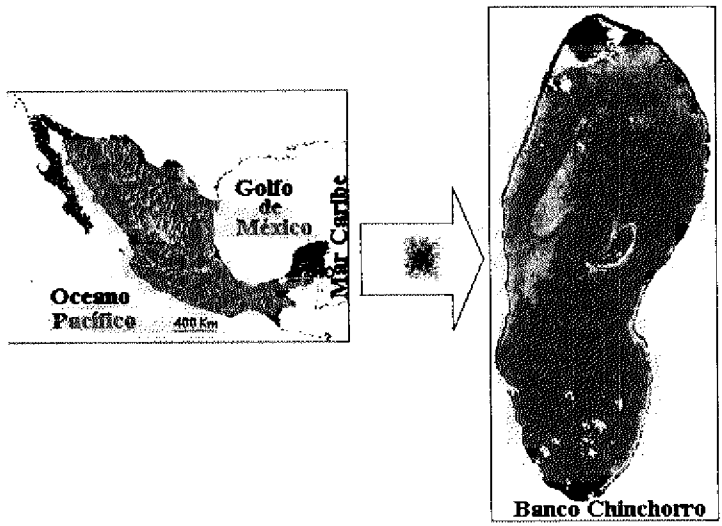


Figura 1. Localización del sitio de muestreo.

Material — Como material para el presente trabajo se utilizó una imagen multiespectral de bajo costo Lansat-MSS del 2 de abril de 1989, la cual fue inicialmente procesada por el programa IDRISI (Clark University, Syracuse, New York) y posteriormente con el programa Erdas Imagine v. 8.4. Dicha imagen fue utilizada para conformar parte de la batimetría lagunar y la clasificación del fondo de la laguna arrecifal. En conjunto con el análisis de la imagen, se utilizaron múltiples datos de campo tanto para evaluaciones ecológicas como para verificaciones de los patrones espaciales obtenidos con las imágenes. Así mismo, se contó con los registros de censos realizados entre los usuarios durante 1996-1997 para conocer los usos tradicionales del banco y las áreas de pesca más frecuentadas (Torruco 1995) y contrastar este esquema con las diferentes zonificaciones propuestas posteriormente por Torruco y González (1994) y INE (2000) y finalmente proponer con los resultados de este estudio áreas de conservación prioritaria.

Métodos — Las bandas de la imagen multiespectral fueron corregidas geométricamente a partir de la cartografía básica del Almirantazgo Británico (Chart No. 1798) y vectores de profundidades conocidas. La clasificación del fondo arrecifal se logró mediante una clasificación supervisada de la imagen. Los datos de campo fueron utilizados tanto para la verificación de la imagen como para la obtención de la biodiversidad dada por la riqueza de especies, la diversidad obtenida por el índice de Simpson y la equidad como un indicador de la madurez prevaleciente en las diferentes áreas de la laguna arrecifal; dichos datos fueron interpolados utilizando el software Surfer V. 6.2 utilizando un kriging universal como algoritmo de interpolación.

RESULTADOS

Análisis de imágenes — A pesar de que la metodología utilizada no permitió separar firmas espectrales únicas, identificando cada clase con diferentes contenidos, el nombre de la clase asociado corresponde al recurso más representativo. La clasificación supervisada mostró 16 clases (máxima verosimilitud). Sin embargo, en la identificación de clases con los datos de campo y utilizando criterios adicionales de separación como son; el color, la textura y la profundidad, sólo se seleccionaron 11. Estos patrones espaciales de tonalidades representan fielmente toda el área de la laguna arrecifal. La correspondencia de estos patrones con el material geomorfológico y biológico se muestra en la capa del fondo arrecifal (Figura 2).

Análisis de datos — Utilizando los mapas de interpolación de los macrodescriptores comunitarios con los grupos de hexacorales y octocorales (los constructores arrecifales más importantes), se definen de manera cuantitativa las áreas con nodos de alta diversidad y madurez y por consiguiente las principales alternativas de conservación (Figura 3). La riqueza de especies usada como un indicador de la biodiversidad muestra en ambos grupos tres zonas de valores altos, una al norte del

banco, otra que rodea Cayo Centro y que se amplia hacia la rompiente de barlovento y la tercera que es quizá la más importante, que se ubica hacia el área sur-sureste del Banco (Figura 3a). La diversidad de Simpson, identifica con ambos grupos dos zonas de altos valores: una rodea Cayo Centro y la segunda en la parte sur-sureste del Banco (Figura 3b). La equitatividad de los octocorales muestra un esquema similar, a pesar de que las áreas con máximos valores se desplazan un poco hacia el sur, se siguen presentando tres nodos de altos valores que involucran a áreas muy cercanas a las definidas por los macrodescriptores anteriores. Los hexacorales por el contrario muestran las zonas de mayor madurez en la rompiente de sotavento frente a Cayo Centro y un nodo al nordeste del mismo Cayo (Figura 3c).



PATRON	AREA	DESCRIPCION
●	0.903	Substrato fangoso-algas verdes filamentosas.
●	172.07	Arena fina-parches de *Thalassia testudinum* -monticulos de *Arenicola*
●	106.61	Substrato coralino
○	41.23	Arena-parches de *Laurencia* -monticulos de *Arenicola*
●	89.57	Ceibadal de *Thalassia testudinum*
●	109.11	Arena fina-Fragmentos de coral
○	64.45	Fanerógamas marinas y algas verdes
●	97.99	Arena muy gruesa-restos coralinos
○	72.81	Algas pardas
○	53.32	Substrato duro-restos libres de coral
●	6.12	Manglar

Figura 2. Capa del fondo de la laguna arrecifal de la reserva de la Biósfera Banco Chinchorro en el Caribe Mexicano. Se muestra el patrón de coloración, el área que representa y la descripción del fondo.

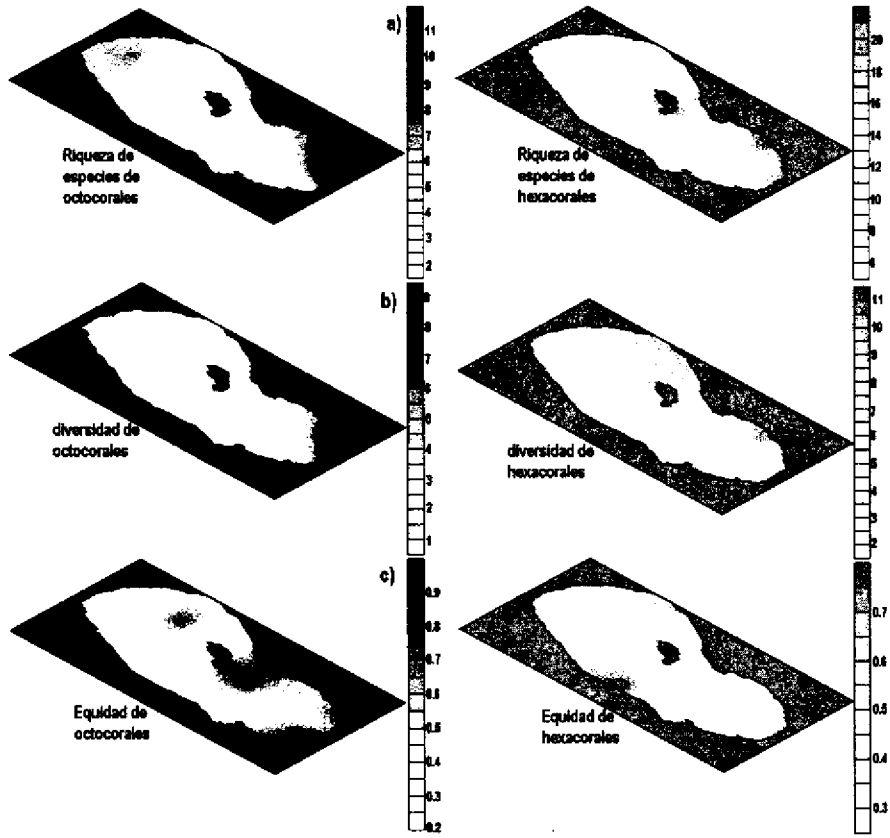


Figura 3. Representación de los valores de macrodescriptores comunitarios de los corales (duros y blandos) en la laguna arrecifal de la reserva de la Biósfera Banco Chinchorro en el Caribe Mexicano. a). Riqueza de especies. b). Diversidad. c) Equitatividad). Se muestran los nódulos de máximos y mínimos valores.

La utilización pesquera tradicional del Banco se determinó con la sobreposición de las capas del fondo arrecifal y de los censos realizados con las cooperativas pesqueras que explotan la zona (Figura 4a). El arrecife presenta una fuerte utilización en la barrera y en la laguna arrecifal; la primera con un área de 247.76 km^2 es utilizada especialmente para la pesca de la langosta *(Panulirus argus)*, abadejo (*Mycteroperca bonaci*), pargos (*Lutjanus* spp.), cabrillas y mero (*Epinephelus* spp.). En la laguna (410.09 km^2) con sus extensos ceibadales y zonas arenosas se pesca caracol rosado y con redes agalleras se realizan capturas de especies pequeñas de mojarras (*Gerres cinereus*) y jureles (*Caranx* spp), tanto para consumo como para carnada de huachinangos. La captura de barracudas en ésta

zona es también común. La zona norte es poco frecuentada y aparentemente no tiene ningún uso pesquero (141.51 km^2). En la zona sur del banco existe un área de solapamiento donde coinciden los tres tipos de pesca (46.09 km^2). Las diferentes capas de macrodescriptores para cada grupo coralino fueron reunidas en una sola que mostrara las características totales del grupo, posteriormente la reunión de ambas capas fueron la base para definir las áreas prioritarias de conservación, dicho esquema fue contrastado con la zonificación propuesta por Torruco y González (1994) y el INE (2000) (Figura 4).

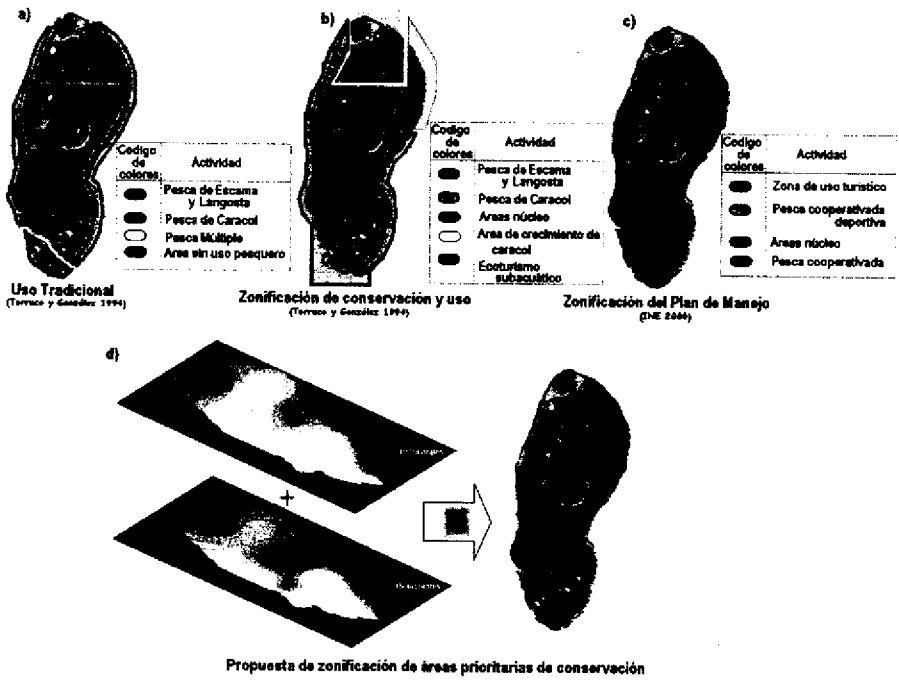


Figura 4. Representación de las diferentes propuestas de zonificación de la laguna arrecifal de la Reserva de la Biosfera de Banco Chinchorro. a). Uso tradicional del arrecife (Torruco y González 1994). b). Zonificación de conservación y uso (Torruco y González 1994). c). Zonificación del programa de manejo (INE 2000). d). Propuesta de zonificación de áreas prioritarias de zonservación (este trabajo).

DISCUSIÓN

Las áreas protegidas constituyen una estrategia social ante la naturaleza (Ordoñez-Díaz y Flores-Villela 1995), ya que son una forma de ordenamiento territorial y representan un factor de equilibrio, es por ello que han sido reconocidas como una solución a los problemas ambientales; sobre todo por su integración a las actividades sociales, culturales y económicas de la región (Miller 1980). La importancia de Banco Chinchorro radica en que es un ecosistema con límites precisos y susceptible a convertirse en un modelo de administración. Además de que el área tiene un gran potencial para desarrollar algunos tipos de turismo ecológico, que deben ser positivos para los usuarios del Banco sin alterar de manera irreversible los procesos ecológicos esenciales del ecosistema ni la organización social de los usuarios.

Los SIG han resultado una herramienta poderosa y flexible para la cartografía de áreas remotas costeras, particularmente cuando no pueden aplicarse técnicas convencionales fotogramétricas (Rodríguez-Bejarano 1991, Claro y Rhomann 1994). Además, la habilidad del SIG para integrar datos exhibe una amplia gama de fuentes y proporciona rápida y fácilmente productos accesibles lo que lo hacen muy conveniente para la planificación de la administración de recursos. Con la imagen de satélite se tiene una visión sinópica del área; sin embargo el éxito de contar con múltiples puntos para la georeferencia estuvo dada por la geomorfología de Banco Chinchorro, cuya definición es clara y precisa. Además su utilización en esta localidad muestra que el sensor remoto del satélite puede ofrecer información valiosa de la estructura del arrecife, siempre y cuando a través de un intenso trabajo de campo se obtenga la georeferencia de la imagen y la separación espectral de las comunidades biológicas, las cuales se dificultan en ambientes marinos, debido principalmente a la columna de agua (Bainbridge y Reichelt 1988, Friel y Haddad 1992). Del análisis visual inicial de los datos se observa en general una separación de clases del fondo, sin embargo posteriormente con la diferencia de bandas, el análisis digital permitió descubrir cambios significativos texturales, que mostraban alta incidencia con los datos de campo, proporcionando una fuente de información con un bajo costo y una alta efectividad (Luczkovich et al. 1993, Zainal et al. 1993),

Los datos muestran que el substrato predominante en la laguna arrecifal de Banco Chinchorro es arenoso, ya que tanto las arenas finas como medias alcanzan un alto porcentaje del área total (aproximadamente el 50%) y están distribuidas principalmente en la parte norte, estas extensas áreas no son hábitat favorable para especies de alto valor comercial; sin embargo, se presentan con gran frecuencia juveniles de caracol rosado. La parte sur en donde el desarrollo de parches arrecifales es más intenso, presenta el 13.09 % del área total de substrato coralino, soportada por las condiciones óptimas de calidad y temperatura del agua. El área registrada más pequeña es de substrato fangoso que apenas alcanza el 0.11% del total; sin embargo, por sus características intrínsecas es una de las áreas más importantes en el Banco (Torruco y González 1992). La vegetación terrestre está compuesta principalmente por mangle, con un área de aproximadamente el 0.75 %. Una parte importante de la extensión del banco esta compuesta por praderas de

Thalassia, ya sea asociada con arena o con otras asociaciones fitobentónicas, estas plantas marinas han tenido un desarrollo extenso, debido a las condiciones arenosas en gran parte del sistema.

De los resultados obtenidos con la zonificación de los usos tradicionales del Banco, el área más extensa es la de pesca de langosta y escama (42.32%); sin embargo, la zona sur (12.9%) parece ser la más diversificada, originada probablemente por la presencia de los parches arrecifales, que sirven de abrigo y protección a las especies que se comercializan. Los esquemas de utilización propuestos anteriormente (Torruco y González 1994, INE 2000)designan áreas núcleos en esas zonas, sin embargo, la designación se había realizado de manera un tanto empírica, y si bien la magnitudes de las áreas son diferentes, la coincidencia geográfica es muy alta. Ambas propuestas de utilización controlada mencionan la designación de áreas núcleo y de amortiguamiento sin ninguna conexión aparente; sin embargo, la interpolación de la riqueza, diversidad y madurez de la comunidad coralina permite conocer el grado de conecctividad y la forma topológica que presenta en el espacio esta relación; si partimos del objetivo inicial de la designación de áreas núcleo, que es el preservar zonas de alta biodiversidad, las áreas núcleo deberán identificarse con las áreas nodulares de valores altos, es por ello que se propone un rearreglo de las áreas prioritarias de conservación esquematizadas en la Figura 4. También debe considerarse que las las zonas productivas son de uso múltiple a pesar de la especificidad de las mismas; sin embargo, esto mismo hace que al proponer una estrategia de utilización múltiple sea más fácilmente aceptada por los usuarios sobre todo si existe una reglamentación con fuertes bases científicas, ya que hasta ahora solo se han regulado por temporadas de vedas y cuotas de pesca sin ningún fundamento sólido.

Con los resultados obtenidos en este trabajo, se pueden descubrir perspectivas de aplicación inmediatas en la conservación y mantenimiento de la biodiversidad de este ecosistema y proponer una diversificación de actividades. Debido a que las líneas generales de uso y conservación solo están basadas en aspectos ecológicos del arrecife, es necesaria la interacción de disciplinas sociales. Ya que el detalle y rigor de los aspectos socioeconómicos utilizados, muestran una cierta ambigüedad e imprecisión en algunos de los parámetros sociales, tanto demográficos como económicos mencionados en las anteriores propuestas. Esto crea la necesidad de mantener un determinado grado de precisión al momento de combinar estos criterios para mejorar la formulación presentada. Por otro lado, solo se utilizaron los grupos arrecifales con mayor importancia como constructores del arrecife; sin embargo, es recomendable que este análisis se realice con otros grupos arrecifales que tienen gran importancia en la dinámica y evolución del arrecife como pueden ser las esponjas, las macroalgas los hidrozoarios y los peces, que pueden dar información que ayuden a delimitar con mayor precisión la zonificación propuesta.

A pesar de que se ha demostrado que el arrecife del coral como recurso natural tiene un valor económico, social, cultural, e inherentemente proporciona servicios biológicos (Chávez e Hidalgo 1988, 1989, Chávez 1994). El arrecife del coral juega un papel importante en el aspecto social de muchas comunidades costeras; son un

recurso de gran belleza estética, incomparable biodiversidad marina y fuente de ingresos importantes para la población local. Y si bien los beneficios del arrecife de coral son muchos, es necesaria la inclusión de parámetros sociales y económicos que ponderen los valores del arrecife con la explotación que se realiza y con las directrices de conservación que buscan un desarrollo sustentable del área. Los beneficios económicos que fluyen del arrecifes de coral son tan diversos como el arrecife mismo e incluye protección de la línea costera, mantenimiento de las pesquerías, valores de la existencia, caliza y joyas. Sin embargo, el turismo subacuático (SCUBA) es el servicio económico de mayor importancia en economías basadas en el arrecife. Y aunque en Banco Chinchorro esta actividad es incipiente, el mantenimiento de un sustentable turismo arrecifal es con frecuencia el elemento central en la justificación de áreas marinas protegidas (Pendleton 1993). Al fomentar el uso sustentable del ambiente marino (Gilmour 1989), se beneficia la economía del área y se evita la degradación ambiental. Esta investigación ha mostrado la atención positiva que un conjunto finito de factores políticos, sociales y económicos son de importancia primaria a la preservación de la biodiversidad marina a través del uso de áreas marinas protegidas. Esperamos que la información proporcionada motive a otros investigadores a ejecutar en el futuro pruebas para determinar el nivel de causalidad entre factores de administración y la efectividad de las áreas marinas protegidas para preservar la biodiversidad de Banco Chinchorro.

LITERATURA CITADA

Bainbridge, S.J. and R. E. Reichelt. 1988. An assessment of ground truthing methods for coral reef remote sensing data. *Proceedings of the 6th International Coral Reef Symposium.* 2:439-444

Chávez, E.A. 1994. Los recursos marinos de la Peninsula de Yucatán. In: A. Yañez-Arancibia (Ed). *Recursos faunísticos del litoral de la Península de Yucatán.* Universidad Autónoma de Campeche. EPOMEX. Serie Científica. 2: 1-12

Chávez,E.A. y E. Hidalgo. 1988. Los arrecifes coralinos del Caribe noroccidental y Golfo de México en el contexto socioeconómico. *An. Inst. Cienc. del Mar y Limnol. Univ. Nal. Autón.* Mexico. 15(1):167-176

----------. 1989. The human impact on the coral reef environment in México. Pages 81-86 in: Chávez, E.A. (Ed) *Proc. Workshop Australia-Mexico on marine science.* CINVESTAV. U. Mérida. México.

Clark,A.E. and S.O. Rhomann. 1994. Mapping and analyzing benthic habitats in the Florida Keys National Marine Sanctuary. *Procc. 2o. Thematic Conference on Remote Sensing of Marine Coastal Environments.* New Orleans 2:542-545.

Friel,C. and K.Haddad. 1992. GIS manages marine resources. *GIS World* 5(9): 33-36

Gilmour, A.J. 1989. Coastal management in Australia. In: Chávez, E.A. (Ed) *Proc. Workshop Australia-Mexico on marine science.* CINVESTAV. U. Mérida. México. 133-142

Hildebrand,I.P. and E.J.Norrena. 1992. Approaches and progress toward effective integrated coastal zone management. *Marine Pollution Bulletin* **25**:94-97

INE, 2000. *Programa de manejo Reserva de la Biosfera Banco Chinchorro.* INE/SEMARNAP, México. 152 p.

Kelleher,G. 1989. Managing the Great Barrier Reef. *Oceanus* **29**(2):13-19

Luczkovich,J.L.,T.W.Wagner, J.L.Michalek and R.W.Stoffle. 1993. Discrimination of coral reef, seagrass meadows, and sand bottom types from space: A dominican Republic case study. *Photogrammetric Engineering & Remote Sensing.* **59**(3):385-389

Miller, K. 1980. *Planificación de parques nacionales para el ecodesarrollo en América Latina.* Fundación para la Ecología y la Protección del Medio Ambiente. Madrid. España.

Mumby,P., P.S.Raines, D.A.Gray and J.P.Gibson. 1995. Geographic information systems: A tool for integrated coastal zone management in Belize. *Coastal Management* **23**:111-121

Ordóñez-Díaz,M.J. O. Flores Villela. 1995. *Areas naturales protegidas.* Pronatura. Conservation International Mexico,A.C.

Pendleton,L.H. 1994. Environmental quality and recreation demand in a Caribbean coral reef. *Coastal Management.* **22**:399-404

Rodríguez-Bejarano, D. 1991. Técnicas de percepción remota y sistemas de información geográfica en el manejo de los recursos naturales. *Memorias del II taller Internacional de Procesamiento Digital de Imágenes y Visión.* IIMAS, UAMI, CCTF y UACH.

Sobel,J. 1993. Conserving biological diversity through marine protected areas: A global challenge. *Oceanus.* **36**(3):22-23

Thomas,Y.F. 1992. Estudio por sensores remotos de los arrecifes de coral del Archipielago de San Bernardo (Colombia). *Taller de arrecifes coralinos, Investigaciones y manejo. Boletín Ecotrópica: Ecosistemas tropicales.* **1**:5-11

Torruco,D. y M.A.González. 1992. *Procesos ecológicos de interacción entre la comunidad bentónica y la explotación pesquera en Banco Chinchorro, Quintana Roo.* Reporte Técnico CONACYT. México.

Torruco, D. 1995. *Faunística y ecología de los corales escleractinios en los arrrecifes de coral del sureste de México.* Phd. Dissertation. Universitat de Barcelona. 268 p.

---------- 1994. *Bases ecológicas para la administración ambiental y el desarrollo económico de Banco Chinchorro.* Reporte Técnico Wildlife Conservation Society.

Zainal, A.J.M., D.H.dalby and I.S. Robinson. 1993. Monitoring marine ecological changes on the east coast of Bahrein with lansat TM photo. *Photogrammetric Engineering & Remote Sensing.* **59**(3):415-421

The Contribution of Inadequate Fines to the Collapse of the Sea-egg Fishery of Barbados

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ABSTRACT

A small but important fishery for the white sea-egg *(Tripneustes ventricosus)* has existed in Barbados for well over a century. Around the mid-1980s the sea-egg fishery of Barbados collapsed, despite over a century of continuous management through legislative control. Throughout this period of management, the imposition of fines was the principle punitive measure taken against offenders of the relevant legislation. Using a variety of reference material ranging from press reports to scientific studies, this paper presents a retrospective comparative analysis of the potential revenue derived from sea-egg fishing and coinciding fines. It is suggested that the maximum legislated fines in effect during the years just prior to the collapse of the fishery were too low to act as effective deterrents to illegal fishing when compared with the profitability of harvesting sea-eggs at the time. Increased profits from the fishery in addition to inadequate fines together may have encouraged both increased fishing intensity and imprudent fishing practices, both of which contributed to the collapse of the fishery.

KEY WORDS: Fines, management measures, sea-eggs.

INTRODUCTION

The Fishery

Sea-eggs are harvested for their roe, which is considered a nutritious and tasty delicacy. Barbados, St. Lucia, and Martinique are the only Caribbean islands where sea-eggs are harvested intensively (Smith and Berkes 1991). Archeological evidence indicates that sea-eggs were harvested in Barbados from pre-historic times, by the island's Amerindian inhabitants and then by the British settlers of the island (Hughes 1750).

The most productive sea-egg fishing grounds were concentrated along the southeast and northwest coasts of the island. However, sea-eggs were also located at several other sites around the island, and although fishers tended to fish in areas that they new best, they would travel to any site where the animals were found if the need arose. Traditionally sea-eggs were transported to shore where the shells were broken open and the roe scooped out with spoons. The roe was collected and washed in pails of water. It was then packed into cleaned intact "half shells", also known as husks. Leaves of the sea grape (*Coccoloba uvifera*) were shaped into

cones, filled with roe and used to cover the "half shells" (Brown 1942, Hickey 1982, Scheibling and Mladenov 1987). It is estimated that, on average, the roe of 15 sea-eggs were required to fill one half shell (Scheibling and Mladenov 1987). From the mid-1980's, sea-egg roe was also sold in plastic ice cream cartons. This latter packaging method rapidly increased in popularity and eventually all but completely replaced the older methods (Nation newspaper, 1991-09-26).

The arrival of the annual sea-egg fishing season was timely, as it came when the season for flying fish and the large pelagic fish, such as dolphin (*Coryphaena hippurus*) and wahoo (*Acanthocybium solandri*), was over. In addition, the beginning of the season coincided with the last weeks of school children's summer holidays. Hundreds of Barbadians, men, women and children, became involved in some aspect of the fishery. In 1948 the industry was described as employing "almost every available fisherman and their families" (Wiles 1949). In 1949, the sea-egg fishery was estimated to net approximately $30,000 per annum (Wiles 1949) making it the second most economically valuable local fishery at the time. Unfortunately the details of how the economic worth of the fishery was calculated were not outlined. In a letter written to the Director of Agriculture in 1950, Wiles stated that the sea-egg fishery comprised 75% of the total island's fisheries during the months of September and October (the pelagic off-season). Wiles went on to emphasize the importance of the fishery to fishermen by stating that: "fishermen of all classes, as well as boat-owners depend on this industry for a livelihood".

Review of Management Legislation

The social and economic importance of the sea-egg fishery to Barbados is evidenced by the fact that it was the first single species fishery in the island to be brought under legal control. The first laws governing the fishery were embodied in the Sea-egg Preservation Act of 1879. In the official announcement of the Sea-egg Preservation Act, printed in the Official Gazette of July 21,1879, the Colonial Secretary, Mr. Walter Huey-Hutchinson stated that the object of the Act was "to preserve a cheap and popular article of food by preventing reckless and wasteful fishing for sea-egg at all seasons of the year" and that "the provisions of the Act will be strictly enforced and the police and rural constables have received instructions accordingly" (O.G. July 21, 1879, Vol. XIII, pg. 1339). The rationale stated for the enactment of the Sea-egg Preservation Act suggests that even in 1879, it was thought that Barbadian sea-egg stocks were in need of protection from overexploitation.

It is noteworthy that in the latter part of the 19th century many still had the view that the ocean's resources were limitless and could never be fished out. T.H. Huxley, a noted zoologist of the time, conveyed this sentiment in his opening address to the International Fisheries Exhibition held in London in 1883 by stating that "...all the great sea fisheries are inexhaustible: that is to say that nothing we do seriously affects the numbers of fish" (King 1996). The Sea-egg Preservation Act of 1879 was therefore a prudent piece of legislation for it's time and is probably one of the first pieces of fisheries management legislation in the world.

The main regulatory mechanism of the Sea-egg Preservation Act of 1879 was the establishment of an annual fishing closed season (April 1st to August 31st, inclusive). The first documented scientific study of the biology and ecology of Barbadian sea-eggs was published by Lewis (1958). The results of this study confirmed that the major spawning period of Barbadian sea-eggs coincided with the closed season prescribed in the 1879 act. Therefore, these laws that were probably based entirely on common knowledge were in principle appropriate for the conservation of sea eggs. The actions of these 19th century legislators to formulate the Sea-egg Preservation Act were in keeping with the spirit of article 7.5.1. of the 1995 FAO Code of Conduct for Responsible Fisheries, which encourages states to apply a precautionary approach to manage and preserve exploited aquatic resources even in the absence of adequate scientific information.

Persons caught harvesting, selling or in possession of sea-eggs during the closed season were subject to fines (forty shillings, maximum) or imprisonment (maximum of 1 month with hard labour) and having their catch confiscated. The act included a clause giving the Governor the power to alter the closed season by simply publishing a notice of the impending change in the Official Gazette.

In October 1899, there appeared to be renewed fears of a possible collapse of the sea-egg fishery, causing the representative for St. Philip, Mr. Lofty to present a bill in parliament seeking to extend the closed season for a period of two years (1900-1902) to give local stocks some time to recover. A parliamentary committee, under the chairmanship of the Attorney General, Mr. William Herbert Greaves was appointed to consider and report on the bill. The committee interviewed sea-egg fishers and concluded that the fishery had declined considerably and that sea-eggs were then scarce. The decline was attributed to "persistent breeches" of the Act. It was suggested that the annual closed season should be extended to the end of September and that enforcement should be improved (Official Gazette, June 21st 1900. Vol. XXXV).

The sea-egg fishing close season was then duly extended to September 30th for each of, at least, the next five years. In addition, an amendment to the Sea-egg Preservation Act was signed into law in July 1900. (O.G., July 20th 1900. Vol. XXXV). This amendment was obviously geared towards improving enforcement of the sea-egg laws by stipulating that Police magistrates should appoint rural constables, who were to be supplied with copies of the Act and to be instructed that: "they are required to use every effort in their power to secure the observance of the provisions of the Act".

In 1904 all of the fisheries laws in existence at the time were consolidated in the Fisheries Regulation Act, 1904. All of the clauses included in the amended Sea-egg Preservation Act were included in the new act. However, some new clauses were also added. Owners of boats or gear used in the illegal harvesting of sea-eggs during the closed season were made liable to punishment under the law and it was made illegal to "...willfully and wantonly destroy sea-eggs lying on any bank or shallows along the coast..." or to "...cleanse any sea-eggs and leave the shell or offal thereof on any bank or shallow on which sea-eggs lie". The system of fines was also

changed, whereby the charges of possession or sale of sea eggs during the closed season carried a lesser penalty (a maximum fine of £2) than the other offences (a maximum fine of £5 along with forfeiture of catch, vessels and gear used). Notably the threat of imprisonment was removed.

The Fisheries Regulation Act was amended three times before it was repealed in 1993. The first of these amendments, the Fisheries Regulation (Amendment) Act, 1960 was enacted in September 1960. The highest fines of ($25 maximum) could be imposed for illegal harvesting, the wanton destruction of sea-eggs, disposal of shells and offal on sea egg grounds and on owners of vessels and gear used in illegal harvesting. A lesser maximum fine of $10 could be imposed on persons selling and possessing sea-eggs out of season. The fines were again increased in 1977, in the Fisheries (Amendment) Act, 1977. The same categories were maintained, except a $250 fine replaced the $25 fine and a $100 fine replaced the $10 fine.

The Fisheries Regulation (Amendment) Act, 1989, enacted in January 1990, was the last amendment made to the Fisheries Regulation Act, 1904. This last amendment substantially increased the maximum penalties for contravening the Act. In addition to fines, a period of imprisonment could once again be imposed. For illegal harvesting and owning a vessel or gear used in illegal sea-egg harvesting, the maximum penalty was a fine of $1000 or 12 months imprisonment. Interestingly, wanton destruction of sea-eggs and the disposal of shells and offal on sea-egg banks seemed to loose its importance and carried the same penalties as for selling and possession of sea-eggs during the closed season. For these offences the maximum penalty was a fine of $500 or 6 months imprisonment. The 1989 Amendment Act also lengthened the annual closed season from January 1st to August 31st.

The clauses of the Sea Egg Preservation Act of 1879 and subsequently of the Fisheries Regulation Act of 1904 that gave government officials powers to alter the annual sea egg fishing close seasons by publishing a notice of the change in the Official Gazette, was often invoked during the first half of the 20th century (Table 1). It is note worthy that closed seasons were shortened on a number of occasions to allow persons to legally access the resource during times of hardship, for example during the two world wars.

Table 1. Annual legal closed seasons for the sea-egg fishery of Barbados (1879-2001). Laws are shown in bold.

Year	Legal closed season	Reference to relevant Law or Notice in the Official Gazette
1879 to 1899	1 April - 31 August	**Sea-egg Preservation Act (1879-1)**
1900 to 1903	1 April - 30 September	June 21, 1900, Vol.XXXV, No.55, pg.1291
1904	1 April - 30 September	August 29,1904, Vol.XXXIX, pg. 1525
1905	1 April - 30 September	July 24, 1905, Vol.XL, pg. 1323
1906 to 1907	1 April – 30 September	No specific reference to the sea-egg close season found for these years, assumed that the extended closed season (1900) still applies
1908	1 April - 8 September	September 7,1908, Vol.XLIII, pg. 1340
1909	1 April - 16 September	September 20, 1090, Vol. XLIV, No. 78, pg.1646
1910 to 1911	1 April - 31 August	Assumed to default to original period as no specific change gazetted
1912	1 April - 14 August	August 9, 1912, Vol. XLVII, No. 66, pg. 1387.
1913 to 1915	1 April - 31 August	Assumed to default to original period as no specific change gazetted
1916	1 April - 14 August	
1917	1 April - 31 July	July 30, 1917, Vol. Vol.LII, No.66, pg.1433
1918	1 April - 31 July	August 1,1918, Vol.LIII, pg. 1343
1919	1 April - 31 July	August 4,1919, Vol. LIV, No. 64, pg. 1029
1920	1 April - 31 July	July 26, 1920, Vol. LV, No. 60, Pg.785
1921	1 April - 31 July	August 1, 1921, Vol. LVI, No. 62, pg. 691
1922	1 April - 31 July	July 24, 1922, Vol. LVII, No. 59, pg. 829
1923	1 April - 31 July	July 30, 1923, Vol. LVIII, No. 61, Pg. 837
1924 to 1926	1 April - 31 August	Assumed to default to original period as no specific change gazetted
1927	1 April - 31 August	July 21, 1927, Vol. LXII, No. 58, pg. 879
1928	1 April - 31 August	July 19, 1928, Vol. LXIII, No. 58, p. pg. 821

Year	Legal closed season	Reference to relevant Law or Notice in the Official Gazette
1929 to 1932	1 April - 31 August	Assumed to default to original period as no specific change gazetted
1933	1 April - 31 August	July 31, 1933, Vol. LXVIII, No. 61, pg. 1281
1934 to 1936	1 April - 31 August	Assumed to default to original period as no specific change gazetted
1937	1 April - 11 August	August 9, 1937, Vol.LXXII, pg. 1219
1938	1 April - 31 August	Assumed to default to original period as no specific change gazetted
1939	1 April - 23 August	August 28, 1939, Vol.LXXIV, pg. 1598
1940	1 April - 23 August	August 8, 1940, Vol.LXXV, pg. 1458
1941	1 April - 15 August	August 4, 1941, Vol. LXXVI, pg. 1031
1945 to 1950	1 April - 31 August	Assumed to default to original period as no specific change gazetted
1987 to 1989	1 September, 1987- 31 August 1989	August 20, 1987, Vol. CXXII, No. 73, pg. 854
1990 to 1993	1 January – 31 August	**Fisheries Regulation (Amendment) Act, 1989-32**
1993 to 1997	No Official Closed Season	**Fisheries Act (1993/27) - No closed season defined**
1998 to 2001	1 August, 1998 to 31 July, 2001	**Fisheries (Management) Regulations, 1998, (S.I. No. 102, 27 July, 1998, Vol. CXXXIII, No. 61) Fisheries (Sea Eggs Closed Season) Notice, 1998 (S.I. No. 103, 27 July, 1998, Vol. CXXXIII, No. 61)**

In 1993 the Fisheries Regulation Act of 1904 was repealed and replaced with the Fisheries Act, 1993. The format of the Fisheries Act was significantly different then that of the Fisheries Regulation Act. Laws related to the management of fisheries were made more general to cover all controlled fisheries and were not written for specific fisheries such as sea-eggs. The laws pertaining to the enforcement of the legislation embodied in the Fisheries Act were made more extensive. Enforcement of the Act was vested with a group of individuals entitled "authorized officers" and the law courts. Authorized officers included officers of the Fisheries Division, Customs, Police and the Coast Guard. The laws gave the authorized officers the power to stop and search fishing vessels and vehicles suspected of being used in contravening any of the laws included in the Act. Any fishing gear, vessel and cargo, or vehicle suspected as being used in the commission of an offence under the Act could be seized. Finally authorized officers had the power to arrest any person suspected to be committing an offence under the Act.

The Act also vested the Minister responsible for fisheries with the responsibility to make regulations relevant to the management of any fishery. These regulations could include, limiting fishing effort, setting maximum allowable catches, prohibiting any fishing method, controlling the use of SCUBA in fishing, prescribing closed seasons and closed areas and regulating the marketing and distribution of captured aquatic fauna. The Minister was also charged with the responsibility of prescribing measures for the protection of marine species such as sea-eggs.

The structure of the Fisheries Act of 1993 mandated that a closed season for sea-eggs had to be prescribed by the Minister. This was in fact not done until 1998. Consequently for the intervening five years the sea-egg fishery was effectively unregulated from a legal standpoint. In 1997, the Fisheries Division published a comprehensive Management Plan for all of the existing Barbadian Fisheries including that of the sea-eggs. The recommendations made to manage the sea-egg fishery were accepted by Government and put into law in August 1998, along with several other regulations related to other fisheries, in the form of the Fisheries (Management) Regulations, 1998. The maximum penalties for contravening any of the regulations were exceptionally stiff, a fine of $50,000 and/or two years imprisonment.

The regulations specifically related to sea-eggs included banning the use of SCUBA equipment for harvesting sea-eggs. The Minister was also to prescribe a closed season for harvesting sea eggs and could designate closed areas as declared by a notice published in the Official Gazette. A companion Statutory Instrument that officially closed the sea-egg fishery for a period of three years was enacted simultaneously with the Fisheries (Management) Regulations. This three year long respite affords the over-fished sea-egg stocks a period in which to recover in numbers while government fashions a co-management arrangement for the fishery with sea-egg fishers. This is in keeping with the recommendations of Government's management plans for the sea-egg fishery (Fisheries Management Plan, 1995).

Despite continued management of the fishery since 1879, there were several occasions when it was feared that the fishery was in danger of collapsing. Government's response to these situations was usually through adjusting the legislation in some way. The causes of the potential collapses were usually attributed to illegal fishing during prescribed closed seasons. However, it was not until around the mid-1980s that it was officially recognized that the fishery had collapsed.

Public education leading to voluntary compliance is the best strategy of ensuring that regulations are obeyed. However, punitive measures must always be attached to any legislation to act as a deterrent to non-compliance. The fines should both fit the crime and be significant to the offender (King 1996). The premise used in this paper is that a fine will only be effective if it exceeds the profits that could be garnered by persons flouting the regulations. Using a variety of source material, including both published and unpublished reports on the fishery, Official Gazettes and newspapers, this paper attempts to offer a simple, economically based retrospective analysis of the profitability of sea-egg fishing in Barbados and the adequacy of imposable fines in managing this fishery.

METHODS

Declining sea-egg abundances were reported at many popular fishing sites during the early 1980s. However, it was not until around 1983 that declines in abundance were observed on all coasts by some fishers (Scheibling and Mladenov 1987). Given that fishers were not necessarily site specific, they would tend to focus their efforts on sites that were productive. Therefore, for the purposes of this study, it was presumed that the critical point at which fishers could not take enough sea-eggs to make their normal profits was when the numbers of sea-eggs at all available sites had declined significantly. All fishers agreed that the east coast was the last bastion for local sea-egg stocks and that the significant decline in populations along this coast was observed in around 1983. Therefore, for the purposes of this economic study the point of collapse of the sea-egg fishery is taken as between 1983-1984, the first season that the decline had reached island-wide proportions.

No quantitative catch and effort data were found for the local sea-egg fishery. However, based on interviews with sea-egg fishers, conducted in 1986, Scheibling and Mladenov (1987) estimated that on a daily basis, fishermen sold between 30-150 sea-egg shells (mean = 78.7) prior to the mid-1980s collapse and between 2-24 shells (mean = 9.4) following the collapse. Using these mean catch sizes, estimates of mean daily revenue from sea-egg sales were calculated based on price data obtained from several sources, for the period 1973-1994 (Table 2), by multiplying the cost per shell by the respective mean catch size (78.7 for years before 1984 and 9.4 for years after 1984). From these calculations it was possible to estimate the revenue that a fisherman taking an average catch in a day would have made in each year.

Using the estimated mean daily revenue of a sea-egg fisherman in 1973 ($78.70) as a basal value and the annual increase in mean wage rates as calculated by the Central Bank of Barbados using the Laspeyres Wage Rate Index for Barbados (CBB, 1995), it was possible by calculation, to estimate what a person earning that amount of money ($78.70 per day) in 1973 would have earned in each successive year. The Laspyres Wage Rate Index used by the Central Bank is an arithmetic mean of wages and salaries for hourly-paid skilled labourers in several employment sectors, using a 40-hour week as the basis for calculation. The values were weighted based on the percentage of the total employment provided by each sector, except where such data was unavailable when percentage contribution to GDP by the sector was used instead. The basal year used is 1980 (CBB 1995). For this study, the wages presented were calculated based on the means over all the sectors and therefore provides a general estimate based on most kinds of employment in Barbados. Simple linear plots were used to compare the rate and pattern of increase in potential earnings from sea-egg fishing over the years with the mean estimated wages earned by persons in other forms of employment. The hourly income for a fisheries assistant employed by Government has been included in some years to provide a benchmark for comparison of the calculated mean estimated wages with real wages.

Table 2. Retail prices reported for sea-egg half shells and information source. *Price converted per shell from price quote per 1 litre container by formula 4 shells=1 litre.

Year	Retail price (¢)	Reference source
1938	3	Report of the Royal West India Commission, 1939
1942	5	H. H. Brown, 1943
1945	8	Control of Prices (Defense) (Amendment) Order 1945 No. 15
1946	8	Control of Prices (Defense) (Amendment) Order 1946 No. 19
1947	8	Control of Prices (Defense) (Amendment) Order 1947 No. 39
1948	8	Control of Prices (Defense) (Amendment) Order 1948 No. 19
1949	8	Control of Prices (Defense) (Amendment) Order 1949 No. 17
1950	8	Control of Prices (Defense) (Amendment) Order 1950 No. 23
1952	12	Advocate Newspaper, 1952-09-02
1953	14	Advocate Newspaper, 1954-09-02
1954	16	Advocate Newspaper, 1955-09-02
1957	20	Advocate Newspaper, 1957-09-03
1960	25	Advocate Newspaper, 1960-09-02
1966	30	Advocate Newspaper, 1967-09-01
1967	30	Advocate Newspaper, 1967-09-01
1968	35	Advocate Newspaper, 1968-09-03
1973	100	Advocate Newspaper, 1974-09-04
1974	125	Advocate Newspaper, 1974-09-04
1978	175	Nation Newspaper, 1978-09-01
1979	200	Advocate Newspaper, 1979-09-11
1982	375	Nation Newspaper, 1982-09-03
1985	600	Scheibling and Mladenov, 1987
1986	625	Sunday Sun Newspaper, 1986-09-07
1989	800	Sunday Sun Newspaper, 1989-09-03
1990	1000	Advocate Newspaper, 1990-09-02
1991	1000	Advocate Newspaper, 1991-09-02
1993	1000	Nation Newspaper, 1993-09-02
1994	2000*	Saturday Sun Newspaper, 1994-11-18

Terms of imprisonment were included as possible punishment for illegal harvesting of sea-eggs in some versions of the various relevant Acts. However, in reality breaking the regulations are misdemeanor offences and offenders would hardly have faced imprisonment. The imposition of fines was the most likely punishment for illegal sea-egg harvesting. As such, this study only focuses on the impact of the maximum imposable fines as deterrents to illegal sea-egg harvesting. For this analysis, simple linear graphs were used to compare the annual estimated revenues for mean sea-egg catches using the estimates of catch size and prices presented above for fishing periods of 1, 2 and 7 days, to the maximum fines

imposable for illegal sea-egg harvesting in force in the corresponding years.

RESULTS AND DISCUSSION

The plot of estimated revenue earned from sea-egg sales in Figure 1 illustrates that the revenue from sea-egg sales increased at roughly the same rate and pattern as ordinary wages between 1973 - 1979. However, from 1979 to 1982 the rate of increase in revenue from sea-egg sales substantially exceeded the rate of increase in mean ordinary wages. Note that although no price data could be found for the years 1980 and 1981 the increasing trend fits well with the apparently exponential trend in price increases occurring from around the early 1970s. From 1986, the revenue from sea-eggs fell dramatically, well below that of the predicted regular wages, and only increased again slightly in 1994. Over this period prices continued to rise but the decline in total revenue was driven by the presumed marked decline in catch sizes.

In essence, these graphs suggests that the profitability of sea-egg sales increased at a faster rate in the years leading up to the mid-1980s collapse than the rate of increase of regular mean wages. The high profitability of the fishery is further emphasized by comparison with the wages that a fisheries assistant, a junior technical government post, would have received in the same years. Given the low capital and operational costs incurred for harvesting and selling sea-eggs and the low level of skill needed to fish the animals, it is quite clear that the fishery at that time would have been very attractive from a financial perspective for anyone capable of free diving. Increased profitability would have encouraged increased fishing effort such as the length of fishing time, on the part of the harvesters. It would also be understandable why many non-professional fishers would have entered the fishery especially in this period of maximum profit making. This would have resulted in a marked increase in total fishing pressure, both in terms of the number of persons fishing and the fishing time per person. Such increased pressure could easily lead to over-exploitation of the resource.

It should be noted that one of the forces that may have driven the price of sea-eggs up in the first place was increasing scarcity of the resource. Signs of resource depletion in the early 1980s had been reported at the time (Hickey 1983, Scheibling and Mladenov 1987). However, in the case of the sea-egg fishery an increase in search time is theoretically all that would be required to gather a profitable catch from a stock that had only just started to decline in numbers. An increase in personal fishing effort costs nothing other than physical exertion to the fisher. It is only after the stock has collapsed and there are too few sea-eggs to be found that the fisher will not, despite his best efforts, be able to gather a profitable catch.

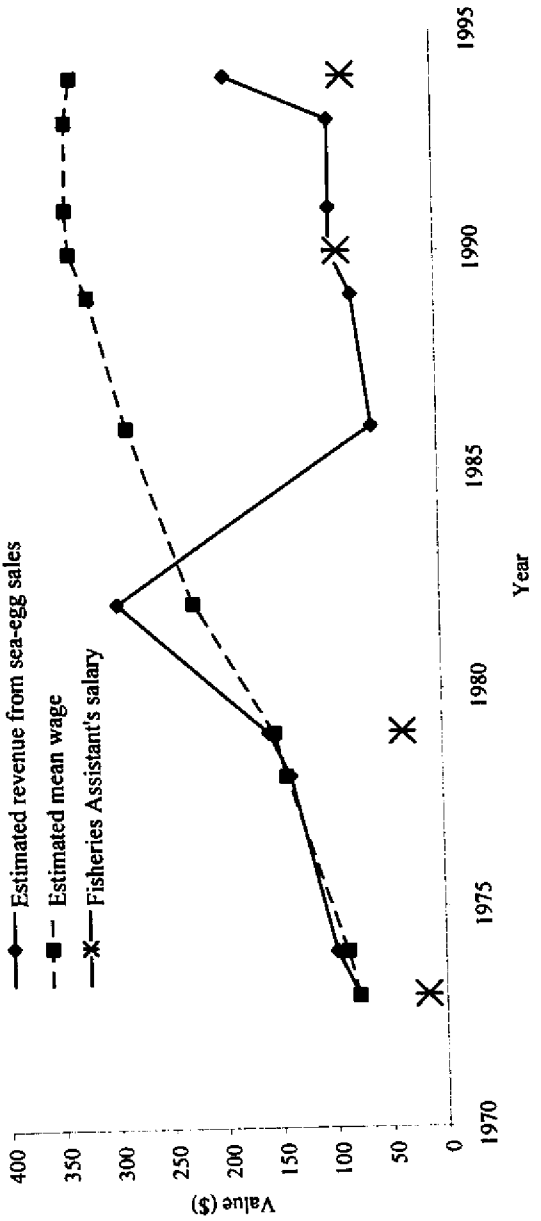


Figure 1. Estimated daily revenue from sea-egg sales compared with estimated mean daily wage, based on Laspeyres Wage Index for Barbados and with daily salary of a Fisheries Assistant, an example of a junior technical government post (1973 - 1994).

One economic mechanism to break the cycle of increasing fishing effort in response to increasing profitability and *vice versa* is to control the maximum retail price of the commodity. The rationale for such a measure is that opportunistic part-time fishers seeking quick financial rewards would be deterred from participating in the fishery, as they would not be able or inclined to spend the necessary time fishing to make the profits they desired. Only persons who truly relied on the income from sea-egg fishing would have continued to fish the resource and expend the time and energy needed to make their efforts financially worthwhile. However, this system would have resulted in increased financial hardship on full-time fishers, as while the money from the fishery only supplements the total earnings of part-time fishers, it represents the total or a much more substantial portion of the total earnings of the full-time fishers.

There are many other more sociologically sensitive methods of controlling the number of persons involved in a fishery that could have been used. One example is the use of a licensing system that only allowed true fishers to harvest the resource. High prices for the commodity may actually have assisted such a licensing system in protecting the stock, as fishers would not have needed to collect such large numbers of sea-eggs to earn a reasonable income. It is, therefore, recommended that such a licensing system be put in place as part of the management system of this fishery.

One of the potential negative impacts of out-of-season harvesting is the increased risk of taking animals during their spawning season, thus reducing the reproductive potential of the stock and consequently the size of the succeeding generation. The other negative impact is taking animals before their gonad volume has increased following spawning, resulting in lower yield and more animals being harvested to supply the demand for roe.

Mahon and Parker (1999) reported that many fishermen interviewed admitted to fishing sea-eggs illegally. Faced with the prospects of increased competition for the dwindling resource during the legal fishing season, many persons would have been tempted to harvest the animals before the season officially began to ensure that they were able to gather a sizeable and profitable catch. The additional "black market" price that out of season sea-eggs would have fetched would have further encouraged those willing to engage in premature harvesting. The reaction would of course be for even the most responsible fishers to engage in the practice, if for no other reason than financial survival. Many fishers suggested that they would not have engaged in out of season fishing if it were certain that others were not going to (Mahon and Parker 1999). The only real deterrent to curb such a trend would have been the threat of harsh punishment.

Figure 2 clearly indicates that the revenue derived from just two days of collecting an average size sea-egg catch exceeded the maximum fine that could be imposed in the years prior to the mid-1980s stock collapse, from as early as the 1960s. Essentially the fisher only needed to successfully illegally fish for two days to earn enough money from the activity to cover the fine. Past this point any additional fishing would have been pure profit. It is well accepted that government's policing of the sea-egg fishery has traditionally been poor. There are several reasons

for this, which will not be dealt with here. What is relevant to this discussion is that the chance of a fisher being caught and charged with illegal sea-egg fishing was small. With the very slim chances of getting caught and the low fines that were easily covered by two days of fishing, it is understandable why fishers would have found it tempting to engage in illegal fishing during this period. With a chance of earning as much as $2,066 for one week of collecting an average number of sea-eggs in 1982, it is not surprising that people would have been encouraged to flout the law especially at this time. Therefore, it is suggested that the fines that could be imposed during the years prior to the stock collapse were totally inadequate as deterrents to illegal fishing.

The substantial fine of $50,000 imposed by the Fisheries Management Regulations of 1998 for illegal fishing activities including those related to the sea fishery, marks a dramatic change in the policy of Barbadian governments regarding punishing offenders of fisheries' legislation. The basic tenet of setting the size of a fine is that the fine must match the weight of the crime. The significant increase in penalties attached to illegal fishing activities clearly demonstrates that the present government is of the view that the threats posed to fished resources, such as sea-eggs is much greater than in the past. However, the severity of the penalties may generate additional problems. For example, persons may be less willing to report offences if they are aware that in so doing they expose the perpetrators to such severe penalties (Dr. J. Horrocks pers. com.). In addition, to escape prosecution, offenders may be more inclined to offer bribes to persons that may potentially report on them and *vice versa* (Dr. D. Brown pers. com.). However, such a large fine should act as an effective deterrent to all but the most determined of poachers.

These historical economic analyses suggest that increased fishing effort driven by high profitability of the fishery and illegal harvesting, not effectively deterred by the system of fines in existence at the time, probably contributed significantly to the over-exploitation and eventual collapse of the Barbados sea-egg stocks. Local stocks have not yet recovered from the decline, and the future of the fishery remains bleak. However, it is hoped that the lessons learned from this experience will not be ignored and can be applied to successfully manage other easily accessible fisheries such as conchs and lobsters.

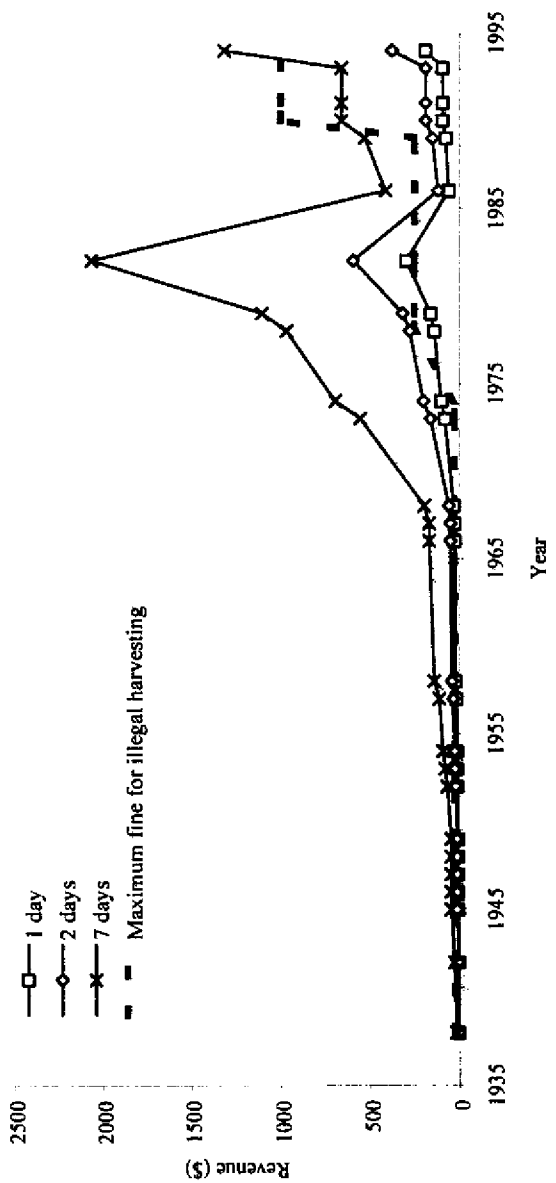


Figure 2. Comparison of estimated revenues from mean catches of sea-eggs for 1,2 and 7 days of fishing with maximum fines for illegal fishing (1993-1994). See text for methods of calculation.

LITERATURE CITED

Brown, H.H. The sea fisheries of Barbados. *Development and Welfare in the British West Indies*. Bull. No. 20. 32 pp.

Central Bank of Barbados. 1995. Annual Statistical Digest. Central Bank of Barbado., 240 pp.

FAO. 1995. Code of Conduct for Responsible Fisheries. Food and Agricultural Organization. 41 pp.

Fisheries Division. 1997. Barbados Fisheries Management Plan: Schemes for the Management and Development of Fisheries in the Waters of Barbados. Ministry of Agriculture and Rural Development, Barbados. 62 pp.

Hickey, A. 1982. *The Reproductive and Fisheries Biology of Tripneustes ventricosus (Lamark)*. Ph.D. Dissertation. University of the West Indies, Barbados. 325 pp.

Hughes, G. 1750. *The Natural History of Barbados*. London, England. 314 pp.

King, M. 1996. *Fisheries Biology, Assessment and Management*. Fishing News books. Oxford, England. 341 pp.

Lewis, J.B. 1958. The biology of the tropical sea urchin *Tripneustes esculentes* Leske in Barbados, British West Indies. *Canadian Journal of Zoology* **36**: 607-621.

Mahon, R. and C. Parker. 1999. Synopsis of technical and fisherfolk information on sea-eggs, *Tripneustes ventricosus*. In: Mahon, R and S. Almerigi. Final report for: Community-based sea urchin management. Prepared for Barbados Coastal Conservation Programme (Phase 1).

Scheibling R.E. and P.V. Mladenov, 1987. The decline of the sea urchin *Tripneustes ventricosus*, fishery of Barbados: A survey of fishermen and consumers. *Marine Fisheries Review* **49**:62-69.

Smith, A.H. and F. Berkes. 1991. Solutions to the "Tragedy of the Commons": Sea-urchin management in St. Lucia, West Indies. *Environmental Conservation* **18**:131-136.

Wiles, D. 1949. The Fisheries of Barbados and some of their problems. *Proceedings of the Gulf and Caribbean Fisheries Institute* 1:65-69.

Managing the Managers – Changing the Emphasis of Fisheries Management

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ABSTRACT

Many Caribbean countries are faced with the challenge of managing complex fisheries against the backdrop of seemingly inadequate human and financial resources. This has often led to frustrated resource managers and ineffective management. Perhaps we need to review our approach to fisheries management in the region and adopt an approach which can allow us to be more effective, in spite of our human resource and financial constraints. It is being suggested:

i) That it is important to build a strong team (team building should start with the local fisheries division and branch out to encompass the fishermen, other resource users, and the regional team players);
ii) Pay more attention to improving synergy among resource managers (this has the potential to significantly improve effectiveness);
iii) Fully utilise local knowledge of the resource;
iv) Change the structure of the fisheries division to reflect the social importance of the fishing industry,
v) Tailor make fisheries training to the needs of the local fisheries division, build in flexibility to allow for responsiveness to change;
vi) Utilize simple yet effective tools such as public awareness campaigns).

It has been said that we manage people, not fish. Perhaps if we place the spotlight on the human factor, we may discover that we have the tools, which we need after all.

KEY WORDS: Human resource management, team building, public awareness

BACKGROUND

During November of 1998, the Government of the British Virgin Islands recruited a Fisheries Officer from Barbados. Armed with basic academic qualifications in Biology and Natural Resource Management, this Officer felt ready for the challenge, excitement and opportunity of working in a discipline that had for a long time held her interest. However, she was soon to realize that her task was going to be more challenging that expected.

The Officer found herself with responsibility for one of the five Units within the Government Department tasked with management of the Territory's natural resources (including fisheries resources). The role of the Unit encompassed all the

roles/functions normally associated with fisheries management. This included marine research, fisheries extension, maintenance of fisheries infrastructure, development of policy and legislation, surveillance, and enforcement.

The Unit had attempted to address all of the above functions in the past with varying degrees of success. Previous fisheries officers had attempted to focus on a few of these areas (namely data collection and research), but few programs had been sustained as a result of these initial attempts. Each of the major functions of the Fisheries Unit has the potential to be a specialist area in itself. However, while it may be argued that the Fisheries Unit had been able to make some progress over the years, progress was slow, sometimes difficult to identify, and seemingly characterized by slow changes around a mean. In Caribbean language, it was often a matter of "one step forward, two steps backward". Several of the programs had never achieved any momentum and the work of the Unit was characterized by an *ad hoc* approach to accomplishing poorly defined goals and objectives. The performance of the Unit tended to be mediocre. This state of affairs had become accepted as "the way things were" and perhaps had to be, and individuals within the Unit had long given up striving for excellence.

However, it soon became clear that fisheries management in the British Virgin Islands (BVI) was reaching a turning point. There were signals in the general climate of the country that it was time for change. The Territory was approaching crossroads and was coming to the recognition that it would need to change its way of doing things if it was to remain competitive in international markets. This recognition resulted in the Public Sector Development Program (PSDP), an ambitious program aimed at creating significant change in the way the public sector of the BVI did business. Prior to the PSDP, a lot of work had also gone into creating the National Integrated Development Strategy (NIDS). In the process of developing the strategy, a lot of thought had been put into analyzing the status of the major economic sectors of the environment and in determining the path that should be taken to developing these sectors. The fisheries sector fell under the purview of the productive sectors as well as under environment. Both of the above mentioned programs (PSDP and NIDS) included extensive consultation with persons at several levels within the public service, as well as with members of the public. The Fisheries Management Plan for the BVI had been developed as part of an initiative of the Natural Resource Management Unit of the Organisation of Eastern Caribbean States (this plan was completed in 1998), a comprehensive piece of modern fisheries legislation had been passed (the 1997 Virgin Islands Fisheries Act). Politicians had gotten wind of the fact that fisheries was a sector with potential to make a more significant contribution to the economy than is occurring at present, and as a result fisheries had become a key topic for discussion on the political agendas. All of this meant that the time was right for fisheries managers who were struggling for years, to finally have the opportunity to make a difference.

While all of the above was occurring at the policy level, the fisheries resources of the BVI were facing new threats, or in some cases, old threats were becoming more serious. With the BVI going into a phase of rapid development, fisheries

resources were coming under increasing pressure from developmental activities such as land reclamation, dredging, and destruction of habitat for use as marinas. There was increasing concern about the status of nearshore reef resources, which were thought to be showing signs of overfishing. In addition, the Government of the BVI was being increasingly faced with an urgent need to find mechanisms to address the high levels of illegal fishing in its waters.

With the increasing expectations of the fisheries sector, the anticipation of what would be needed to address the changes which were about to occur in the public sector, and the reality that if the fisheries resources weren't adequately managed they would be lost, it was clearly time to reorganize the Fisheries Unit or face the possibility of the Unit becoming totally ineffective. However, before setting out to solve problems and create change, it was necessary to first clearly define the problems and constraints to effective fisheries management in the BVI. This paper identifies the challenges (problems/constraints) being faced by the Fisheries Unit, it discusses some of the approaches that have been taken to create change, it summarizes the lessons learned, and it attempts to apply these lessons to other aspects of the work of the Unit.

CHARACTERISATION OF FISHERIES MANAGEMENT IN THE BRITISH VIRGIN ISLANDS

Formal fisheries management in the British Virgin Islands is less than twenty-five years old. As in other Caribbean countries, the functions of fisheries management were initially tied to those of agricultural development. However, in the last decade, fisheries management has been conducted through the Conservation and Fisheries Department, a Department with a wide range of responsibilities that run the gamut of environmental management. As a result, fisheries management is a new and poorly understood discipline in the British Virgin Islands. This lack of understanding of the complexity of fisheries management issues is sometimes reflected in the quality of decisions that are made with regard to resource allocation, natural resource management, and human resource development. The challenge is to educate. In order to be effective, different approaches to building awareness and understanding of fisheries issues would be needed for different target groups. The policy makers and the resource managers are among the key groups that need to be targeted.

Another constraint faced by the BVI is the heavy reliance on the external labour force. In the short history of formal fisheries management in the BVI, there have been at least five Fisheries Officers. Several of these Officers have not stayed with the Department for more than two to four years (two years being the average length of a Government contract). This has resulted in a lack of continuity. It has also meant that the direction and focus of the Fisheries Unit also changed as Officers changed. To date, the BVI has been unable to produce a truly local Fisheries Officer, and this continues to be of concern to the Conservation and Fisheries Department. Another problem created by this high turnover is that there is the

possibility for key posts to remain open for a long period of time, as occurred prior to 1998. This causes the Fisheries Unit to lose momentum, and may also have a negative impact on program development. Related to the above problem is the recognition that not enough persons are recruited into or staying in the field of fisheries management. An alternative way of looking at this is that the right type of person is not being recruited.

To add to these difficulties, the staff of the Fisheries Unit is inadequately trained and inexperienced in fisheries management. This places serious limitations on the most enthusiastic and energetic of staff, and often leads to frustration as a result of the perceived inability of individuals to create change.

Another challenge to fisheries management in the BVI results from its geography. Several islands make up the Territory, and each is unique with respect to its fisheries. Resources differ from island to island, social as well as economic aspects differ, and as a result the management needs of each island may differ. The BVI has four major population centers (Tortola, Virgin Gorda, Anegada and Jost Van Dyke), and the situation on each island may demand a special approach to management. The other problem that results from this is working out the logistics of getting to the 'outer' islands often enough to make a difference (the Conservation and Fisheries Department is physically located on Tortola).

Within the Fisheries Unit and amongst the fishermen, there is a perception that policy makers are not genuinely committed to sustainably managing the fisheries, and that this has been limiting the development of the fisheries.

While the Government may have a key role to play in guiding fisheries management, it has been recognised that this cannot be done without the cooperation of the fishermen. While the Fisheries Management Plan and the Fisheries Act of the BVI encourage fisher participation, the mechanisms are not in place to foster this type of participation.

CHALLENGES TO BE FACED AS THE BVI MOVED TOWARDS EXCELLENCE IN FISHERIES MANAGEMENT

Given what has been stated above, there are several things that the Fisheries Unit of the BVI must master as it moves towards playing a more significant role in the management of the fisheries resources of the Territory. These can be briefly summarised as follows:

i) Make the most efficient use of current resources, while making preparations for the acquisition of the resources needed.
ii) Develop and build an appropriate foundation/framework that would facilitate the current and future work of the Department.
iii) Develop an approach to fisheries management in the BVI which is sustainable – fisheries management in the BVI cannot rely on hard to acquire skills.
iv) Find ways of utilising the strengths of the persons within the Fisheries Unit while building on the weaknesses (see the strengths more than the

weaknesses).

v) Develop a way of tailor making training of staff to the needs of the Department. Training should be relatively low in cost, easy to obtain, easy to achieve over a short time span or short blocks of time and should make an immediate difference in the ability of the Territory to manage its resources.

vi) Develop commitment and dedication to the tasks at hand and loyalty to the organisation.

vii) Build a learning organisation. Such an organisation would allow persons to learn from their mistakes, and encourage them to take the risks that may be necessary in the quest for success.

viii) Challenge the traditional approaches to fisheries management where they do not meet the needs of the Territory or where they are not appropriate in the context of the country.

LESSONS LEARNED

People generally resist change. Reasons for this differ and may include lack of understanding of the reason for change and the change process, fear that they may be displaced as a result of change, or discomfort with the uncertainty associated with periods of accelerated change. As perhaps should have been expected, there was a slowness in responding to the change in direction of the Fisheries Unit. However, after approximately two years there is an increasing willingness and ability to respond to change and an understanding of the need to move in a different direction. In the interim, a lot of lessons have been learned.

Lessons were learned about the process of change itself, and about change management. Creating major change is easier if persons are prepared beforehand for the change that is expected. The more people understand about where the organization wants to go, how it hopes to get there and where they fit in, the easier it becomes for them to adapt to the change. Several techniques make be used to assist in achieving this. The vision of the organization must be clear to all involved. It is sometimes better to paint a detailed picture rather than a vague sketch. Commitments much be obtained from persons for achieving small steps along the way (huge steps may appear a bit daunting at first). The concept of the psychological contract may be useful here, in such a contract there is a clear agreement between two persons about what is to be done and how. Feedback is used to clarify that both persons understand the agreement in the same way. People must be encouraged to think critically. Rather than providing an answer for every query, or a solution for every problem (or as Caribbean persons would say, a plaster for every sore), encourage persons to become actively involved in developing the solutions or ask them to think of why the solution you suggested might be a good one (can they think of any merits to the suggested approach?). A truly participatory approach usually results in more commitment to action. Patience is another virtue that must be learned. Persons may take a lot longer than you expect to respond to

change. However, it must be remembered that they may not have the same training, experiences or perspectives that you have (and which you may actually have gained over a long period of time without realising it). They therefore cannot be expected to respond in the way that you would. To some extent, people must be allowed to learn and change at their own rate. However, once the environment is one that fosters that change, it will probably occur.

Building a team also takes time and the elements of a sucessful team must be clearly understood. First, it must be acknowledged that a team can accomplish a lot more (and accomplish it much more easily) than individuals working alone. Also a team is much more than a group of individuals working towards the same goal. Team building is a process, and it depends on the interactions between the individual members of the group. Team members must develop an understanding and tolerance for each other; they must develop a set of shared values, including a shared commitment to work together to achieve their objectives. A successful team will also develop a strong team identity. The team leader, or facilitator (the person managing the managers), must find ways to identify the contribution that each person can bring to the team and encourage the other team players to recognise what these contributions are. A lot of effort must go into ensuring that each person understands their role, and is made to feel comfortable as they try to play that role. Persons must be allowed to work in an environment where they can take the risks that may be necessary for them to grow as an individual, and for the organisation to move forward. Each member of the team must feel valued as an individual. While there should be attempts to meet the needs and aspirations of individuals, this should be done within the context of the team and not at the expense of it. Where there is the opportunity to recruit new members to the team, care should be taken not to select persons on the basis of academic qualifications alone; rather attitudal competencies and ability to work as part of a team should be taken into account. Several tools may also be used to enhance the performance of the team. One human resource management tool that can be used successfully (if well understood), is the Performance Management Agreement (PMA). In the Fisheries Unit of the BVI, this tool has been used to give team players a very clear understanding as to what role they are expected to play on the team and within the overall development of the organisation. The PMA, when properly used, will set very clear standards, objectives, and guidelines. PMAs can be designed to reflect the conceptual picture of where the organization wants to go and how it wants to get there. While each PMA is separate, they should link together to from a whole (like pieces in a puzzle). An important aspect of the PMA that is being used by the Government of the BVI is that there is a section where persons can identify and commit to the actions that would be necessary to enhance the ability of the individual to perform and by extension improve the probability of the organisation achieving success. PMAs allow for a stepwise progression in a forward direction and can therefore act as a link between what occurs in the present and what is desired in the future. PMAs are dynamic and can be one means by which an organisation may achieve the flexibility to respond to new challenges. Used wisely, the PMA can be a method by which

persons can be encouraged to make use of their current skills while being challenged to improve.

Another tool is the development of effective linkages with other stakeholders who can assist in facilitating change, wherever these persons may be found. The Fisheries Unit has been able to benefit from relationships from key Departments and other organizations both within and outside the country. Further development of these relationships and development of relationship with other key individuals and organizations can greatly enhance the effectiveness of the Fisheries Unit at little additional cost.

CHANGING THE EMPHASIS

Given the changes in the approaches and performance of individuals within the Fisheries Unit that have occurred within the last two years, there is reason to believe that the team approach can be successfully used to improve the performance of the organization. It must be recognized that team building is a process whereby a group evolves into a team, i.e. a collection of persons with similar objectives moves towards a becoming a group of persons who work skillfully together to achieve these objectives. Some schools of thoughtstate that there are three phases in the progression from group to team (Honey 1997). The first stage is the chaotic stage, perhaps the most discouraging stage. Individuals within the group have not learned to accomplish goals together as yet, nor have they defined the rules and procedures that characterize how the group works. In the second stage, the formal stage (the Fisheries Unit of the BVI is arguably at this stage now), the group begins to develop ways of working together, it formalizes its procedures, and defines the roles of its members. In this stage the role of the group leader is emphasized. In the third stage (if the group survives the first two) the group develops a synergy and the ability to work together well, each person's work enhancing that of the others. In this stage individuals are more confident of themselves and in the other team members; they have built an atmosphere of trust, openness and cooperation. During this phase the leader/facilitator of the group (now team) can participate more in the activities of the team rather than provide direction. It not essential for every member of the team to be involved in the successful completion of every task, and wisdom must be used in determining when the team approach can enhance the process and when it can act as a hindrance. For instanc,e the entire team may not have to be involved in routine daily tasks.

The team approach may solve the problem of making the maximum use of current resources, but this alone is not enough to solve the problems associated with fisheries management in the BVI. The most serious constraint to the effectiveness of the Fisheries Unit of the BVI is development of human resources. Traditionally throughout the Caribbean, Fisheries Divisions and Departments have placed an emphasis on the biological aspects of fisheries management, i.e. some Departments have focused on scientific data collection, stock assessment, and biological solutions to problems. At the moment, this approach is not practical for the BVI. Past

attempts at focusing on scientific projects and programs has meant that these programs have lasted only as long as there is a Fisheries Officer with that capability. It takes at least five years to develop a good scientist (and this is probably a conservative estimate), and then that scientist needs a lot of support services if they are to be effective. With the diverse fisheries resources present in the BVI, several scientists would be needed to make a meaningful impact.

It is therefore being suggested that the Fisheries Unit see its role as coordinating Fisheries Management and ensuring the effective and efficient management of the resource. Rather than expending limited resources trying to develop the capacity to do everything itself, the Department should focus more strongly on developing the linkages that could facilitate its work. For instance, the Unit could work closely with the local Community College, as well as with regional Universities (such as the University of the West Indies and the University of the Virgin Islands), to ensure that the necessary scientific research is done. The Unit should further ensure that the research done meets fisheries management needs.

Education is also a key element on which to focus. An aggressive public awareness campaign, tailor made to target the specific groups of persons (e.g. students, tourist, fishermen, policy makers etc.), has the potential to create more change than merely passing regulations that may be difficult to enforce. Many people in the community have expressed a willingness to change their behaviors, but they need more information and guidance to do so. Such a public awareness campaign should have specific objectives and should be based on the Fisheries Management Plan of the Territory.

More attention should be given to the socioeconomic aspects of the fisheries, especially since a fisheries management solution that is socially unacceptable is likely to fail. This shift in focus should be reflected in a change in the composition of the Fisheries Unit, and a social scientist (or a person from a similar discipline) should be a part of the Fisheries Team.

Having a person trained in understanding social behavior and perhaps community development on the team should enhance the ability of the Fisheries Unit to do extension work. Within the BVI, the need for, and importance of, involving fishermen and other stakeholders in the decision making process has been identified, accepted and written into law. The challenge will come in implementing these concepts and ideas. The Fisheries Unit will have to act as a catalyst for participatory fisheries management, as this type of thinking and decision making is relatively new to many fishers; a substantial amount of effort will be required to produce strong, durable, and effective fisher organizations. Appropriately trained professionals, along with knowledgeable stakeholders, such as fishermen, will ensure that useful information is harnessed so that it is available for use in fisheries management.

More attention should also be paid to developing easily available, low cost, fisheries specific training for fisheries personnel and other interested persons. This may not be difficult, as the H. Lavity Stoutt Community College within the BVI is already looking at the possibility of becoming a center of excellence in marine studies, and It may be appropriate for the College to incorporate fisheries

management into their curriculum planning.

Natural resource management, and by extension fisheries management, is a multi-disciplinary subject. Many universities offer fisheries management programs that provide students with exposure to fisheries biology, fisheries management, fisheries legislation and policy, and other relevant subjects. However, natural resource management is not wholly about managing natural resources; it includes managing the use of those resources so that they continue to be beneficial to mankind – natural resource management is about people. It is about how natural resources have in the past, or will in the present or future, impact people (and vice versa). It is important that decision-makers are attentive to the people. The discipline of fisheries management may benefit from the body of knowledge and experiences that already exist in other disciplines, such as human resource management and sociology. By successfully applying that body of knowledge and applying the energies of a cadre of enthusiastic, efficient, and effective natural resource managers, the Caribbean could gain the ability to more effectively manage its fisheries resources

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SUGGESTED READING

Bradford D.L. and Cohen A.R. 1984. *Managing for Excellence: The Guide to Developing High Performance in Contemporary Organisations*, John Wiley and Sons. New York, New York U.S.A. 289pp

Honey P. 1997. *Improve Your People Skills*. Short Run Press Ltd. Great Britain 165 pp.

Katzenbach J.R. and Smith D.K. 1993. *The Wisdom of Teams Creating the High Performance Organisation*, Harvard Business School Press. Cambridge, Massachusetts U.S.A. 265 pp.

Some Aspects of the Culture of Red Snapper

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ABSTRACT

Information is scarce on the optimal rearing conditions for red snapper (*Lutjanus campechanus*). Rearing and large scale production of red snapper have been hampered because it is difficult to produce enough prey of appropriate size to ensure survival of larvae to a size at which they can consume *Brachionus plicatilis* and artemia nauplii. Secondly, it has not been possible to rear snapper larvae in small containers for short term experiments; all successful rearing to date has been in containers $\geq$ 200 L. We evaluated the relationship between copepod nauplii available per fish on the day of first feeding and survival of red snapper. Additionally, we assessed the suitability of various types/sizes of containers, from 10 L black plastic containers through 20 L polycarbonate containers to 200 L black plastic containers filled with 100 L of seawater, for rearing snapper larvae. There was a significant positive correlation between prey number per fish on the day of first feeding and survival of snapper (Spearman's rank correlation, $r_s = 0.83$, $n = 10$, $P = 0.013$). Similarly, larval survival was positively correlated with number of copepod nauplii/mL ($r_s = 0.73$, $n = 10$, $P = 0.029$).

Rearing studies using 10 L and 20 L black plastic containers resulted in 100% mortality of larvae by day 7 post-hatch. Experiments carried out using polycarbonate containers and 200 L black tubs containing 50 L or 100 L of brown seawater resulted in 0 to 34% larval survival. Number of larvae that survived was significantly higher in polycarbonate containers (mean = 46.7$\pm$ 21.9 S.E.) than in black tubs with 50 or 100 L of water (mean=5 $\pm$ 4.67 S.E.) [Unpaired t-test value = 2.622, df = 5, P = 0.047]. Differences in larval survival in the culture containers probably resulted from interactions between the amount of light present in the containers and container color that, presumably, affected prey visibility to, and therefore consumption by larval snapper.

KEY WORDS: Larval survival, copepod nauplii density, culture tanks.

INTRODUCTION

Red snapper (*Lutjanus campechanus*) are offshore reef fish of economic importance (Goodyear 1995). They are long-lived, seem to have limited movement, and aggregate around structures as adults (Szedlmayer 1997, Szedlmayer and Shipp 1994) which makes them susceptible to overfishing. The juveniles are captured mainly in areas where water temperature is 24 – 26°C, salinity is around 35 ‰ and dissolved oxygen level is at least, 5 mg/L (Gallaway et al. 1999). Additionally, larval snapper settle out to the bottom of the ocean after about one month of pelagic existence and subsequently live in areas of the northern Gulf of Mexico where shrimp trawling intensity is high (Workman and Foster 1994). As a result, they suffer high by-catch mortality that substantially affects their population abundance and has necessitated the implementation of measures to reduce shrimp by-catch. Recently, much interest has grown in the culture and release of red snapper to assess the feasibility of enhancing the wild stock. However, there is very little information in the literature on the optimal rearing methods and conditions for lutjanids, in general, and red snapper in particular, even though attempts have been made to culture them (Rabalais et al. 1980, Minton et al. 1983, Turano et al. 2000).

Rearing and large scale production of red snapper have been hampered because it is difficult to produce adequate numbers of prey of appropriate size to ensure survival of a large number of larvae to a size at which they can consume *Brachionus plicatilis* and artemia nauplii, the prey commonly used for rearing larval fish. It has also not been possible to rear snapper larvae in small containers for short-term experiments. Thus, adequately replicated experiments to evaluate the effects of environmental conditions on survival of larval snapper have not been undertaken without running the risk of depleting available prey resource and number of larvae required for juvenile fish production. The objectives of this study were:

i) To determine whether survival of red snapper larvae is related to copepod nauplii available per fish on the day of first feeding, and

ii) To assess the suitability of various types/sizes of containers, from 10 L black plastic containers through 20 L polycarbonate containers to 200 L black plastic containers filled with 100 L of 30 ‰ seawater, for rearing snapper larvae.

MATERIALS AND METHODS

Larval red snapper produced in the spring and summer of 1999 and 2000 were stocked into 200 L or 1000 L culture containers a day after hatching. Culture containers were placed outside under a shed covered with a screen that eliminated about 25% of the solar radiation. Larvae were fed copepod nauplii harvested from copepod culture ponds. Larval density in the culture containers was 5 - 10 /L, and prey density was maintained between 1.0 and 6.0/ml. Water samples were collected in the morning prior to feeding fish, and in the afternoon after daily feeding to assess the density of nauplii in the culture tanks. Temperature varied from 25°C to 30°C, and salinity was maintained at about 35 ‰.

In another set of experiments, we assessed the survival of snapper larvae in two types of containers, polycarbonate and black plastic containers. First, we set up 10 L and 20 L black plastic containers in replicates, filled them with 30 ‰ seawater, and stocked them with snapper larvae. The larvae were then fed copepod nauplii at a density of about 2/ml for about seven days after which we compared survival of larvae in the two containers. In another experiment, we compared larval survival in 20 L polycarbonate containers and 200 L black plastic tubs containing 50 or 100 L of 30 ‰ seawater. Each container had 250 larvae in all experiments. The experiment lasted one week after which the number of larvae remaining in each container was counted after passing the culture water through a 65 μ mesh net. Data for 1999 and 2000 were pooled and subjected to a Spearman's rank correlation analysis to assess if there is a relationship between prey number and larval fish survival. We used a t-test following, log (1 + x) transformation of the data, to determine whether snapper larvae survived better in polycarbonate containers than in black plastic tubs.

RESULTS

There was a significant positive correlation between prey number per fish on the day of first feeding and survival of larval snapper (Spearman's rank correlation, $r_s = 0.83$, $n = 10$, $P = 0.013$). Similarly, larval survival was positively correlated with prey density, copepod nauplii/mL ($r_s = 0.73$, $n = 10$, $P = 0.029$). Survival of larval snapper ranged from < 1% to about 18% at prey densities of < 2 to about 3.5/mL, respectively (Figure1).

Rearing studies carried out using 10 L and 20 L black plastic containers resulted in 100% mortality of larvae by day 7 post-hatching. Experiments carried out using polycarbonate containers resulted in 3.6 to 34% larval survival, whereas survival in 200 L black tubs containing 50 L or 100 L of brown water were 0% and 0 to 7.6% respectively. Number of larvae that survived was significantly higher in polycarbonate containers (mean = 46.7 $\pm$ 21.9S.E.) than in black tubs with 50 or 100 L of water (mean = 5 $\pm$ 4.7SE) [Unpaired t-test value = 2.622, df = 5, P = 0.047] (Figure 2).

DISCUSSION

Survival of larval snapper after about 23 days of rearing in 200 L, 500 L, or 1,000 L of seawater ranged from about 0.3 to 18 %, and was affected by prey availability. Survival of larvae of other species of snapper were reported to vary from 0.9 % to about 16% (Doi and Singhagraiwan 1993, Duray et al. 1996a, Watanabe et al. 1998). Density of prey of appropriate size during early larval development is critical for larval survival. Below an optimum density, survival may be poor due to starvation; above a certain level survival may also decrease because of overfeeding or fouling of the culture water (van der Wal and Nell 1986). Prey density used for rearing marine fish larvae depends on the type of prey and fish. It

is usually 0.5 – 6 *Artemia* nauplii/ml, 1 - 10 copepod nauplii/ml, 5 – 20 rotifers/ml, and 100 dinoflagellates/ml (see review by Tucker 1998). Red snapper rearing practice, at present, at the University of Southern Mississippi Gulf Coast Research Laboratory consists of harvesting zooplankton (mainly copepod nauplii) from outdoor culture ponds and feeding them to fish during the first week of exogenous feeding before switching to enriched *Artemia* nauplii. The density of copepod nauplii during larval fish rearing in this study ranged from about 1.5 to 4.5 /ml (mean = 2.4) which falls in the lower end of the range usually used for rearing larval fishes (see Tucker 1998). In general, an increase in prey density up to a limit results in higher food consumption and therefore, larval survival (van der Wal and Neil 1986, Duray et al. 1996b, Duray et al. 1997), although it is also influenced by larval density (Hagen 1993). Our results suggest that increasing prey density and therefore, prey/larval ratio may increase red snapper survival. However, more adequately replicated experiments with larvae from the same batch of eggs needs to be conducted to establish optimum prey and larval densities required for maximum survival of snapper.

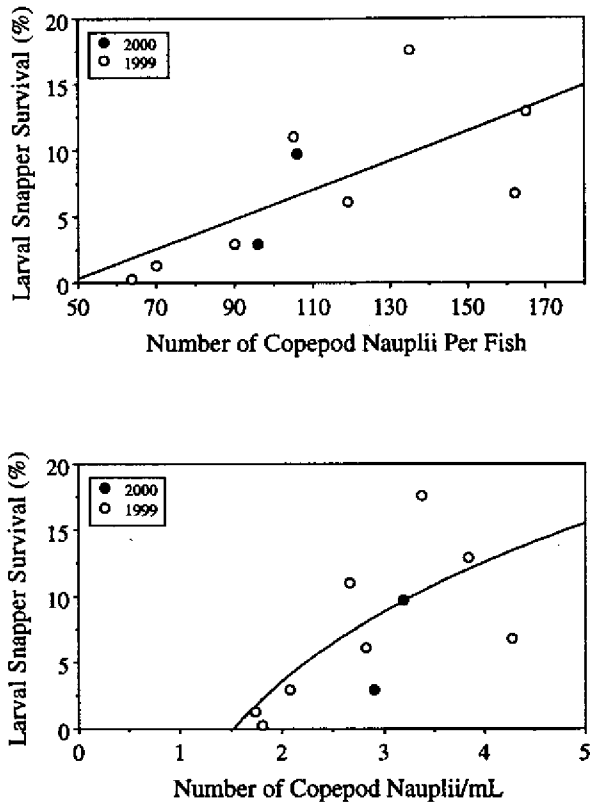


Figure 1. Relationship between larval red snapper survival (%) and copepod nauplii density.

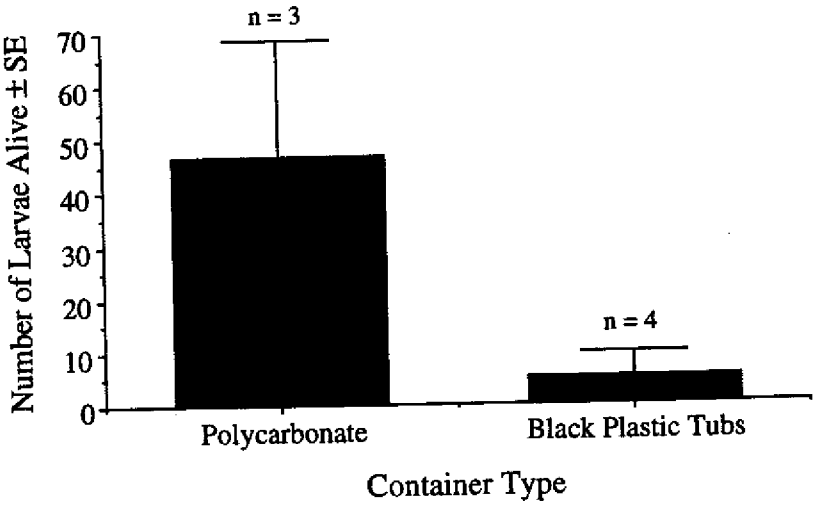


Figure 2. Effect of container type on larval red snapper survival.

Culture tanks used for rearing snapper larvae range in size from 300 L to more than 100,000 L (Doi & Singhagraiwan 1993, Riley et al. 1995, Duray et al. 1996a, Clarke et al. 1997, Watanabe et al. 1998). Not much success has been made in rearing snapper larvae in smaller containers for short-term experiments. We observed significantly higher larval survival in 20 L polycarbonate containers than in black plastic containers with 100 L or less water. All fish reared in 20 L black plastic containers and 200 L black tubs with 50 L of water died within five days. Differences in larval survival in the culture containers probably resulted from interactions between the amount of light present in the containers and container color that, presumably, affected prey visibility and feeding success. Culture tanks with dark colored walls are considered best for rearing marine fish larvae, perhaps because dark colors increase the visibility of prey to fish, reduce reflected light which might distract the larvae, and therefore increase larval food consumption and survival (Browman and Marcotte 1987, Tucker 1998). For example, survival of dolphin larvae was two times greater in black fiberglass tanks than in tan 30 L tanks (Ostrowski 1989). Nevertheless, for short-term experiments we do not recommend the use of black plastic containers with < 100 L of seawater, because of high mortality of red snapper observed in this study, but rather the use of 20 L polycarbonate culture tanks.

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LITERATURE CITED

Browman, H.I. and B.M. Marcotte 1987. Effects of prey color and background on feeding by Atlantic salmon alevins. *Progressive Fish Culturist* **49**:140-143.

Clarke, M.E., M.L. Domeier and W.A. Laroche. 1997. Development of larvae and juveniles of the mutton snapper (*Lutjanus analis*), lane snapper (*Lutjanus synagris*) and yellowtail snapper (*Lutjanus chrysurus*). *Bulletin of Marine Science* **61**:511-537

Doi, M. and T. Singhagraiwan. 1993. *Biology and Culture of the Red Snapper, Lutjanus argentimaculatus*. Res. Proj. Fishery Resource Dev. Kingdom of Thailand. 51 pp.

Duray, M.N., L.G. Alpasan, and C.B. Estudillo 1996a. Improved hatchery rearing of mangrove red snapper, *Lutjanus argentimaculatus*, in large tanks with small rotifer (*Brachionus plicatilis*) and *Artemia*. *Bamidgeh* **48**:123-132.

Duray, M.N., C.B. Estudillo and L.G. Alpasan 1996b. The effect of background color and rotifer density on rotifer intake, growth and survival of the grouper (*Epinephelus suillus*) larvae. *Aquaculture* **146**:217-224.

Duray, M.N., C.B. Estudillo and L.G. Alpasan. 1997. Larval rearing of the grouper *Epinephelus suillus* under laboratory conditions. *Aquaculture* **150**:63-76.

Gallaway, B.J., J.G. Cole, R. Meyer, and P. Roscigno. 1999. Delineation of essential habitat for juvenile red snapper in the northwestern Gulf of Mexico. *Transactions of the American Fisheries Society* **128**:713-726.

Goodyear, C.P. 1995. *Red snapper in U.S. waters of the Gulf of Mexico*. National Marine Fisheries Service, Southeast Fisheries Science Center, Contribution MIA-95/96-05, Miami, Florida USA.

Hagen, N. 1993. Effect of different prey- and larval densities on the gut content of plaice (*Pleuronectes platessa* L.) at initial feeding. Pages 180-182 in: B.T. Walther and H.J. Fyhn (eds.) *Physiological and Biochemical Aspects of Fish Development*. University of Bergen, Norway.

Minton, R.V., J.P. Hawke, and W.M. Tatum. 1983. Hormone-induced spawning of red snapper, *Lutjanus campechanus*. *Aquaculture* **30**:363-368.

Ostrowski, A.C. 1989. Effect of rearing tank background color on early survival of dolphin larvae. *Progressive Fish Culturist* **51**:161-163.

Rabalais, N.N., S.C. Rabalais and C.R. Arnold. 1980. Description of eggs and larvae of laboratory reared red snapper (*Lutjanus campechanus*). *Copeia* **1980**:704-708.

Riley, C.M., G.J. Holt, and C.R. Arnold. 1995. Growth and morphology of larval and juvenile captive bred yellowtail snapper *Ocyurus chrysurus*. *U.S. Fisheries Bull.etin* **93**:179-185.

Szedlmayer, S.T. and R.L. Shipp 1994. Movement and growth of red snapper, *Lutjanus campechanus*, from an artificial reef area in the northeastern Gulf of Mexico. *Bulletin of Marine Science* **55**: 887-896.

Szedlmayer, S.T. 1997. Ultrasonic telemetry of red snapper, *Lutjanus campechanus*, at artificial reef sites in the northeast Gulf of Mexico. *Copeia* **1997**:846-850.

Tucker, J.W. Jr. 1998. *Marine Fish Culture*. Kluwer Academic Publishers, Boston, Massachusetts USA. 750 pp.

Turano, M.J., D.A. Davis and C.R. Arnold. 2000. Observations and technique for maturation, spawning, and larval rearing of the yellowtail snapper, *Ocyurus chrysurus*. *Journal of the World Aquaculture Society* **31**:59-68.

Van der Wal, E.J. and J.A. Nell. 1986. Effect of food concentration on the survival and growth of Australian bass (*Macquaria novemaculata*) larvae.*Progressive Fish Culturist* **48**:202-204.

Watanabe, W.O., E.P. Ellis, S.C. Ellis, J. Chaves, C. Manfredi, R.W. Hagood, M. Sparsis and S. Arneson. 1998. Artificial propagation of mutton snapper *Lutjanus analis*, a new candidate marine fish species for aquaculture.*Journal of the World Aquaculture Society* **29**:176-187.

Workman, I.K. and D.G. Foster. 1994. Occurrence and behavior of juvenile red snapper, *Lutjanus campechanus*, on the commercial shrimp fishing rounds in the northeastern Gulf of Mexico. *Marine Fisheries Review* **56(2)**:9-11.

Culture of the Copepod *Acartia tonsa* Utilizing Various Artificial Feeds

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ABSTRACT

In the interest of increasing zooplankton yields from culture tanks several supplemental feeds were evaluated. Triplicated trials utilizing small 1,000 L tanks with no water exchange were sampled weekly during four weeks for copepod abundance. Abundance of *Acartia tonsa* nauplii decreased for the unfed control and tanks fed algae, bacteria, and Isomil®. Nauplii numbers increased in tanks fed artificial plankton, rice bran and Rotirich®

KEY WORDS: Copepod, nutrition, *Acartia tonsa*

INTRODUCTION

The most widely accepted food offered to the larvae of fish has been plankton taken from the wild which consists mostly of copepods (May 1970, Turner 1984). The difficulty in providing sufficient quantities of copepods when needed has led researchers to try other less suitable foods and to attempt to culture copepods. Little success has been reported in using phytoplankton as a larval fish food. Success in rearing fish larvae has been limited using other foods, such as barnacle nauplii, mysids, oyster and mussel larvae, ciliates, and nematodes. It was the discovery by Rollefsen (1939) that plaice could be reared on *Artemia* sp. nauplii that first allowed the mass rearing of a number of marine fish. The use of the rotifer has likewise allowed the rearing of an additional group of fish species for which the larvae could not eat an *Artemia sp.* nauplii at first feeding. It has recently been recognized that a third group of fish larvae which will not feed on *Artemia* sp. or rotifers can be reared on the nauplii of copepods. It has also recently been suggested that even for those fish which can eat *Artemia* sp. or rotifers, the growth and survival is better if they are fed copepods (Neller 1985, Whitt et al. 1984, Pedersen 1984, Ogle and Lotz 2000a). The major drawback to the use of copepods is still the difficulty in providing sufficient quantities.

Traditionally fish larvae have been stocked into ponds that had been fertilized to increase zooplankton abundance (Horvath et al. 1984). The ponds may be fertilized with organic fertilizers, such as manure, cotton seed meal, fish meal or various inorganic fertilizers (Nees 1949, Swingle 1947, Hepher 1962, Yamada 1986, Boyd 1990). Ponds may also be enhanced by inoculating with a specific

zooplankton (Chamberlain et al. 1987, Horvath et al. 1984). Copepods have also been successfully cultured in large outdoor tanks which were fertilized with organic (Ono and Okamura 1988) or inorganic (Raymont and Miller 1962) fertilizers. Regardless, such blooms follow a natural succession of phytoplankton to zooplankton and then collapse. They are difficult to control and predict.

In attempting to find a species of copepod for mass culture Ikeda (1973) concluded that a small neritic brackish water species should be used. *Acartia* spp. are the dominant zooplankton in most neritic water of the United States (Roman 1977) and come to dominate in large fertilized tanks (Raymont and Miller 1962). It is also the dominate species within Davis Bayou adjacent to this laboratory. *Acartia* sp. is possibly able to dominate these estuarine areas due to its wide salinity tolerance (Stein 1981, Raymont and Miller 1962).

Acartia tonsa has been described as an omnivorous particle grazer and opportunistic feeder (Poulet 1962) and as an opportunistic omnivorous suspension feeder (Lonsdale et al. 1979). Energetic studies on feeding in a number of copepods has suggested that in the wild they can not derive enough energy from grazing exclusively on phytoplankton (Heinle and Flemer 1975). It has been demonstrated that copepod adults (Pafenhofer and Strickland 1970) and nauplii (Poulet 1977) can utilize detritus and indeed there is five times more detrital than phytoplankton biomass in the ocean. Dissolved organics have also been suggested as a source of food for copepods especially for pre-feeding and developmental stages (Poulet 1983). Direct uptake of organics is, however still controversial, and the amount of organic carbon is 10 times less than that of detritus. Poulet (1983) suggested that free bacteria are not used as a food by copepods, and there is 200 times less bacterial biomass in the ocean than detrital biomass.

Interestingly, in laboratory studies feeding detritus has not generally been successful (Roman 1977), whereas, the use of phytoplankton is standard (Omori 1973, Turner 1984). Culture systems designed to produce *Acartia* sp. have also relied primarily on phytoplankton (Stottrup et al. 1986, Schipp et al. 1999). The only reported use of a mixed detrital system being used as a food to produce *Acartia tonsa* is that of Ogle (1979). That system has been expanded recently and used to supply food to larval red snapper (Ogle et al. 2000, Ogle and Lotz 2000a). The system has also been investigated by Lemus et al. (2000) and compared to systems receiving rice bran as an organic food source. Rice bran was used by Turk et al. (1982) as a sole food source to produce *Acartia tonsa*. Rice bran has also been used to enhance zooplankton in ponds (Bishara 1979) and to feed *Artemia* sp. (Sorgeloos et al. 1980).

The "brown water system" of Ogle (1979), while successfully used at the Gulf Coast Research Laboratory to produce several thousand juvenile red snapper (Ogle and Lotz 2000a.), requires a ratio of 100:1 for food to larval culture volumes. One advantage of the system is that it can be easily managed for collapses in production. Such declines in copepod production are usually the result of increases in competitors, such as mussels, oysters, barnacles or tunicates, or predators, such as jellyfish. The 100 m^2 tanks can easily be drained and cleaned in a matter of hours

and will be back to full copepod production in a matter of days. One disadvantage of the system is that such management is required. A long term goal, therefore, is to intensify production of a specific copepod in an indoor system. The first step in achieving that goal is to identify an alternate food to the "brown water". Therefore, a variety of foods were evaluated for their suitability as food for the copepod *Acartia tonsa*.

MATERIALS AND METHODS

Copepods were cultured in black polyethylene tanks holding 1,000 L of water. Water from an existing 100 m^2 outdoor tank, filtered to 300 microns was used to fill the tanks. The water from the outdoor tank was clear and contained a resident population of *Acartia tonsa*. The tanks were located under an open sided greenhouse having a 85% shade cover. Three replicates of each of four diets were evaluated for a total of 12 tanks during each of three trials. Three separate trials were conducted over the period January-April 2000. Four diets (algae, bacteria, Isomil, and shrimp water) and the unfed control were only used once. The other three diets, Rotirich® , rice bran , and artificial plankton were evaluated twice.

Tanks were fed every third day with commercially available diets consisting of the following: an algae paste of *Tetraselmes* sp., a bacteria The shrimp tank uses a bacterial floc as an internal filter (Ogle and Lotz 2000b). The control tanks received no additional food.

Every tank was sampled initially and once weekly for three successive weeks. A length of 2" pvc pipe was plunged vertically to the bottom of the tank to insure a uniform sample. Five replicate 200 ml vertical samples were taken from each tank for a total sample volume of 1 L. The contents of the entire sample was enumerated for nauplii and adults under a dissecting microscope. Copepodite and juveniles were included in the counts as adults. Results were reported as number of copepods/L

RESULTS

The salinity of the water throughout all trials was 25‰. Where as the temperature varied from 6 °C to 16 °C. Initial stocking densities varied between the three trials decreasing with season. Average stocking density for the first trial was 15.5 adults/L and 110 nauplii/L, for the second trial the average stocking density was 12.6 adults and 24 nauplii/L. and for the third trial the average stocking density was 10.0 adults and 10 naupllI/L. Since the stocking densities varied by tank and season the results are presented as the percent change from the initial estimate and averaged for the three replicates (Table 1).

The number of nauplii in the unfed control decreased with a first week increase in the number of adults followed by a decline. This suggests that some nauplii were able to molt before the overall numbers started to decline. The bacteria and Isomil® fed tanks both showed the same trends as the unfed control. Both adults and nauplii declined in the algae fed tanks. The number of adults and nauplii both increased

when fed shrimp water, artificial plankton, Rotirich® and rice bran. The number of nauplii continued to increase in the tanks fed shrimp water while a decline during the fourth week was noted for tanks fed artificial plankton, rotirich and rice bran. The greatest increase in adults were noted for the artificial plankton (2,306%) during the fourth week and rotirich (2,194%) during the third week. These percent increases represent 240 and 121.6 adults/L, respectively. Overall, the greatest increase in number of nauplii was noted for the Rotirich® during the third week (937%). This percent represents 120.3 nauplii/L which was the second highest density. The greatest average density of nauplii achieved was 171/L also for Rotirich® in the third week. However, due to the high initial stocking density in this trial (118 nauplii/L) this represents only a 44.9% increase.

Table 1. Average percent change from initial numbers of *Acartia tonsa*

	Adults and Juveniles				Naupiii			
Diet	Initial #	Week 2	3	4	Initial #	Week 2	3	4
Algae	16.0	-50.0	-62.5	-75.0	137.0	-39.4	-81.7	-87.6
Bacteria	15.0	113.0	113.0	100.0	88.0	0	-23.8	-45.4
Isomii	16.6	32.5	153.0	420.0	27.0	-3.8	-24.8	12.2
Shrimp Water	10.3	87.4	259.0	1006.8	15.6	83.3	250.0	339.7
Control	11.3	247.8	197.3	156.6	95.0	-18.9	-44.2	-49.4
Artificial Plankton	10	416.0	1663.0	**2306.0**	24.3	266.7	111.1	-91.7
Artificial Plankton	18.6	172.0	247.0	-16.1	14	71.4	437.8	68.5
Roti Rich	17	276.0	1105.9	1188.2	118	40.6	44.9	31.3
Roti Rich	5.3	1283.0	**2194.3**	471.7	11.6	193.1	**937.0**	299.1
Rice Bran	12.3	422.8	796.7	652.8	24.3	263.3	355.1	20.5
Rice Bran	6	826.7	850.0	1226.7	12.3	89.4	**536.5**	495.9

DISCUSSION

The results of this study would seem to confirm that *Acartia tonsa* is indeed an omnivorous particle feeder (Poulet 1962) able to feed and reproduce on several of the diets offered. The lack of survival for the copepods offered the algae diet is unexplained. The algae was preserved and not living. However, even if the algal cells were considered as a detrital particle, some success would be expected. In addition such a product has been successfully used for oyster and shrimp larvae. It would be interesting in the future to compare the preserved algae with live algae. Live algae were not available at the time of these comparisons. The poor performance of bacteria was not surprising as bacteria are not considered a major food of copepods (Poulet 1983). The Rotirich® fed tanks with the greatest percent increase in nauplii, greatest total number of nauplii/L and second highest percent increase in adults appears to have promise as an artificial feed. Rotirich® outperformed rice bran in nauplii production and artificial plankton in percent increase of adults.

The success in this study of maintaining and in some cases increasing the number of copepods held in static cultures when fed an artificial diet offer the possibility of captive culture of *Acartia* sp. The selection of an appropriate diet will facilitate the selection, isolation, and cultivation of *Acartia* sp. indoors under controlled conditions. The final goal would be to enhance production to provide sufficient numbers of copepod nauplii for feeding to larval fish.

LITERATURE CITED

Avault, J.W.. 1996. *Fundamentals of Aquaculture*. AVA Publishing Company. Baton Rouge, Lousiana USA. 889 pp.

Bishara, N.F. 1979. Fertilizing fish ponds. III. Growth of *Mugil capito* in Egypt by pond fertilization and feeding. *Aquaculture* **16**:47-55.

Boyd, C.E., 1990. *Water Quality in Ponds for Aquaculture*. Auburn Univ., Alabama Agriculture Experiment Station. Auburn, Alabama USA. 482 pp.

Chamberlain, G. R. Miget, M. Haby. 1987. *Manual on red drum Aquaculture*. Red Drum Aquaculture Conference, June 22-24, 1987. Corpus Christi, Texas USA.

Heinle, D.R. and D.A. Flemmer. 1975. Carbon requirements of a population of the estuarine copepod *Eurytemora affinis*. *Marine Biology* **31**:235-247.

Hepher, B. 1962. Ten years research in fish ponds fertilization in Israel. *Bamidgeh* **14(2)**:29-38

Horvath, L, G. Tamas and I. Tolg. 1984. *Special Methods in Pond Fish Husbandry*. Halver Corporation, Seattle, Washington USA. 148pp.

Ikeda, T. 1973. On the criteria to select copepod species from mass culture. *Bulletin of the Plankton Society of Japan* **20(1)**:41-48

Lemus, J.T. J. Ogle and J. Lotz. 2000. Mass production of two species of calanoid copepods. Page 199 In: Aquaculture America 2000. February 2-5 New Orleans LA. U.S Chapter World Aquaculture Society (Abst).

Lonsdale, D., D. Heinle and C. Siegfried. 1979. Carnivorous feeding behavior of the adult calanoid copepod *Acartia tonsa*. *Dana. Journal of Experimental Marine Biology and Ecology* **36**:235-248.

May, R.C. 1970. Feeding larval marine fishes in the Laboratory: A Review. Calif. Marine Resource commission. CalCOFI Rept. **14**:76-83

Nees, J.C. 1949. Development and status of pond fertilization in Central Europe. *Transactions of the American Fisheries Society* **76**:335-358.

Nellen, W. 1985. Live animal food for larval rearing in aquaculture. Non-artemia organisms. In: Bilio, H. Rosenthal and C.J. Sinderman (eds.) *Realism in Aquaculture*. Proceedings of the World Aquaculture Society, Venice 1981.

Ohno, A. and Y. Okamura. 1988. Progagation of the calanoid copepod, *Acartia tsuensis*, in outdoor tanks. *Aquaculture* **70**:39-51

Ogle, J.T. 1979. Adaptation of a brown water culture technique to the mass culture of the copepod *Acartia tonsa*. *Gulf Research Reports* **6**(3):291-292.

Ogle, J.T., and J.M. Lotz. 2000a . Culture of red snapper. *Global Aquaculture* **3**(5):23-27

Ogle, J.T. and J.M. Lotz. 2000b. Closed systems for maturation and grow-out of shrimp. *Global Aquaculture*.

Ogle, J.T., J. M. Lotz, L.C. Nicholson, and D. Barnes. 2000. Larval culture of red snapper *Lutjanus campechanus* using copepod nauplii for first feeding. Page 249 in: *Aquaculture America 2000: Book of Abstracts*. February 2-5 New Orleans, LA. World Aquaculture Society. Baton Rouge, Louisiana USA.

Omori, M. 1973. Cultivation of marine copepods. *Bulletin of the Plankton Society of Japan* **20**(1): 3-11.

Pafenhofer, G.A. and J.D.H. Strickland. 1970. A note on the feeding of Calanus Helgolandicus on detritus. *Marine Biology* **5**:97-99

Pedersen, B.H. 1984. The intestinal evacuation rates of larval herring (*Clupea harengus* L.) Predating on wild plankton. *Dana* **3**:21-240.

Poulet, S.A. 1977. Grazing of marine copepods developmental stages on naturally occurring particles. *Journal of the Fisheries Research Board of Canada* **34**(12):2381-2387

Poulet, S.A. 1983. Factors controlling utilization of non-algal diets by particle-grazing copepods: a review. *Oceanologica Acta* **69**(3):221-234.

Raymont, J.E.G. and R.S. Miller. 1962. Production of marine zooplankton with fertilization in an enclosed body of sea water. *Hydrobiologia* **47**(2):169-209.

Roman, M.R. 1977. Feeding of the copepod *Acartia tonsa* on the diatom Nitzschia closterium and brown algae (*Fucus vesiculosus*) detritus. *Marine Biology* **42**:149-155.

Rollefsen, G. 1939. Artifical rearing of the fry of sea water fish. Preliminary communication. *Rapp. Et Proc.-Verb. Cons. Int. Explor. Mer*. **30**:204-221.

Schipp, G.R., J.M.P. Bosmans and A.J. Marshall. 1999. A method for hatchery culture of tropical calanoid copepods, *Acartia spp. Aquaculture* **174**:81-88.

Sorgeloos, P. et al. 1980. Culture of *Artemia* on rice bran: the conversion of a waste-product into highly nutritive animal protein. *Aquaculture* **21**:393-396

Stein,J.P. 1981. *Spatial and Temporal Distribution of Zooplankton in a Low-Salinity Mississippi Bayou System.* Ph.D. Dissertation. University of Mississippi.

Stottrup, J.G., K. Richardson, E. Kirkegaard and N.J. Pihl. 1986. The cultivation of *Acartia tonsa* for use as a live food source for marine fish larvae. *Aquaculture* **52**:87-96.

Swingle, H.S. 1947. Experiments on pond fertilization. *Bulletin of the Auburn University Agriculture Experiment Station* **6**:171-183.

Turk, P.E., M.E. Krejci and W.T. Yang. 1982. A laboratory method for the culture of *Acartia tonsa* using rice bran. *Journal of Aquariculture and Aquatic Sciences* **III** (2): 25-27

Turner, J.T. 1984. The feeding ecology of some zooplankters that are important prey items of larval fish. NOAA Technical Report NMFS-7:

Witt, U., G. Quantz, O. Kuhlmann and G. Kattner. 1984. Survival and growth of turbot larvae, *Scophthalmus maximus* L. reared on different food organisms with special regard to long chain polyunsaturated fatty acids. *Aquaculture Engineering* **3**(3):177-190

Yamada, R. 1986. Pond production systems: fertilization practices in warmwater fish ponds. Pages 97-110 in: Lannan, J.E., R.O. Smitherman, and G. Tchobanoglous (eds.) *Principles and Practices of Pond Aquaculture.* Oregon State University Press. Corvallis, Oregon USA.

Overview of Aquaculture in Mexico: Biomass Production and Research

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ABSTRACT

Mexico has 11,500 km of littoral zone. Fishery production in 1994 was 1,260 ,019 metric tons (mt) with aquaculture contributing 171,389 mt. Species traditionally reared in Mexico are trout, catfish, eastern oyster, carp, tilapia and freshwater crayfish. Many aquatic species have been cultured on an experimental and/or pilot scale. However, only a few species have reached commercial-scale development, including mojarra (47%), American oyster (22%), carp (14%) and shirmp (10%). Only shrimp and a little quantity of oyster were produced by a intensive aquaculture. The other 90% aquaculture production is produced by extensive aquaculture.

Mexico has 79 institutions in Marine Science or Biology, which 23 have been working with 60 aquatics species, and they have produced 162 scientific manuscripts (Science Citation Index). These results show few studies for anyone aquatic species. 52 studies were conducted on shrimp (*Panaeus vannamei* = 47 studies, 30.3%), 51 papers (32.9%) on mollusks (*Haliotis* = 15 papers, 10.3%), 28 on fish (14%), scallops (*Argopecten ventricosus* = 13 papers) and queen conch (*Strombus gigas* = 10 studies). Marine fishes and freshwater fishes have been less studied. Seventeen subject areas were identified; nutrition was the most studied (32 studies), while others included pollution, physiology, reproduction, etc. Mexico does not have an academic institution specializing in aquaculture, and so it begs the question. What is better for developing the aquaculture industry in Mexico? — to have Institutes specializing in particular subject ares,, or to have Research Institutes with many specialists?.

KEY WORDS: Aquaculture, Mexico

OVERVIEW OF THE AQUACULTURE IN MEXICO

Mexico and its Littorals

Mexico has 11,500 km of littorals and an exclusive economic zone of 2,892,000 km^2, which is larger than the entire Mexican Republic territory. Mexico is bordered by the Gulf of Mexico to the east, the Caribbean Sea to the southeast, and the Pacific Ocean and Gulf of California to the west.

Fish Production in Mexico

The most significant Mexican fishery production was 1,565,465 metric tons (mt) in 1981. Subsequently, fishery production has achieved the same volume; fishery production in 1994 was 1,260,019 mt, 19.5% lower than 1981. Since 1992, fishing activity was conducted by only 1.3% of the total population.

Mexico has a large market for seafood products. Tuna represents the largest share of the Mexican catch, estimated at 106,000 mt. Other important seafood products include shrimp, mojarra, and sardines. Domestic consumption of seafood was 692,000 mt in 1997, approximately 7.9 kilograms per person (Gand 1997). Both production and consumption fell 18% between 1991 and 1997, and exports declined from 58,000 to 37,000 metric tons.

Global Fisheries Production by Aquaculture

In the last century, world marine fisheries production has increased 25 fold from around three million tons at the turn of the century, to a peak of 82 million tons in 1989.

Aquaculture production in 1994 made up to a total of nearly 25.5 million mt, valued at around US $40 billion. By far the greatest amount is produced in China, whose total aquaculture production is estimated to account for 48% of the total production of all aquacultured products. It is estimated that in 50 years, most of the world's fish supply will come from aquaculture production.

Latin America and Caribbean Aquaculture Production

South America does not have a long tradition of aquatic farming, although in recent years it has grown at a rapid rate. In 1994 FAO (FAO/FIDI 1999) reported that the total aquaculture production in Latin American and the Caribbean was 472, 429 mt, which represented 1.85% of the world production, with a value of US$1,884.74 millions. From 1984 to 1994 this production increased 288% in biomass and 240% in foreign exchange. In 199, aquaculture produced 193,403 mt of fish (41%), 151,914 mt of crustaceans (32%), 65,798 mt of algae (14%), and 61 251 mt of mollusks (13%).

Latin America aquaculture production statistics from 1984 to 1994 indicate that Chile is the main producer of fish (salmon) and Ecuador of shrimp. Mexico is the main producer of cultured mollusks in Latin America, with 48,583 mt, representing 90% of the total for Latin America and the Caribbean.

Mexican Aquaculture Production

Aquaculture is developing in Mexico, but fluctuations in production indicate that the industry is in a period of unstable development. During 1983 - 1989, aquaculture production increased at an average rate of 8.6% annually (122,148 mt in 1983), but in 1994 aquaculture production was 7.03%, less than 1989.

Although aquaculture has acquired importance, providing social and economic benefits, it has not produced the expected returns. There are three million hectares

of inland waters and coastal lagoons adequate for the culture of penaeid shrimp and others species. Environmental diversity affords a variety of aquaculture opportunitiess, producing different kinds of organisms, by many modalities — extensive, semi-intensive and intensive aquaculture.

In the 1930s, aquaculture in Mexico was focused on rural aquaculture and replenishing water reservoirs. Aquaculture efforts were conducted mainly in inland waters, primarily fish culture for stocking and population replenishment. Today there are programs to develop aquaculture, but the lack of support for new aquaculture initiatives persists in most the cases.

Species traditionally reared in Mexico were trout, catfish, american oyster, carp, tilapia, and freshwater crayfish — the last three species are non-indegenous to Mexico. More recently, other aquaculture species have been farmed in the country — peneaid shrimp, bay scallop, lion paw scallop, ornamental fish, marine food fish, abalone, pearl oyster, mussels, and some others. With the exception of shrimp, the remaining species have not shown any significant commercial impact.

Many aquatic species have been cultured on an experimental and/or pilot scale since the early 1970s (Table 1). However, only a few species have reached commercial-scale development, including freshwater fish, american oysters, and shrimp.

Figure 1 compares total fishery catch in mt and aquaculture production during 1997. The main aquaculture species produced included mojarra (47%), american oyster (22%), carp (14%) and shrimp (10%). Only shrimp and a small quantity of oyster were produced through intensive aquaculture. The other 90% of aquaculture production was produced through extensive aquaculture.

Tilapia, american oyster, and carp have a high social impact, their volume represents 79% of the total production, almost exclusively for domestic consumption. Shrimp production has increased an average of 49% annually from 1988 to 1994.

Figure 2 shows aquaculture production in biomass (mt) and value. Shrimp is the most valued commodity, other species are cheaper in the market. Table 2 shows Mexico's aquaculture production by region. Shrimp are produced primarily along the Pacific coast, while mojarra and american oyster are produced in the Gulf of Mexico.

Shrimp rearing has introduced an important number of social and private enterprises, generating new jobs and foreign exchange. Nonetheless, care must be taken to ensure that shrimp farming has minimal affect upon other productive activities and natural resources. Also, the lack of research and development in the shrimp farming sector has restrained the industry's development.

From 1983 to 1995 aquaculture production has had an annual average growth of 2.7%, from 122,148 mt in 1983 to 171,389 mt in 1994.

Table 1. Aquatic species cultured commercially (C) , experimentally (E), pilot (P) culture.

Common name	Scientific name	Culture	Papers	%
FRESH WATER FISH				
Mojarra	*Cichlasoma urophtalmus*	C	5	3.08
Carp	*Cyprinus carpio*	C	5	3.08
	Cyprinus carpio variedad specularis	C		
	Ctenepharyngodon idella	C		
Black Bass	*Micropterus salmonoides*	C	1	0.60
Catfish	*Ichtalurus puntatus*	C	1	1.60
Trout	*Onchorynchus mykiss*	C	2	1.23
Charal	*Chrirostoma spp*	C	-	-
Tilapia	*Oreochromus niloticus*	C	6	3.70
	Oreochromus mozambicus	C		
	Oreochromus aureus	C		
Ornamental fishes			2	1.23
MARINE FISHES				
Grouper	*Epinephelus morio*	E	1	0.60
Snapper	*Lutjanus argetiventris*	E	1	0.60
Other fishes			4	2.50
CRUSTACEANS				
Shrimp	*Penaeus vanamei*	C	47	29.01
	Penaeus californiensis	P		
	Penaeus stylirostris	E		
	Penaeus setiferus	E		
Freshwater prawn	*Macrobranchium rosembergi*	E	1	0.06
	Procambarus clarkii	E		
MOLLUSKS				
American oyster	*Crassostrea virginica*	C	10	6.17
Japanese oyster	*Crassostrea gigas*	C		
Scallops	*Argopecten ventricosus*	P	13	8.02
Mussels	*Mytilus galloprovincialis*	E	3	1.85
	M edulis			
	M. californianus			
Abalone	*Haliotis fulgens,*	P	16	9.87
	H. Rufescens			
Queen conch	*Strombus gigas*	E	9	5.55
	S costatus			
	S. pugilis			
FROGS	*Rana toro*		3	1.85
MICROALGAE			6	3.70
MACROALGAE	*Gracilaria spp*	E	5	3.08
ZOOPLANCTON	*Artemia naupli, A. Franciscana, A. Spp, Brachiorus plicatilis*	E	10	6.17
OTHERS	0.66		12	7.41

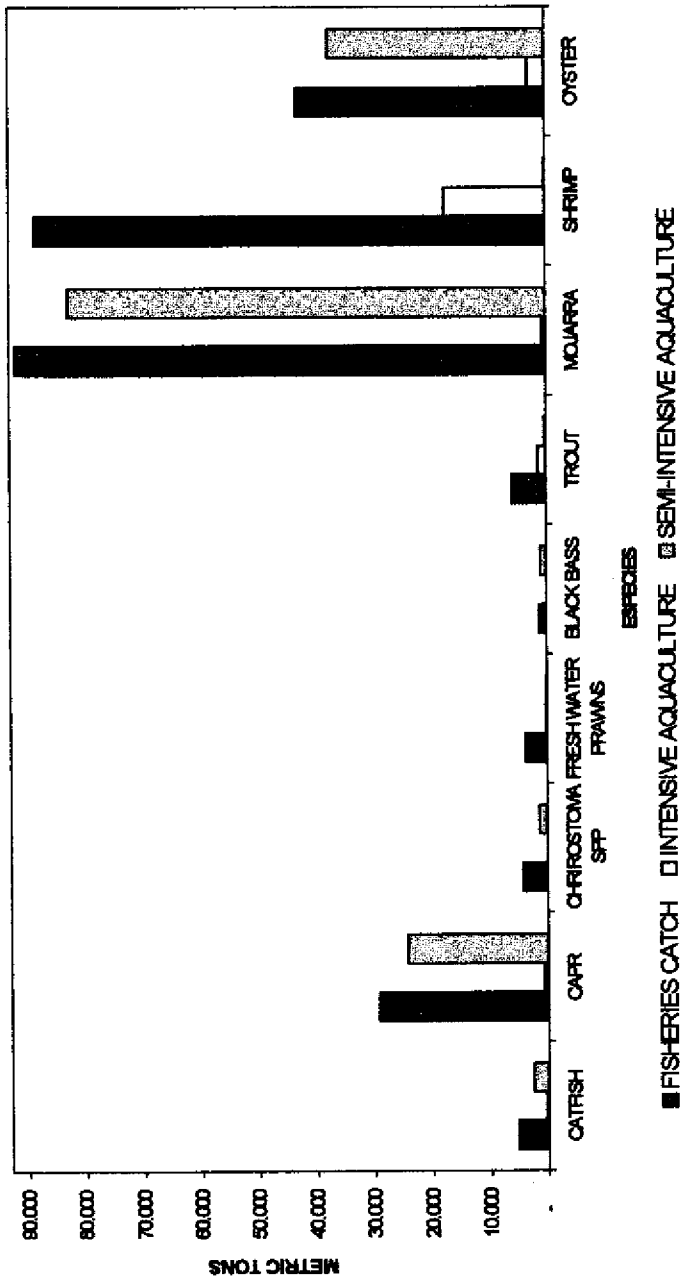


Figure 1. Mexican aquaculture production and fisheries catch for different species (1997).

Table 2. Mexican aquaculture production (mt) by categories of species in different States (Quantities in mt).

	Total	Mojarra	Shrimp	Oyster	Carp	Catfish	Trout	Chirostoma spp.	Black Bass	Freshwater Prawns
TOTAL	**173,878**	**83,132**	**17,670**	**40,381**	**24,848**	**2,816**	**1,512**	**1,330**	**1,006**	**130**
Pacific	57,660	30,193	16,856	2,910	4,764	1,064	210	742	578	98
B. California N	1447	-	-	1,230	-	-	-	-	-	-
B. California S	116	-	43	73	-	-	-	-	-	-
Sonora	7,527	757	4,688	1,243	234	483	-	-	121	-
Sinaloa	13,734	2,793	10,215	5	-	503	-	-	218	-
Michoacán	15,882	12,623	-	-	2,885	2	110	-	234	1
Chiapas	5,794	5,050	500	-	232	-	12	-	-	-
Gulf of México and Caribe	80,405	41,020	714	37,471	-	913	135	-	59	-
Veracruz	38,048	23,620	8	14,285	-	-	135	-	-	-
Tabasco	32,087	14,045	149	17,893	-	-	-	-	-	-
Yucatán	283	3	277	-	-	-	-	-	-	-
Inland waters	35,815	11,920	-	-	20,085	838	1,168	589	368	32
México	4,463	435	-	-	3,376	5	359	218	22	7
Nuevo León	153	45	-	-	46	61	-	-	-	-

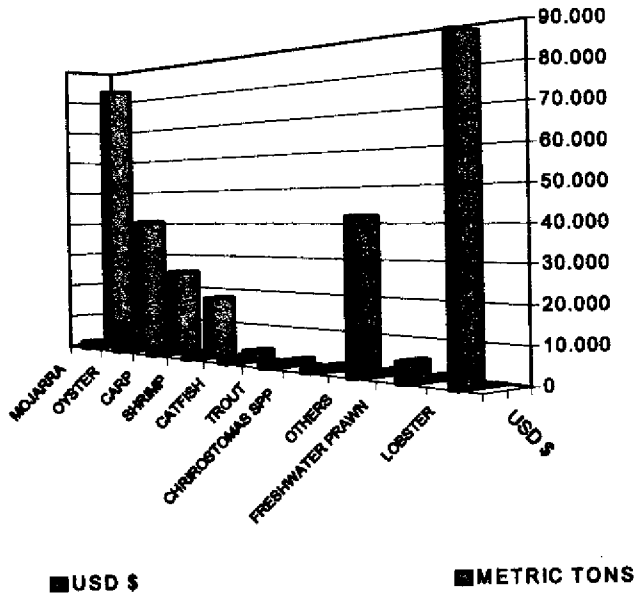


Figure 2. Mexican aquaculture production, volume, and value (1997)

Although production of some species has fallen, during the years1983 to 1994 tilapia production inceased by 3.1% annually, from 58,000 to 7, 000 mt. Carp production increased by 8.8%, from 7,000 to 19,000 mt. Aquaculture production of trout and catfish showed growth increments of 17.9% and 5.5%, respectively. Oyster production reached a maximum of 57,000 mt in 1989, however, this production decreased to 33,000 mt in 1995. These decreases have been related to water quality and diseases.

Aquaculture of charal (*Chrirostoma spp.*) shows an average decline per year of 9.1% from 1987 to 1994. The production of Black-bass had a reduction of 1.2% per year in the same period.

An analysis of the aquaculture official programs in 20 years (1980-1989), shows the lack of adequate techniques, human and economics resources to achieve the goal of these programs. The objectives from 1988 to 1994 were not reached, due to problems in public administration. The hatcheries and nurseries were eventually without support.

In these 20 years, aquaculture has introduced new species, of high commercial value, like shrimp. In 1987 were obtained 286 mt and in 1994 13 138 mt.

For the development aquaculture is necessary to solve the met subjects: diseases, reproductive biology, and nutrition among the most critical, to know the patters reproductive cycle for natives species and their nutritional requirements. Another problem is the poor infrastructure of Mexican hatcheries, which can not produce the spats or juveniles required for further expansion.

IDENTIFICATION FOR ESTABLISHING RESEARCH COOPERATIVE PROJECTS

Mexican Institutions of Marine Sciences

Mexico has 79 academic institutions, 19 of which offer programs in Biology or Marine Science and 11 related to Fisheries and Aquaculture (Table 3). Thirty schools offer a bachelors degree in Biology, and 49 a bachelors degree in topics related to marine science. Three of the main fishing regions of Mexico (Tamaulipas, Yucatán and Quintana Roo) do not offer a bachelors degree on marine science topics. Sixty one percent of the acadmeic institutions that offer courses in marine science are located on the Pacific coast, 24% on the Gulf of Mexico coast, and 15% in Mexico City; none on the Caribbean. These schools have 9,550 students, of which only 793 (8.3%)graduated, 78% studied for a degree in biological science, 7.4% in marine science, 2.3% in fisheries, and 0.05% in ecology.

Table 3. Bachelor degrees in natural science, biology or marine science related: Oceanography, fisheries and aquaculture offered in Mexico.

Area	Carreer	Schools
Natural Science	Biology	30
	Fisheries biology	3
	Marine biology	3
	Experimental biology	2
	Systematic biology	1
	Ecology biologist	6
	Aquaculture biologist	3
	Agriculture biologist	1
	Hydrobiology	1
Oceanology	Chemical oceanography	1
	Oceanology	1
Ecology	Marine ecology	1
Engineer	Naval engineer	4
	Oceanology engineer	1
Fisheries and Aquaculture	Aquaculture engineer	6
	Fisheries engineer	9
	Marine food technology engineer	3
	Fishing technology engineer	2
	Aquatic resources engineer	1
Total		**79**

Mexican Institutions with Graduate Studies in Marine Sciences

Table 4 shows the different graduate studies programs in Marine Science in Mexico, year it started, Institution that offers it, degree offered. The board of professors increased 62% from 1989 to 1994, even though the percentage of graduated students has been low. During 1989 there was 0.16 new PhD. by year going up to 0.36 PhD in 1995.(Aldana Aranda 1997).

The mean duration of these graduate studies programs is 13.7 years. So, Mexico has only ten years of production of graduate students in marine science.

Most mexican scientists have graduated abroad. Only 25% of the coastal states have graduate studies in marine science, 64% on the Pacific coast, 5% on the Gulf coast, and 32% in Mexico city. During 1995, 124 students graduated with a Master of Science on marine science and 8 for a PhD.

Table 4. Graduate studies programs in Marine Science in Mexico. (M) Master of Science, (D) PhD and (E) Speciality.

Program	Institution	Year it started	Certified
1.Biology : Sistematic of Marine	CICESE	1978	E
invertebrates	CICESE	1978	E
2. Marine Pollution	CICESE	1978	E
3. Benthos Ecology	CICESE	1978	E
4. Larvae and fishes Ecology	CICESE	1978	E
5. Plankton Ecology			
6. Marine Ecology	CICESE	1978	M, D
7. Phisic Oceanography	CICESE and ICMyL	1978	M, D
8. Management of Marine resources	UABC	1980	E
9. Coastal Oceanography	UABC	1980	M, D
10. Biology Oceanography	UABC	1980	M
11.Marine Sciences	CICIMAR, ITESM	1978	M
12. Fishery Sciences	CICIMAR	1978	M
13. Management of Marine resources	CICIMAR	1993	M
14. Management of Coastal Natural	CIBNOR	1995	D
Resources			
15. Management of Natural Resources	UABCS	1993	M
	U.Sinaloa		M
	U.Oaxaca	1996	M
	U.Yucatán	1990	M
16. Aquaculture	UABCS	1993	
	U.Campeche	1996	
	U. Manzanillo	1993	
	ITESM		
17. Ecology	E.N.C.B IPN	1961	M, D
18. Biology and Fishery Oceanography	ICMyL UNAM	1970	M, D
19. Chemistry Oceanography	ICMyL UNAM	1970	M, D
20. Geology Oceanography	ICMyL UNAM	1970	M, D
21. Biologic Sciences of aquatics systems	UNAM F. Ciencias		M, D
and resources			
22. Ecology and Environmental Sciences	UNAM, F.Ciencias		M, D
23. Biology	UNAM, F.Ciencias		M, D
24. Zoology	UNAM, F.Ciencias		M, D
25. Aquatic Ecology y pesca	UNAM, F.Ciencias		M, D
26. Ictiology	UNAM, F.Ciencias		M, D
27. Aquaculture and Fishery	UNAM, F.Ciencias		M, D
28. Ecology, Aquaculture and Fishery	U. Nuevo león		M
29. Aquaculture Production	U. Nuevo León		M
30. Fishery Sciences	U. Sinaloa		M
31. Marine Sciences	CINVESTAV IPN	1982	D
	CICIMAR	1978	M
32. Marine Biology	CINVESTAV IPN	1980	M

Mexico's Budget for Research in Marine Science

From 1991 to 1995 the Mexican Institution for the development of Science CONACYT approved 2,278 research projects providing US$ 279,045,992. Only 51 projects were related to marine science, accounting for 4.38% of the total budget for five years. During 1991 - 1995 this budget increased from 0.64% (1991) to 2.43% (1995). However, the budget is limited to studies of aquatic species for aquaculture.

Mexican Scientist Within the National Scientist Program

The National Scientist Program (SNI) had 5 871 registered members for the year 1995, 56% working at Mexico city, and 44% in the United States, but only 57 worked on a marine science topic (Table 5).

Table 5. Number of scientists from SNI with their specialty in marine science and the percentage of the total number of scientists in the biological sciences

Specialty	Number of Scientists	Percentage (%)
Marine Biology	22	2.75
Marine Ecology	15	1.88
Aquaculture	5	0.63
Marine Botany	5	0.63
Ichthyology	4	0.50
Malacology	3	0.38
Carcinology	1	0.13
Marine Physiology	1	0.13
Marine Microbiology	1	0.13
Total	**57**	**7.16**

Figure 3 shows the papers (indexed in Science Citation Index) produced during 1986 - 1999 by Mexican Institutions. Mexico has 21 different Institutions that have produced at least one manuscript related to aquaculture. CIBNOR has produced the most papers in aquaculture with 28 published (Table 4). UNAM produced 22 manuscripts, followed by the University of Baja California with 15 and CINVESTAV and CIAD with 13 each.

Figure 4 illustrates the species studied in different mexican institutions during 1986 -1999. Mexican institutions have been working with 60 different aquatics species and they have produced 162 scientific manuscripts indexed. These results show few studies for every one species. So, UNAM studied 14 species. University of Baja California and CIBNOR are working with 12 and 11 different species respectively. Finally, CICESE, CINVESTAV and UAM are working with 6 or 8 different species.

Nutrition has 32 papers realised by 12 different centers. Aquaculture techniques has 27 papers realised in 16 different Institution. Growth has been studied by 12 institutions, which have been produced 25 scientific manuscripts. Topics like Biochemistry has 14 studies produced by 9 Institutions. Physiology 9 papers by 6 Institutions, Marine Pollution 8 papers in 6 Institutions. Finally, Pathology has 10 papers produded by 8 institutions. So, Mexico does not have an institution specialised in only one topic of Aquaculture. The question to know is: ¿what is better for developing aquaculture, to have institutions with any specific topic, or to have research centers with many specialists?

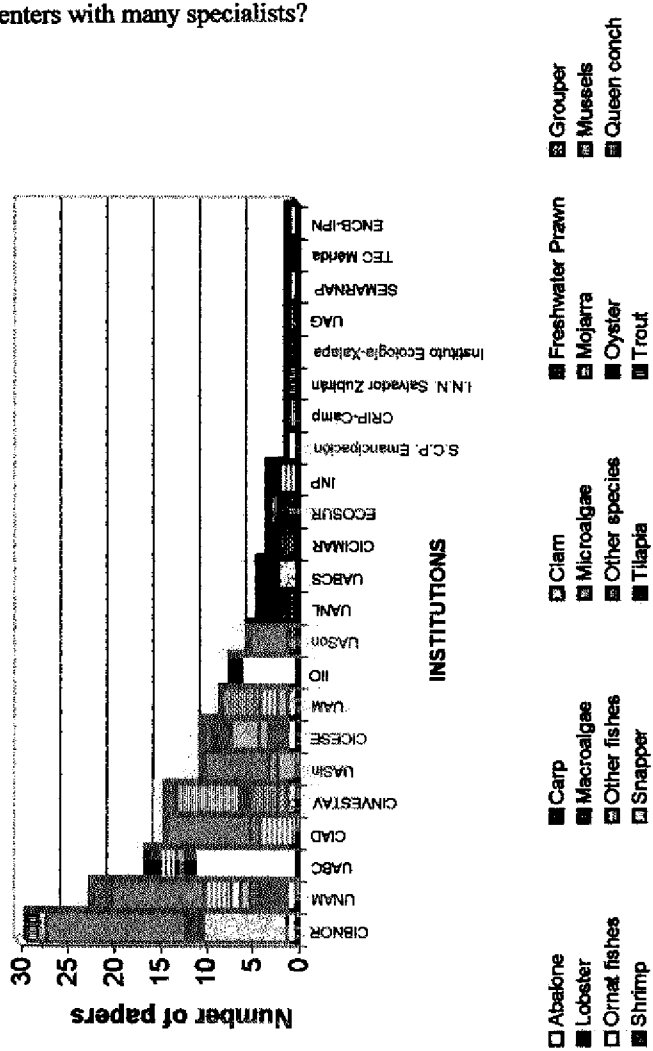


Figura 3. Number of papers produced by different mexican institutions (1986 - 1999).

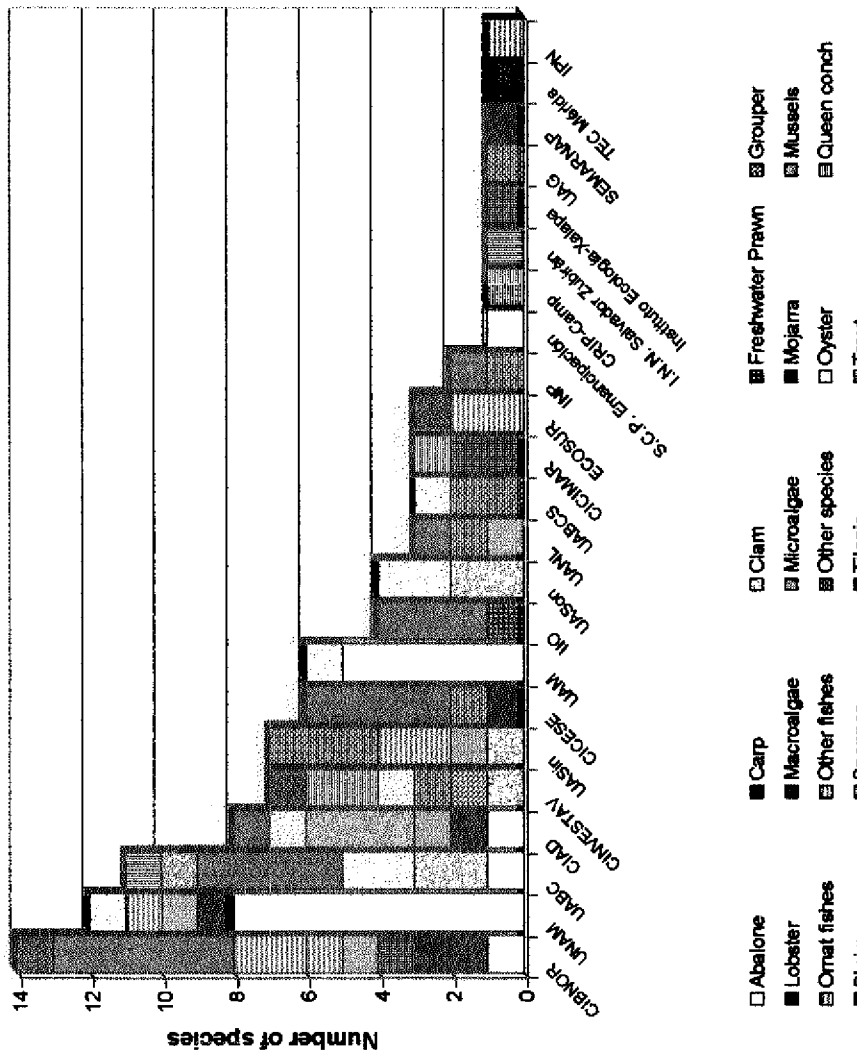


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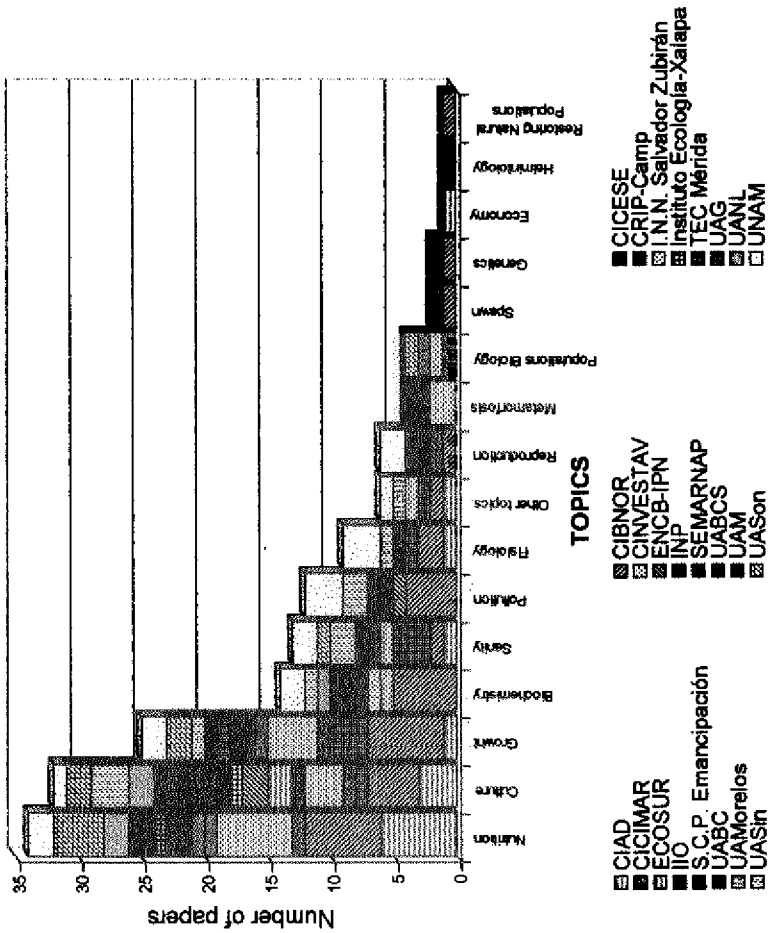


Figura 5. Number of papers realized by different mexican institutions on different topics (1986 -1999).

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LITERATURE CITED

Aldana Aranda, D. 1997. La educación de las Ciencias Marinas en México. *Ciencia* **48**(3):14-22.

Gand. 1997. *The World Aquaculture. Present Status and Development Prospects.* 111 pp.

FAO/FIDI 1999. Aquaculture production statistics 1988-1997. FAO Fisheries Circular No. 815 Revision 11. FAO. Rome, Italy. 203 pp.

SEMARNAP (Secretaría de Medio Ambiente, Recursos Naturales y Pesca) 1995. Programa de Pesca y Acuacultura. 1995-2000. 96 pp.

SEMARNAP (Secretaría de Medio Ambiente, Recursos Naturales y Pesca) 1997. Anuario Estadístico de Pesca. 235 pp.

Sustainable Development of Offshore Aquaculture in the Gulf of Mexico

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ABSTRACT

Within the Gulf of Mexico, no offshore aquaculture industry exists to provide a model for potential investors to adopt. The Gulf of Mexico Offshore Aquaculture Consortium (OAC) has initiated a planning and applied research process to develop a sustainable offshore aquaculture industry. An OAC research plan has been developed to provide a vision for the future of offshore aquaculture in the Gulf of Mexico.

Proper site selection is critical to the success of aquaculture. This is particularly true in the marine environment, either coastal or offshore, where minimal control over the ambient environmental conditions are possible. Future industry planning will require the OAC to select appropriate sites to assist governing agencies, as well as ensure success to investors.

The OAC has selected an experimental offshore aquaculture site in federal waters off the coast of Mississippi. This site, in the vicinity of a Chevron gas platform, will provide passive protection to the cage from vessel traffic and surveillance to storm damage and vandalism. Throughout OAC research and development, environmental issues associated with aquaculture impacts on the environment – eutrophication, biopollution and artificial reef effects – and environmental impacts on the aquaculture operation – biofouling, seasonal anoxia, sediment resuspension, episodic tropical storms – will be addressed. Legal research on the fragmented regulatory framework is being conducted, focussing on the current permitting process and determining the best Marine Aquaculture Zoning strategy for the Gulf of Mexico. Economic sustainability will be paramount, with careful observation of market situations, recording associated expenditures, and revenues from the conducted research. Finally, logistics of operating an aquaculture venture 40 kilometers from shore will require enormous engineering ingenuity.

KEY WORDS: Offshore aquaculture, Gulf of Mexico, regulatory framework

BACKGROUND AND RATIONALE

It is the goal of the Gulf of Mexico Offshore Aquaculture Consortium (OAC) to develop a sustainable offshore aquaculture industry. "Sustainable development" has numerous working definitions that, depending on ignorance or misuse, have been

modified to fit user needs. The Food and Agriculture Organization of the United Nations (FAO) defines "sustainable development", in their *Code of Conduct for Responsible Fisheries* (1997), as:

> "...the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry, and fisheries sectors) conserves land, water, plant, and animal resources, is environmentally non-degrading, technically appropriate, economically viable, and socially acceptable."

By using this FAO definition, sustainable fisheries requires the natural fish stock to be harvested at a rate equal to the regenerative rate of that stock. However, due to poor fish harvesting management, increased perturbations to fish habitat and an increased demand for fisheries products, sustainable fisheries have rarely existed, providing the impetus for increased aquaculture production, or "cultivated natural capital" (Goodland and Daly 1996). Goodland and Daly (1996) describe input-output rules required for environmental sustainability of renewable and nonrenewable resources. This concept should be applied for the sustainable development of aquaculture to ensure the industry will exist for future generations (Costa-Pierce 2001).

However, negative environmental impacts associated with marine cage aquaculture have become a global phenomenon (Pullin et al. 1993, Black 2000). The areal holding capacity for aquaculture operations may be determined from the total possible area available to site grow-out cages. However, an areal stocking method may result in overstocking the environment where the biological carrying capacity is much lower than the required area for grow-out. Overestimation may occur as the industry neglects to account for flushing rate, naturally occurring organic input, additional anthropogenic nutrient inputs, and numerous temporal oceanographic or hydrographic parameters that may limit total allowable nutrient input from aquaculture. Using Goodland and Daly (1996) input-output rules for sustainable aquaculture development requires that farm effluents - excess feed and metabolic wastes - "should be within the assimilative capacity of the local environment to absorb without unacceptable degradation of its future waste-absorptive capacity or other important service" (Goodland and Daly 1996). Hence, "assimilative capacity" is warranted and necessary to describe allowable aquaculture farm effort accepted in a given area. Further, Goodland and Daly (1996) separate sustainability into social, economic and environmental categories. This classification scheme is central to OAC research to ensure a sustainable offshore aquaculture industry will develop within the region.

AQUACULTURE SITE SELECTION CRITERIA

Appropriate site selection of aquaculture facilities must take into account biological, physical and social criteria to ensure success. It is generally recognized that fish are distributed within the acceptable zone of tolerance of numerous complex, interrelated parameters comprising its ambient environment. Fish habitat may be defined as an area "where they [fish] may feed, rest, breed and find shelter from both predators and inhospitable environmental intrusions" (Ryder and Kerr 1989). Quite often this habitat is not optimal for growth but must remain within the zone of tolerance for each ambient environmental parameter (e.g. temperature, salinity, dissolved oxygen) to allow survival.

Wild fish, in an open-ocean environment, must either tolerate changes to these parameters or display an avoidance behavior to environmental perturbation. Within an aquaculture setting, fish are contained in a given spatial environment and; therefore, the fish have no choice but tolerate environmental change. It is for this reason that aquaculture development and operations ***must*** proceed in a sustainable manner to ensure the local natural environment has the assimilative capacity to absorb fish farm wastes without unacceptable degradation of the environment. Aquaculture is the ***only*** user-industry of the oceans that ***require*** a constant, clean supply of water for success, and often times aquaculture operations may enhance the form and function of the natural environment by providing habitat to natural systems (Costa-Pierce and Bridger 2001).

GULF OF MEXICO OFFSHORE AQUACULTURE CONSORTIUM

In 1999, the OAC was formed to create a collaborative, Gulf-wide, university-based interdisciplinary research program to address social, environmental and technological issues that have plagued offshore aquaculture endeavors in the Gulf of Mexico (Table 1). By developing university/industry partnerships and seeking broad public/commercial input, the Consortium's goal is to develop socially and environmentally acceptable offshore aquaculture models that are appropriate to all stakeholders in the Gulf of Mexico region.

OAC Aquaculture Site

A site was chosen in 26 m of water approximately 40 km off the coast of Mississippi, in federal waters (29° 58.649'N, 88° 36.297'W) (Figure 1). This site is adjacent to a Chevron gas platform and within the Chevron minerals lease. Placing the cage in close proximity to a gas platform has provided the OAC cage passive protection from numerous user groups currently present in the Gulf of Mexico and some surveillance to cage damage resulting from storm events and vandalism. Although there has been much debate in the past regarding the integration of the oil and gas industry with offshore aquaculture (Stickney 1999), a recent analysis of aquaculture-oil/gas integration has shown that such an industry marriage may not be feasible (Bridger et al. submitted).

Table 1. The Gulf of Mexico Offshore Aquaculture Consortium (OAC), outlining the holistic development approach by member institutions.

Expertise Area	Institution
Legal/Regulatory Research · Permitting · Aquaculture Zonation · Operation Regulations	· MS-AL Sea Grant Legal Program, MS · LA Sea Grant Legal Program, LA · TX Sea Grant College Program, TX
Engineering Design and Monitoring	· MIT Sea Grant College Program, MA · Ocean Spar Technologies LLC, WA · Good Streak Marine Inc., LA
Site Selection with GIS	· Auburn University, AL · C-FAST Inc., NC
Hatchery Systems	· Texas Parks and Wildlife · The University of Southern Mississippi · Virginia Institute of Marine Sciences
Fish Husbandry/Grow-out	· The University of Southern Mississippi · MS-AL Sea Grant Consortium · Texas Sea Grant College Program
Fish Health	· Texas A & M University · The University of Southern Mississippi
Fish Nutrition	· Land O'Lakes Farmland Feed, AR
Fish Genetics	· Texas A & M University · The University of Southern Mississippi · Florida Marine Research Institute
Environmental Monitoring	· The University of Southern Mississippi · Mississippi-Alabama Sea Grant Consortium · National Marine Fisheries Service, Pascagoula, MS · Louisiana State University
Economics/Marketing	· Mississippi State University
Social Research	· Auburn University, AL
Education/Outreach	· Auburn University · Mississippi-Alabama Sea Grant Consortium

Cage and Mooring System

Typically, coastal aquaculture cages may be classified as gravity cages or Class 1 cages according to Loverich and Gace (1998). This cage configuration often experiences deformation and loss of internal cage volume associated with water movements due to wind, wave and current action. Up to 80% of the expected growing volume, used to base stocking density calculations, may be lost in currents of 1 m/s (Aarsnes et al. 1990). Gravity cages also have all their buoyancy located at the water

surface and cannot sink to avoid storm surges. To sustain the high energy environment expected in the Gulf of Mexico and allow cage sinking to decrease hurricane damage while maintaining possession of the fish stock, an Ocean Spar Sea Station (OSSS) was chosen for OAC research (Figure 2; Loverich and Gace 1998). OSSS cage design is based on the floating spar buoy concept to shape the net enclosure and provide rigidity to the netting (Loverich and Croker 1993).

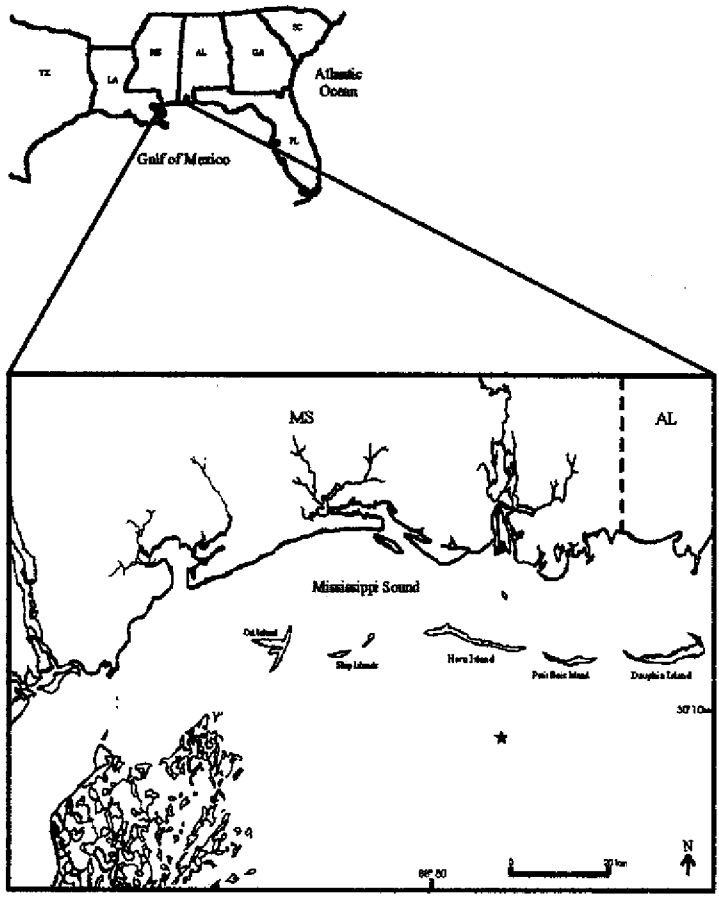


Figure 1. OAC offshore aquaculture experimental site (H) located in 26 m of water approximately 40 km off the coast of Mississippi, in federal waters (29° 58.649'N, 88° 36.297'W), near a Chevron gas platform.

The OSSS has a 600 m^3 volume, that is retained by its semi-rigid structure and netting. In contrast to the Ocean Spar Sea Cage, utilizing anchor tension to retain a constant shape and volume, the OSSS is self-supporting and will hold its shape and volume in the absence of both gravity and tensioned anchors (Loverich and Goudey 1996). The OSSS has a double-cone shape that is considered optimal for raising pelagic fish species, providing increased internal volume. To maintain constant volume and shape, the OSSS netting remains taut between a central spar buoy, approximately 1 m diameter and 9 m long, and an octagonal rim, located in the middle of the double-cone configuration and having an approximate 15 m diameter. The octagonal rim is composed of eight flanged sections of steel pipe that are individually pressurized and sealed to allow floatation of the central rim on the water surface. The central spar buoy has a lower variable buoyancy chamber that allows the OSSS to be submerged during harsh environmental conditions at a rate of approximately 25 m in a 15 minute period. For OSSS submergence, the spar buoy is ballasted with water that enters from the bottom of the spar when a valve in the top of the spar buoy is opened to release the air. Raising the OSSS simply requires displacing the ballast water in the spar buoy with air introduced from a SCUBA tank by divers.

Recent open ocean aquaculture projects have opted for the more commonly used submerged grid mooring system (Fredriksson et al. 2000). To decrease mooring costs, system complexity and potential environmental impact, the OAC OSSS is moored to the Outer Continental Shelf (OCS) on a single-point mooring (SPM) (Figure 2; Goudey et al. in press). An OSSS/SPM configuration will also decrease potential impacts of offshore aquaculture to marine mammal species by eliminating the need for a predator net surrounding the cage.

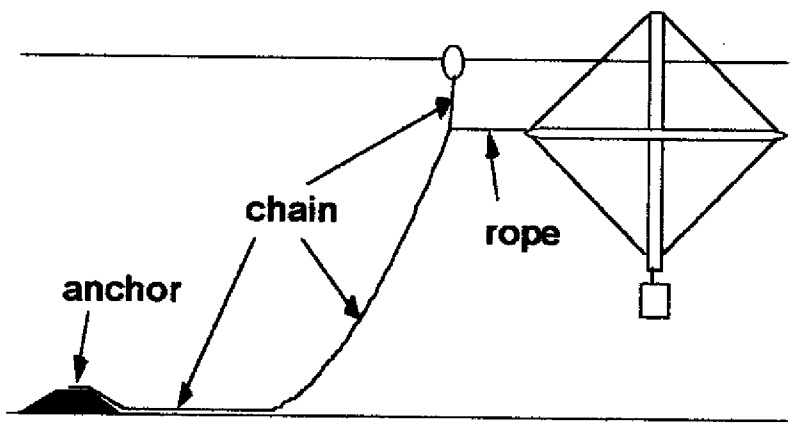


Figure 2. Representation of the Gulf of Mexico Offshore Aquaculture Consortium single-point mooring (SPM) system and Ocean Spar Sea Station cage.

Cage and Mooring Deployment

Although deploying any cage and mooring is site and environment specific, siting a cage and mooring it in a distant offshore location poses new challenges to overcome. Perhaps the most efficient mode of deploying the cage and mooring 40 km from shore would have involved carrying the assembled rim, central spar buoy, ballast weight and single-point mooring components to the site on a barge. This strategy would have decreased the necessary travel time associated with towing system components, similar to other project deployment strategies (Baldwin et al. 2000). Further, the OAC research team expected use of a lift-boat, with sufficient working deck space, would have created the safest and optimal deployment conditions by jacking the lift-boat out of the water and creating a stable work platform, offshore. However, just days prior to the scheduled cage deployment, the northern Gulf of Mexico experienced approximately 2.5 m waves which delayed access to a lift-boat, creating the necessity to explore alternative methods for cage and mooring deployment. At this time, The University of Southern Mississippi research vessel IX 508 was chosen for towing the cage and mooring block to the site and subsequent system deployment following careful consideration and discussion.

Prior to towing the cage components to the permitted aquaculture site, the rim sections were assembled at the NOAA National Marine Fisheries Service dock in Pascagoula, Mississippi. This dock provided sufficient workspace to assemble the 15 m octagonal rim and stage the various cage and mooring components, near the water, for efficient transfer to the water surface. On October 28, 2000, a crane was contracted to lift the 12,275 kg (27,000 lbs) mooring block in position, approximately three meters below the IX 508 wash and rutters, and secure it to the IX 508 A-frame to ease deployment. This mooring block was previously attached and welded to the assembled single-point mooring chain, and lifted to the stern of the IX 508. The central spar buoy was hoisted to the water surface and allowed to float in a horizontal position during the towing operation. The assembled octagonal rim was hoisted to the water surface and positioned in such a manner to enclose the central spar buoy to ease towing and cage assembly. Finally, the ballast weight, harvest ring, work platform and netting were all lifted to the IX 508 deck, prior to departing Pascagoula.

To ensure site arrival at sunrise, towing began at approximately 1800 hours. At a maximum towing speed of three knots, the IX 508 arrived on station at approximately 0400 hours, at which time the vessel remained in the vicinity of the Chevron gas platform until sunrise.

Mooring deployment commenced at sunrise, October 29, 2000. The octagonal rim and central spar buoy components were released from the IX 508 prior to lowering the mooring block to the sea floor to increase safety and maneuverability of the vessel. The mooring block and single-point mooring chain were slowly lowered to the desired location, followed by divers descending to inspect the block on the seafloor and release the lowering IX 508 rope. The octagonal rim and central spar buoy were then retrieved and connected to the single-point mooring line.

The central spar buoy had to be in a vertical position to create the taut netting, double-cone configuration of the OSSS. The ballast weight, a circular concrete block

weighing approximately 3,181 kg with a toggle through its middle to attach it to the bottom of the spar buoy, was lowered to the water surface, attached to the bottom of the spar buoy, and further lowered until the spar buoy was vertical by receiving the tension of the ballast weight from the IX 508 crane cable. Divers disconnected the crane cable from the ballast weight. Once in a vertical position, the harvest ring was lowered over the spar buoy. The netting was attached to this harvest ring, which will later facilitate fish harvesting by raising it up the central spar buoy and effectively decreasing the internal cage volume. The netting was further lowered over the spar buoy and attached to the top of the spar buoy, followed by the work platform, positioned on the top of the spar buoy.

The spar buoy was then floated to the central portion of the octagonal rim. The netting was stretched to each flanged region of the octagonal rim and shackled to the inside corner of the rim section. This completed formation of the upper-cone section of the OSSS and created a very taut net. The lower portion of the net was attached to the harvest ring and tightened as much as possible. The cage and netting were secured for the night and the vessel departed the site.

The following morning the deployment team returned to the aquaculture site in a smaller research vessel (RV Tom McIlwain) and completed cage assembly. The net was further tightened over the central spar buoy and the netting, mooring shackles and connections were inspected.

Cage and Environmental Monitoring

No fish will be stocked within the aquaculture cage during the first year of OAC research. The novel OSSS/SPM configuration will be monitored to determine the degree of motion resultant from the ambient oceanographic conditions. Specific environmental monitoring of the cage and environment will determine the potential seasonal influence of the nepheloid layer and hypoxic layer to stocked fish, and the impact of hurricanes and storm surges on sediment resuspension. Baseline benthic environmental data will be collected to determine the impact of offshore aquaculture operations on the environment.

FUTURE DIRECTION OF OAC RESEARCH

Following Year 1 research, one of the candidate species summarized in Table 2 will be stocked in the cage and grown to a market size. These species each have excellent grow-out and market potential characteristics. Numerous criteria are used to select candidate species for aquaculture including required growth rate to a market size. Calculated growth performance indices (ϕ'; Longhurst and Pauly 1987), using L_∞ and K values from wild stock literature, for candidate northern Gulf of Mexico species provide favorable growth attributes to attain economically feasible grow-out (Table 2). Throughout candidate species grow-out trials, careful notes will be taken regarding grow-out inputs and outputs to determine economic feasibility of offshore aquaculture operations in the Gulf of Mexico.

Table 2. Growth performance index (Φ')[a] calculated from cited L_∞ (cm) and K values for potential aquaculture species indigenous to the northern Gulf of Mexico. Values shown in parentheses are standard errors. (Taken from Bridger et al. submitted)

Species	Sex	L_∞ (cm)	K	Φ'	Source
Rachycentron canadum	male	117.07 (2.808)	0.432 (0.046)	3.77	Franks *et al.* (1999)[b]
	female	155.50 (3.514)	0.272 (0.017)	3.82	
Lutjanus campechanus	combined	95.0 (1.35)	0.175 (0.005)	3.20	Nelson and Manooch (1982)[c]
Sciaenops ocellatus	combined	91.8 (2.1)	0.422 (0.023)	3.55	Doerzbacher *et al.* (1988)[d]
Seriola dumerili	combined	127.2 (N.P)[e]	0.227 (N.P.)	3.57	Manooch and Potts (1997)[f]

[a] $\Phi' = \log_{10}K + 2\log_{10}L_\infty$ (Longhurst and Pauly 1987)
[b] Cobia were caught from northeastern Gulf of Mexico within the recreational hook-and-line fishery and aged with sagittal otoliths (male N=170; female N=395).
[c] Red snapper were caught in the commercial hook-and-line fishery off Louisiana and aged with scales (N=403).
[d] Tagged red drum returns from recreational and commercial fishery off Texas and growth determined from tag and release measures (N=2010).
[e] N.P. = not provided
[f] Greater amberjack captured from headboats operating in the Gulf of Mexico from Naples, Florida, to Port Aransas, Texas and aged with sagittal otoliths (N=340).

Further engineering research will focus on mooring redundancy while maintaining a SPM configuration, optimization of aquaculture operational procedures with the OSSS, and the design and subsequent manufacture of a lift-boat strategy specifically for offshore aquaculture in the Gulf of Mexico (Bridger *et al.* submitted). Genetics research will be conducted to develop a genetic marker specific to each candidate species and broodstock to distinguish harvested aquaculture product from wild conspecifics. Disease monitoring will occur to document the extent of poor fish health throughout grow-out cycles. Careful planning for a future offshore aquaculture industry will also be conducted using GIS to select favorable aquaculture sites with minimal user conflicts. Finally, it is a priority for the OAC to educate the public of the project's operations and economic potential of offshore aquaculture to Gulf of Mexico fishery-based communities.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Aarsnes, J.V., H. Rudi and G. Løland. 1990. Current forces on cage, net deflection. Pages 137-152 in: *Engineering for Offshore Fish Farming*. Proceedings of the Conference Organized by the Institution of Civil Engineers. October 17-18, 1990. Glasgow, U.K. Thomas Telford, London.

Baldwin, K., B. Celikkol, R. Steen, D. Michelin, E. Muller and P. Lavoie. 2000. Open ocean aquaculture engineering: Mooring & net pen deployment. *Marine Technology Society Journal* **34**:53-58.

Black, K.D. 2000. *Environmental Impacts of Aquaculture*. CRC Press, Boca Raton, Florida USA.

Bridger, C.J., B.A. Costa-Pierce, C. Goudey, R.R. Stickney and J.D. Allen. Integration of offshore oil/gas platforms and cage aquaculture in the Gulf of Mexico. Proceedings of the Symposium Gulf of Mexico Fish and Fisheries: Bringing Together New and Recent Research, American Fisheries Society Symposium, 24-26 October 2000, New Orleans, Louisiana USA. Submitted.

Costa-Pierce, B.A. (ed.) 2001. *Ecological Aquaculture: The Evolution of the Blue Revolution*. Blackwell Science, U.K.

Doerzbacher, J.F., A.W. Green, H.R. Osburn, and G.C. Matlock. 1988. A temperature compensated von Bertalanffy growth model for tagged red drum and black drum in Texas bays. *Fisheries Research* **6**:135-152.

FAO Fisheries Department. 1997. Code of Conduct for Responsible Fisheries. FAO, Rome, Italy.

Franks, J.S., J.R. Warren, and M.V. Buchanan. 1999. Age and growth of cobia, *Rachycentron canadum*, from the northeastern Gulf of Mexico. *Fisheries Bulletin* **97**:459-471.

Goodland, R. and H. Daly. 1996. Environmental sustainability: Universal and non-negotiable. *Ecological Applications* **6**:1002-1017.

Goudey, C., G. Loverich, H. Kite-Powell, and B.A. Costa-Pierce. [In press]. Mitigating the environmental effects of mariculture through single-point moorings (SPMs) and drifting cages. ICES Journal of Marine Science.

Longhurst, A.R., and D. Pauly. 1987. *Ecology of Tropical Oceans*. Academic Press, Inc. London, England.

Loverich, G.F. and T.R. Croker. 1993. OCEAN SPAR® net pen system: 32 months of offshore operations. Pages 243-249 in: H. Reinertsen, L.A. Dahle, L. Jørgensen and K. Tvinnereim (eds.) *Fish Farming Technology*. A.A. Balkema, Brookfield and Rotterdam, Netherlands.

Loverich, G.F., and L. Gace. 1998. The effect of currents and waves on several classes of offshore sea cages. Pages 131-144 in: C.E. Helsley (ed.) Open Ocean Aquaculture '97, Charting the Future of Ocean Farming. Proceedings of an International Conference. April 23-25, 1997. Maui, Hawaii, USA University of Hawaii Sea Grant College Program #CP-98-08.

Loverich, G and C. Goudey. 1996. Design and operation of an offshore sea-farming system. Pages 495-512 in M. Polk, editor. *Open Ocean Aquaculture*. Proceedings of an International Conference. May 8 - 10, 1996. Portland,

Maine. New Hampshire/Maine Sea Grant College Program Rpt.# UNHMP-CP-SG-96-9.

Manooch III, C.S., and J.C. Potts. 1997. Age, growth, and mortality of greater amberjack, *Seriola dumerili*, from the U.S. Gulf of Mexico headboat fishery. *Bulletin of Marine Sciences* **61**:671-683.

Nelson, R.S., and C.S. Manooch III. 1982. Growth and mortality of red snappers in the west-central Atlantic Ocean and northern Gulf of Mexico. *Transactions of the American Fisheries Society* **111**:465-475.

Pullin, R.S.V., H. Rosenthal and J.L. Maclean (eds.). 1993. Environment and aquaculture in developing countries. ICLARM Conference Proceedings 31.

Ryder, R.A. and S.R. Kerr. 1989. Environmental priorities: placing habitat in hierarchic perspective. Pages 2-12 in C.D. Levings, L.B. Holtby and M.A. Henderson (eds.) Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. *Canadian Special Publication of Fisheries and Aquatic Sciences* **105**.

Stickney, R.R. (compiler). 1999. Joining forces with industry. Proceedings of the Third International Conference on Open Ocean Aquaculture. May 10-15, 1998. Corpus Christi, Texas USA TAMU-SG-99-103.

Modelo del Desarrollo Larvario de *Strombus gigas* versus *Strombus pugilis*

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RESUMEN

El desarrollo larvario de *Strombus gigas* y *S. pugilis* fue estudiado en condiciones de laboratorio durante un período de 21 días. El experimento fue conducido a 29° ± 1°C. Las larvas velígeras se cultivaron a una densidad de 200 larvas/L en recipientes de 30 litros. Las larvas fueron alimentadas con la microalga *Tetraselmis suecica* a una concentración de 1000 cél/ml. El modelo para *S. gigas* fue establecido en función del tiempo de aparición de 14 características morfológicas: larvas con cuatro lóbulos del velum y 2.0 vueltas de espiras de la concha, larvas con cuatro lóbulos del velum y 2.5 vueltas de espiras de la concha, larvas con cuatro lóbulos del velum y 3.0 vueltas de espiras de la concha, larvas con seis lóbulos del velum y 3.0 vueltas de espiras de la concha, corazón adulto, formación del pedúnculo izquierdo, larvas con cuatro lóbulos del velum y 3.5 vueltas de espiras de la concha, larvas con seis lóbulos del velum y 3.5 vueltas de espiras de la concha, pigmentación del manto, pigmentación del pie, migración de los ojos a los pedúnculos, larvas con cuatro lóbulos del velum y 4.0 vueltas de espiras de la concha, presencia de probóscis y rádula. De la eclosión al día 21, 14 características morfológicas del desarrollo fueron descritas para ambas especies. Se realizó una comparación de la aparición y evolución de éstas características larvarias entre *S. gigas* y *S. pugilis*. Las larvas de *S. gigas* eclosionaron con cuatro lóbulos del velum y 2.0 vueltas de espira de la concha, contrariamente las larvas de S. *pugilis* tuvieron dos lóbulos y 1.5 vueltas de espira. Para ambas especies el corazón adulto apareció por primera vez al día 11; En *S. gigas* el 100% de las larvas presentó este caracter al día 16, mientras que en *S. pugilis* fue hasta el día 21. Para *S. gigas* la probóscis apareció al día 18 y para *S. pugilis* al día 20. En general, los 14 caracteres morfológicos considerados en este estudio aparecen primero en *S. gigas*, el tiempo que tardan las características en desaparecer es menor y duran menos tiempo en llegar al 100% en la población que para *S. pugilis*.

PALABRAS CLAVE: *Strombus*, desarrollo larvario, modelo

Larval Development Model of *Strombus gigas* *versus Strombus pugilis*

ABSTRACT

The development of *Strombus gigas* and *S. pugilis* larvae was studied over a period of 21 days in laboratory culture. Experiments were conducted at 29° ± 1°C. Veliger were reared at 200 larvas/L in 30 liter containers. Larvae were fed with the microalgae *Tetraselmis suecica* at 1000 cells/ml. The model of *S. gigas* was based on chronological appearance of the fourteen morphological characteristics: larvae with four lobes and 2.0 whorls, four lobes and 2.5 whorls, four lobes and 3.0 whorls, six lobes and 3.0 whorls, adult heart, left tentacle stalks begin to form, four lobes and 3.5 whorls, migration of eyes up the tentacles stalks begins, pigmentation of the mantle, pigmentation of the foot, six lobes and 3.5 whorls, six lobes and 4.0 whorls, proboscis appears, radula appears. From hatching to 21 day, fourteen development characteristics are described for both species. A comparison on time of appearance and evolution of these larval characteristics was determined between *S. gigas* and *S. pugilis*. *S. gigas* larvae at hatching have four velar lobes and two whorl shell, while *S. pugilis* larvae showed two velar lobes and one and half whorl shell. For both species the adult heart first appears on the 11th day; however *S. gigas* larvae showed 100% of the characteristics at 16 days *versus S. pugilis* larvae that developed the adult heart (100%) at 21 days. The proboscis appears on day 18 in *S. gigas*, while for *S. pugilis* it appeared at 20 days. In general, based on fourteen morphological caracters *S. gigas* larvae exhibited more rapid development than *S. pugilis* larvae.

KEY WORDS: *Strombus*, laboratory culture, model, larval development

INTRODUCCIÓN

El caracol rosado, *Strombus gigas*, es un recurso marino de importancia comercial, alimenticia y ecológica en la región del Caribe (Berg 1976, Brownell, 1977, Berg et al. 1983). El caracol de uña, caracol canela o chivita, *Strombus pugilis* es un de las seis especies de gasterópodos de importancia comercial distribuídos en las aguas del Caribe. Esta especie, en particular, representa un potencial pesquero y acuícola para los habitantes de la Península de Yucatán. Una estimación de la captura total en el Caribe es de 4 000 toneladas métricas, lo cual representa un valor de US $40 000 000.00 (Appeldoorn 1994). En la Península de Yucatán el caracol es una importante fuente de proteína de interés económico para los habitantes de la región. En la Península el recurso caracol está constituído por 19 especies, entre las que destacan por su abundancia y valor comercial *S. gigas, S. costatus, S. pugilis, Busycon contrarium, Xancus angulata, Fasciolaria tulipa* y *Pleuroploca gigantea* (Baqueiro Cárdenas 1997). Sin embargo, la sobre-explotación ha colocado al recurso en peligro de extinción, en

particular en el Estado de Yucatán donde se decretó una veda permanente desde 1988 (Baqueiro Cárdenas 1997).

Por otra parte, *S. gigas* por ser hervíboro, por su potencial reproductivo y su importancia comercial, ha sido considerado como una especie apropiada para la maricultura (D'Asaro 1965, Brownell, 1977), ya sea como estrategia de manejo o para la producción de juveniles para repoblar bancos naturales (Ballantine and Appeldoorn 1983, Laughlin y Weil 1983). Por su importancia económica en la Península de Yucatán, *S. pugilis* está empezando a ser estudiado.

En el presente trabajo se comparan los modelos de desarrollo larvario orgnogenético de *Strombus gigas* y *Strombus pugilis*, dado que en general los Strombidos se cultivan con las mismas técnicas, pero sin saber si el desarrollo y el crecimiento son iguales. El interés de este trabajo es ver si existen diferencias en el desarrollo entre estas dos especies, a lo largo de los días de cultivo.

MATERIAL Y METODOS

Para realizar el cultivo larvario se utilizó una masa de huevos fertilizada de *S. gigas* la cual fue colectada en el Arrecife Alacranes, Yucatán, situado a 22°29' Latitud Norte y 89°45' Latitud Oeste. La masa de huevos de *S. pugilis* se colectó en Seyba Playa, México (20°45' Latitud Norte y 91°45' Latitud Oeste). Ambas colectas fueron realizadas de hembras que se encontraban ovopositando. Las masas fueron colocadas en un recipiente de plástico con agua de mar para su transporte al laboratorio de Biología Marina del CINVESTAV IPN Unidad Mérida.

Una vez en el laboratorio las masas de huevos fueron colocadas individualmente sobre un tamiz de 300 µm de luz de malla, sumergidas en un recipiente de plástico con capacidad de 25 litros con agua de mar filtrada a 2 µm y esterilizada con luz U.V. La temperatura de incubación fue de 29° ± 1°C. Los recambios de agua y de tamiz se realizaron cada 24 horas hasta el momento de la eclosión.

Las larvas velígeras recién eclosionadas de cada especie se cultivaron en recipientes de plástico inertes de cuatro litros a una densidad de 200 larvas/L. Las larvas fueron alimentadas con la microalga *Tetraselmis suecica* a una concentración de 1 000 cél/ml (García Santaella y Aldana Aranda 1994). Se montaron tres series experimentales. La temperatura de cultivo fue de 29°± 1°C. Cada 24 horas se colectaron 30 larvas al azar de cada una de las réplicas para realizar las observaciones morfológicas del desarrollo larvario. Durante el cultivo los recambios de agua fueron cada 24 horas.

El modelo sintético del desarrollo larvario de *S. gigas* fue planteado en base al modelo sintético desarrollado por Brito-Manzano et al. (1998) para *S. pugilis*, tomando como base la estructura del velum: número de lóbulos y reabsorción de éste, número de espiras de la concha, presencia de probóscis y rádula, pigmentación del manto y pie, corazón larvario, pedúnculos oculares. El desarrollo morfológico de éstas características fue numerado cronológicamente

conforme fueron apareciendo, cuantificando el porcentaje de su presencia para cada uno de los días del desarrollo larvario.

RESULTADOS

Desarrollo Larvario

Las larvas velígeras de *S. gigas* recién eclosionadas poseen un velum con cuatro lóbulos y una concha con dos vueltas de espiras, mientras que las de *S. pugilis*, eclosionan con dos lóbulos y con una y media vueltas de espira de la concha. El conjunto de todas las características morfológicas a partir de la eclosión y su evolución hasta el día 21, para ambas especies se resumen en la Tabla 1, en la cual 16 características morfológicas describen el desarrollo larvario. Después de 21 días las larvas de *S. gigas* y *S. pugilis* poseen seis lóbulos del velum, 3.5 ó 4.0 vueltas de espira de la concha, corazón adulto, probóscis, rádula, el pie y el manto se encuentran pigmentados y los ojos ya han migrado a los pedúnculos oculares.

Tabla 1. Descripción de las características del desarrollo larval de la eclosión al día 21 de cultivo para *S. gigas* y *S. pugilis*, bajo condiciones de laboratorio.

		Días de Aparición	
Número de la Característica	Característica Morfológica del Desarrollo	*S. pugilis*	*S. gigas*
1	Dos lóbulos y 1.5 espiras de la concha	1	*
2	Cuatro lóbulos y 1.5 espiras de la concha	5	*
3	Cuatro lóbulos y 2.0 espiras en la concha	*	1
4	Cuatro lóbulos y 2.5 espiras de la concha	8	2
5	Cuatro lóbulos y 3.0 espiras en la concha	11	3
6	Seis lóbulos y 3.0 espiras en la concha	*	8
7	Aparición del corazón adulto	11	11
8	Aparición de los pedúnculos oculares	11	5
9	Cuatro lóbulos y 3.5 espiras en la concha	15	11
10	Seis lóbulos y 3.5 espiras en la concha	15	11
11	Inicia la migración de los ojos a los pedúnculos	15	13
12	Pigmentación del manto	15	14
13	Pigmentación del pie	17	15
14	Seis lóbulos y 4.0 espiras en la concha	18	16
15	Aparece la probóscis	20	18
16	Aparece la rádula	20	20

* Característica no observada

Modelo Sintético

En la Tabla 2 se presenta el porcentaje de las 16 características morfológicas que se presentaron durante el desarrollo larval, desde la eclosión hasta el día 21 de cultivo para ambas especies. De éstas características fueron identificados dos grupos: Maduración larval y Proceso de metamorfosis. El grupo de maduración larval comprende del día 1 al día 11 del desarrollo y está formado por las características: 1, 2, 3, 4, 5, 6, 9, 10 y 14, las cuales están relacionadas con la evolución del velum y de la concha. Todas éstas características son reemplazas una por otra durante el desarrollo. El resto de las características 7, 8, 11, 12, 13, 15 y 16, son características morfológicas aditivas, constituyendo el proceso de metamorfosis, el cual dura del día 12 al día 21 de cultivo. Este período se caracteriza por el desarrollo de órganos adultos (Figuras 1 y 2).

DISCUSION

Las larvas de *S. gigas* al eclosionar poseen 2.0 vueltas de espira de la concha y cuatro lóbulos del velum, lo que las diferencia de las de *S. pugilis* y *S. costatus* que tienen 1.5 vueltas de espira al momento de la eclosión (Brito-Manzano et al. 1998; Davis et al., 1993).

Brownell (1977) reportó que la proboscis aparece a los 25 días en *S. gigas* y *S. costatus*. En el presente trabajo esta característica apareció a los 18 días en *S. gigas* y a los 20 en *S. pugilis*.

En general, la mayoría de los 16 caracteres morfológicos considerados para este estudio aparecen primero en *S. gigas* y duran menos tiempo en desaparecer y alcanzar el 100% de la población la característica que para *S. pugilis*, mientras que otros inclusive no se presentan (Tabla 2). En la tabla se puede apreciar que las larvas de *S. gigas* tienen un desarrollo más avanzado y más rápido que las de *S. pugilis*, lo cual se hace más evidente durante los primeros días de su vida larval.

El aporte original del presente estudio es el planteamiento de un modelo sintético, el cual está basado en la evolución de las 16 características morfológicas del desarrollo larval de ambas especies, así como de los dos procesos de desarrollo (maduración larval y proceso de metamorfosis).

La maduración larval en ambas especies, comprende un período de uno a nueve días, un intervalo de tiempo en donde se interconectan características de la maduración larval y del proceso de metamorfosis que va del día 10 al día 21 de cultivo.

Tabla 2. Porcentaje de larvas de *Strombus gigas* y *Strombus pugilis* presentando las características del desarrollo larvario en negritas *Strombus gigas* y *S. pugilis* normal. * característica no observada

		Edad larval (días)																			
Groupos	**Caract**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
	1	0																				
	1	100	100	100	100																	
	2	*																				
	2					100	100	100														
	3	**100**																				
	3	*																				
	4	**100**																				
	4								100	100	100											
Maduración	5			**100**	**100**	**100**	**100**	**100**														
	5											100	100	100								
	6								**100**	**100**	**100**											
	6	*																				
	9											**77**	**62**	**47**								
	9															73	62	50	41	30		
	10											**32**	**38**	**53**	**62**	**63**	**51**					
	10															27	38	50	59	54		
	14																**49**	**63**	**79**	**82**	**86**	**86**
	14																			16	59	
	7											**44**	**62**	**73**	**89**	**93**	**100**	**100**	**100**	**100**	**100**	**100**
	7											35	35	42	53	57	69	76	81	94	94	100
	8					**26**	**34**	**43**	**43**	**58**	**61**	**69**	**75**	**75**	**82**	**93**	**100**	**100**	**100**	**100**	**100**	**100**
	8											30	40	60	73	73	86	89	93	100	100	100
	11													**19**	**19**	**33**	**65**	**83**	**94**	**100**	**100**	**100**
	11															11	11	19	32	41	56	72
Metamorfosis	12														**17**	**22**	**47**	**71**	**88**	**91**	**100**	**100**
	12															12		24	35	44	53	62
	13															**12**	**15**	**32**	**57**	**82**	**96**	**100**
	13															23	41	56	65	74	80	86
	15																		**25**	**25**	**38**	**67**
	15																				13	30
	16																				**22**	**33**
	16																				19	30

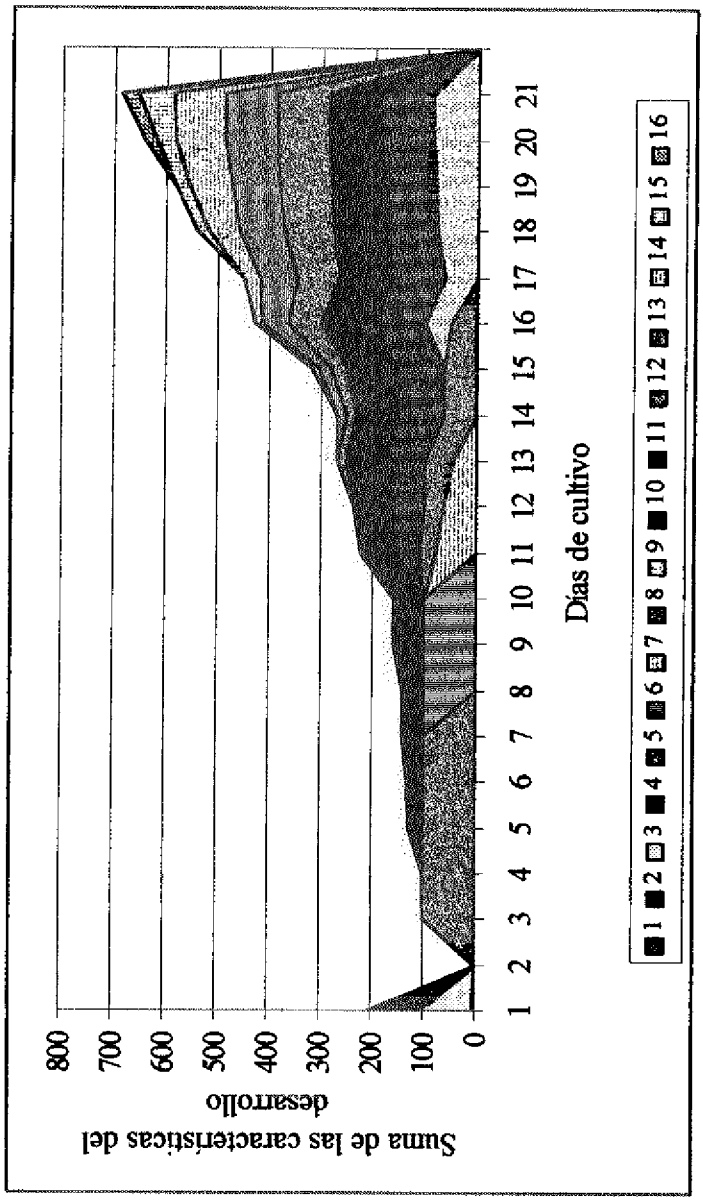


Figura 1. Modelo del desarrollo larvario de *Strombus gigas*, bajo condiciones de laboratorio.

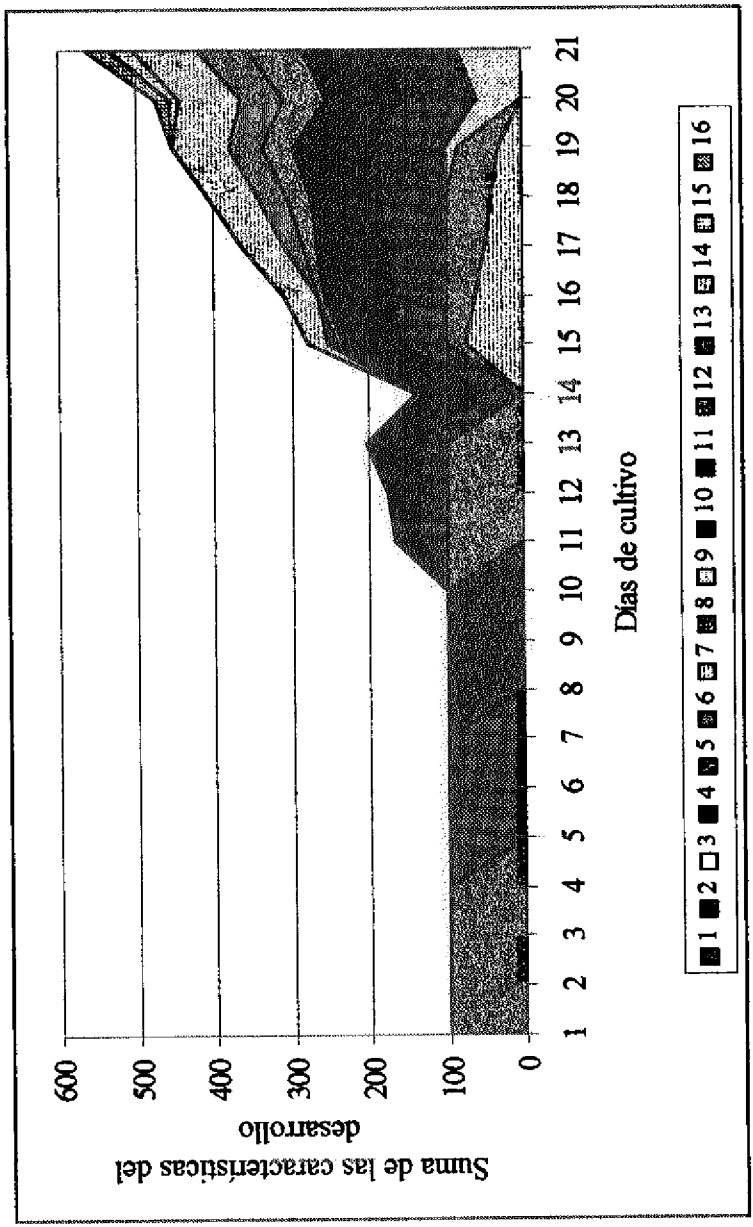


Figura 2. Modelo del desarrollo larvario de *Strombus pugilis*, bajo condiciones de laboratorio.

Sin embargo al realizar la comparación de los modelos de ambas especies se encontró que existen diferencias en el desarrollo organogenético (Tabla 3). Las larvas de *Strombus gigas* presentan ciertas características (cuatro lóbulos y 2.0 espiras de la concha y seis lóbulos y 3.0 espiras de la concha) que las de *S. pugilis* no presentan, mientras que las larvas de ésta última especie posee dos lóbulos y 1.5 espiras de la concha, así como cuatro lóbulos y 1.5 espiras de la concha, características que las larvas de *S. gigas* no presentó. Además el desarrollo de *S. gigas* es más rápido en términos de aparición de determinadas características, del tiempo en que el 100% de la población logra presentar la característica y el tiempo que tardan en desaparecer las características es también menor.

De igual manera, se presentan diferencias en función de la edad de las larvas, ya que las larvas de *S. gigas* a una determinada edad poseen características que las de *S. pugilis* presentan de 2 a 4 días más tarde.

De los resultados encontrados en el presente trabajo se concluye que el desarrollo de las dos especies estudiadas no es igual a pesar de emplear el mismo tipo de cultivo larvario, la misma densidad larvaria, la misma temperatura y el mismo alimento.

Tabla 3. Comparación del tiempo de aparición de las características del desarrollo, así como del porcentaje que presentan del primer día de aparación al día 21 de cultivo larval de Strombus gigas y Strombus pugilis, bajo condiciones de laboratorio.

Características	*Strombus gigas*		*Strombus pugilis*	
	Día	Porcentaje (%)	Día	Porcentaje (%)
Dos lóbulos y 1.5 espiras	*	*	1	100
Cuatro lóbulos y 1.5 espiras	*	*	5	100
Cuatro lóbulos y 2.0 espiras	1	100	*	*
Cuatro lóbulos y 2.5 espiras	2	100	8	100
Cuatro lóbulos y 3.0 espiras	3	100	11	100
Seis lóbulos y 3.0 espiras	8	100	*	*
Aparición corazón adulto	11	44	11	35
Aparición pedúnculos oculares	5	26	11	30
Cuatro lóbulos y 3.5 espiras	11	77	15	73
Seis lóbulos y 3.5 espiras	11	23	15	27
Inicia migración de ojos a pedúnculos	13	19	15	11
Inicia pigmentación del manto	14	17	15	12
Inicia pigmentación del pie	15	12	17	23
Seis lóbulos y 4.0 espiras	16	49	19	16
Aparece la probóscis	18	25	20	13
Aparece la rádula	20	22	20	19

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LITERATURA CITADA

Ballantine, D.L. y R.S. Appeldoorn 1983. Queen conch culture and future prospects in Puerto Rico. *Proceedings of the Gulf and Caribbean Fisheries Institute* **35**:57-63.

Baqueiro, C.E. 1997. The molluscan Fisheries of Mexico. Pages 39-49 in: NOAA Tech. Rep. NMFS 129: *The History, Present Condition and Future of the Molluscan Fisheries of North and Central American and Europe*. U.S. Dept. of Commerce.

Berg, C.J., Jr. 1976. Growth of queen conch, Strombus gigas, with a discussion of the practicality of its mariculture. *Marine Biology* **34**:57-63.

Berg, C.J., Jr., K.S. Orr, and J.B. Mitton. 1983. Genetic variation in the queen conch, *Strombus gigas*, across its geographic range. Preliminary results. *Biological Bulletin* **165**,505.

Brito-Manzano, N., D. Aldana Aranda, y E. Baquiero Cárdenas. 1998. Modelo sintético del desarrollo larvario de *Strombus pugilis* (Mesogastropoda: Strombidae). *Revista Biologico Tropical* **46 (5)**:23-28.

Brownell, W.N. 1977. Reproduction, laboratory culture and growth of *Strombus gigas, Strombus costatus* and *Strombus pugilis* in Los Roques, Venezuela. *Bulletin of Marine Science* **27**:668-680.

D'Asaro, C.N. 1965. Organogenesis, development and metamorphosis in the queen conch *Strombus gigas*, with notes on breeding habits. *Bulletin of Marine Science* **15**:359-416.

Davis, M., C.A. Bolton, and A.W. Stoner. 1993. A comparison or larval development, growth and shell morphology in three Caribbean *Strombus* species. *The Veliger* **36**:236-244.

García Santaella, E. and D. Aldana Aranda. 1994. Effect of algal food and feeding schedule on larval growth and survival rates of the queen conch, *Strombus gigas* (Mollusca, Gastropoda), in Mexico. *Aquaculture* **128**:261-268.

Laughlin, R.A. y E. Weil. 1983. Queen conch mariculture and restoration in the Archipielago de Los Roques. *Proceedings of the Gulf and Caribbean Fisheries Institute* **35**:64-72.

Produccion de Masas de Huevos en el Laboratorio del Caracol Marino, *Strombus pugilis* (L)

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RESUMEN

En México el recurso caracol se encuentra sobre-explotado y desde hace 10 años se estableció una veda permanente y hasta la fecha existe una gran dificultad de encontrar en el campo las puestas de masas de huevos, debido a que los caracoles se encuentran muy aislados. Ante esta problemática el objetivo principal de este trabajo es la producción masiva de puestas de masas de huevos en condiciones controladas en el laboratorio de aprovechamiento de recursos marinos y agropecuarios del Instituto Tecnológico de Mérida. Las condiciones controladas en el sistema fueron: un flujo de agua de mar de 200 ml/min, con una tasa de recambio del volumen total de 5 horas, relación del sexo de 5 caracoles hembra por 2 machos, una temperatura de 28 ± 0.5°C, salinidad de 37.5 ± 0.5 ppm, pH de 7.5 ± 0.5 y alimento peletizado. Cada una de las puestas de masas de huevos fue limpiada de la arena y tratada con una solución de cloro al 0.2% entre 30 y 40 segundos. Un total de 30 puestas de masas de huevos fueron colectadas de un sistema de recirculación de agua de mar, donde se encontraban un total de 7 progenitores durante un período de 10 meses. Los resultados de esta investigación son importantes por proporcionar desde el mismo laboratorio mencionado, las puestas de masas de huevos para estudios posteriores como: el conocimiento de su biología básica, el efecto de la temperatura sobre el desarrollo embrionario, fisiología energética, bioquímicos y para el manejo adecuado de las masas de huevos y larvas en el cultivo de *S. pugilis;* en la práctica de su maricultura con la finalidad de recuperar el recurso aunado a la regulación pesquera.

PALABRAS CLAVE: *Strombus pugilis*, maricultura, puestas de masas de huevos.

INTRODUCCION

Aunque la regulación pesquera sigue siendo una forma de recuperar las poblaciones explotadas, la maricultura es una alternativa prometedora. La maricultura es una crianza controlada y protegida de especies marinas, generalmente desde la fase de huevo a juvenil o estado adulto dependiendo de la especie y sus aplicaciones. Con ella se pueden reducir los efectos de la pesca sobre las poblaciones naturales ya sea por limitar la sobrepesca actual o por la repoblación de las áreas ya sobreexplotadas, incluso se pudieran cosechar poblaciones naturales de

valor comercial con individuos totalmente crecidos en granjas (Rodríguez 1995 a).

La producción a gran escala de postlarvas y el cultivo en el laboratorio "Hatchery" de los caracoles marinos se hace actualmente en forma rutinaria, pero pudieran mejorarse los aspectos de crecimiento y engorde a partir de un mejor conocimiento del desarrollo larvario y post-larvario. En estos estadios puede mejorarse la alimentación natural y/o artificial de alto rendimiento en condiciones ambientales adecuadas, incluyendo la temperatura, la salinidad y el pH.

Entre los recursos de mayor importancia económica para los pescadores del Estado de Yucatán y otros habitantes de las costas de la Península, están los caracoles de las especies *Strombus gigas* L, *S. costatus* (G) y *S. pugilis* (L). El mas conocido en sus aspectos biológicos, ecológicos y tecnológicos es *S. gigas* y los otros dos son menos conocidos. Las tres especies antes mencionadas se encuentran distribuidas ampliamente en las zonas costeras de aguas marinas someras de la región.

El recurso caracol, particularmente *S. gigas* y *S. costatus*, ha mostrado síntomas evidentes de sobrexplotación en aguas de la región y en general, en toda su área de distribución, incluyendo Cuba y otros países del Caribe. Esta situación ha obligado a algunos de los países del Atlántico centro-occidental a declarar la veda permanente del recurso (Rodríguez 1994, Solís 1994).

Desafortunadamente, el aprovechamiento de estas especies en México se ha realizado, hasta la fecha, como una captura directa indiscriminada e ilícita sin dar consideración suficiente a sus necesidades reproductivas que asegure el mantenimiento de poblaciones viables. Reflejo de ello es la actual escasez generalizada de estos organismos. En Yucatán, México, se estableció hace 15 años una estricta prohibición sobre su captura pero se desconoce si - después de 15 años - ello ha sido efectivo para la recuperación de sus poblaciones.

Por razones ecológicas, económicas y sociales, resultaría muy conveniente encontrar en el corto plazo alternativas para mantener la producción y reproducción de éstos caracoles. Entre las opciones a las que se ha dado mayor atención está el cultivo de caracoles en estanques o encierros costeros comúnmente referido como maricultura. A través de esta actividad se cría a los individuos desde su condición de huevecillo hasta etapas larvarias y juveniles que son entonces liberadas al mar donde tendrán mayores posibilidades de sobrevivir y contribuir a la repoblación del medio natural.

Junto con otras Instituciones Nacionales e Internacionales, el Instituto Tecnológico de Mérida (ITM), en su División de Estudios de Posgrado e Investigación, ha venido realizando estudios de campo y laboratorio sobre las condiciones en las que pudiera mejorarse el maricultivo del caracol.

Dentro de este contexto, el objetivo de este trabajo esta enfocado a la producción masiva de puestas de masas de huevos del caracol marino *S. pugilis* en el laboratorio, bajo condiciones controladas, para realizar estudios que contribuyan a tener un mejor entendimiento de la especie como: el conocimiento de su biología básica, el efecto de la temperatura sobre el desarrollo embrionario, fisiología energética, bioquímicos y para el manejo adecuado de las masas de huevos y larvas

en el cultivo de *Strombus pugilis*; en la práctica de su maricultura con la finalidad de recuperar el recurso aunado a la regulación pesquera.

MATERIALES Y METODOS

A continuación se mencionan los principales pasos del cultivo hasta la obtención de las puestas de masas de huevos y su incubación en el caracol lancetilla *S. pugilis*. desinfección y lavado del material, tratamiento del agua de mar, colecta de los progenitores, traslado al laboratorio, puesta de los progenitores en los sistemas de mantenimiento con recirculación de agua de mar y filtro biológico, lecturas de pH, S‰, T, Alimentación. Colecta de las puestas de masas de huevos, limpieza de las masas de huevos para eliminar protozoarios, Observación de las masas de huevos para asegurar que sean fértiles y con el mismo estado de desarrollo y por último la incubación.

Desinfección y Lavado de Material

El material de campo y laboratorio empleado fue de cristal y plástico, previamente lavado con agua dulce (normal) y jabón neutro para evitar su contaminación. Posteriormente el material se desinfectó con una disolución de agua dulce y cloro comercial al 2%, se enjuagó con agua destilada y se dejó escurrir. El material ya desinfectado se colocó en un lugar seco y ventilado para evitar el desarrollo de organismos patógenos (Rodríguez 1995, Góngora 1999).

Tratamiento del Agua de Mar

El agua de mar se obtuvo del Puerto de Progreso y se transportó hasta las instalaciones del laboratorio donde se almacenó en una cisterna circular de cloruro de polivinilo (PVC). El agua pasa después a un depósito con capacidad de 10 m^3. Con la ayuda de una bomba eléctrica (marca Siemens, 110-220 volts; 3 505 a 3 470 rpm) el agua se envió al laboratorio de Recursos Marinos, pasando por un filtro rápido de arena (Baker Hydro, modelo TSF-24), tres filtros de cartucho de polipropileno y filtro de celulosa (Cole Parmer) con una capacidad de retención de 25, 15 y 5 mm, respectivamente. Al final el agua pasa por una batería de luz ultravioleta, para almacenarla en tres tanques de plástico con capacidad de 50 l, cada uno de los cuales permanecieron cerrados para evitar su contaminación (Rodríguez 1995, Góngora 1999).

Colecta y Establecimiento de los Progenitores

Siete progenitores se colectaron el 13 de septiembre de 1999 entre 10:00 a.m. y 2:00 p.m., mediante buceo autónomo en puntos ubicados entre los 700 m de la estación de Isla Contoy, Quintana Roo a profundidades de 3.5 a 4 m, sobre arena fangosa y el pasto marino *Siringodium filiforme* y *Thalassia testudinum*. De los siete progenitores colectados, cinco fueron hembras y dos machos; se colocaron en contenedores de plástico con agua de mar fresca, a 28°C y salinidad de 38 ‰. Posteriormente, se trasladaron al laboratorio de aprovechamiento de recursos

marinos del Instituto Tecnológico de Mérida, teniendo cuidado que durante la transportación la temperatura no rebasara los 32°C (Rodríguez 1995).

LABORATORIO

Sistema de Mantenimiento de los Progenitores

Ya en el laboratorio fueron colocados en un acuario de 80 L, con agua de mar previamente tratada con luz U.V, velocidad de flujo de 200 ml/min con una tasa de recambio de volumen total de 5 horas y filtro biológico formado de arena, graba, tul, lámina de fibra de vidrio y tubos de PVC respectivamente. Se aplicó aireación y calefacción al agua para conservar la temperatura a 28°C. Se tomaron lecturas periódicas de pH, salinidad y temperatura (Rodríguez 1986, Góngora 1999) (Figura 1).

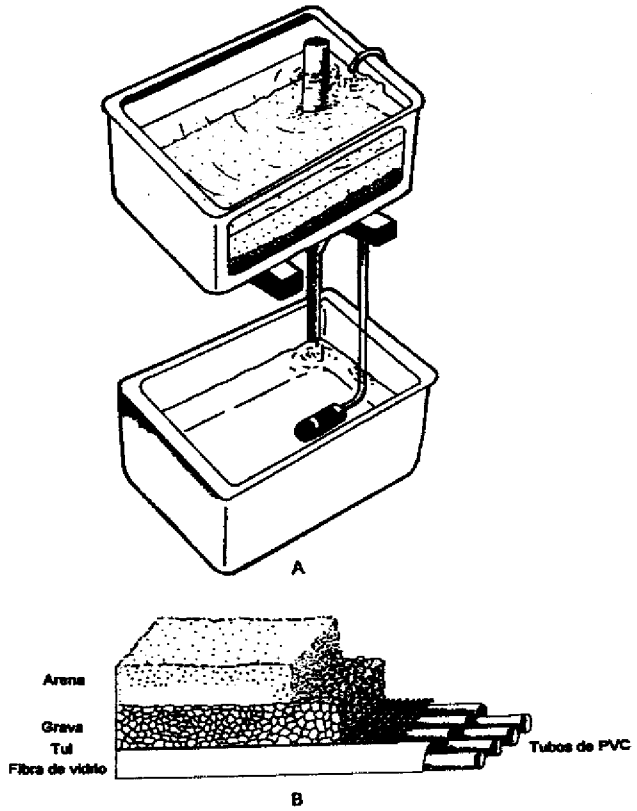


Figura 1. A) Sistema de recirculación de agua de mar y filtro biológico para el mantenimiento de progenitores del caracol marine *Strombus pugilis*. B) Detalle de las capas en el filtro biológoco.

Alimentación

Los progenitores fueron alimentados con algas filamentosas y alimento peletizado con 36% de proteína, 7% de grasa, 4% de fibra, 12% de humedad y 10% de cenizas. El alimento fue elaborado en el CINVESTAV-Unidad Mérida.

Obtención, Limpieza y Observación de las Masas de Huevos

Las masas de huevos colectadas en el laboratorio en un sistema de mantenimiento de los progenitores y fueron limpiadas con la ayuda de un colador de 1 mm de abertura para quitar el exceso de arena. Posteriormente se pasaron por cuatro contenedores, el primero de ellos con una solución de cloro comercial (hipoclorito de sodio) y agua de mar filtrada al 0.2% entre 30 y 40 segundos. Esto se hace para eliminar protozoarios y otras especies indeseables. Inmediatamente después se colocaron en otros tres contenedores restantes conteniendo agua de mar previamente filtrada para eliminar la solución de cloro (Siddall 1979, Berg 1981, Pillsbury 1985, Rodríguez 1995). La masa de huevos fue observada bajo un microscopio óptico de campo obscuro para asegurar que los huevos fueran fértiles, viables y que se encontraran en el mismo estado de desarrollo, es decir, con la membrana de fertilización presente.

Incubación

La masa de huevos fue extendida para contar su dimensión y fraccionada para poder contar el número de embriones presentes en 2 cm y en toda la masa de huevos. Cada sección se colocó en un vaso de Precipitado de 1 000 ml con agua de mar filtrada a una salinidad 37‰. Estas manipulaciones se realizaron a una temperatura ambiente (aproximadamente 28°C). Paralelamente se instalaron tinas con agua de mar dentro de los cuales se depositaron los vasos de Precipitado, cada uno con las secciones de las masas de huevos. Todas las masas obtenidas fueron incubadas a una temperatura de 28 ± 0.2°C para efectuar el desarrollo embrionario y posteriormente la eclosión

Se tomaron lecturas periódicas de salinidad, pH y temperatura. Con el fin de evitar perturbaciones y contaminación con el exterior, las tinas estuvieron cubiertas con malla, y con un sistema de aireación en el agua (Góngora 1999).

RESULTADOS

Los resultados promedio de los parámetros físicos-químicos a lo largo de 10 meses fueron los siguientes: temperatura 28 ± 0.5°C, salinidad 37.5 ± 0.5‰ y pH 7.5 ± 0.5. Un total de 30 puestas de masas de huevos fueron colectadas en un sistema de mantenimiento de los progenitores, en la Tabla 1 se muestra el número total de puestas de masas de huevos, en relación al sexo y biometría bajo condiciones de laboratorio de Septiembre de 1999 a Junio de 2000. Se puede observar que en el número de puestas de masas de huevos no hay una correlación entre el número de puestas y el peso del animal.

Tabla 1. Producción total del número de puestas de masas de huevos, en relación a la razón del sexo y biometría de los caracoles marinos *Strombus pugilis* bajo condiciones de laboratorio de Septiembre de 1999 a Junio del 2000.

Número de organismo	Sexo	Largo (cm)	Peso (g)	Puestas
1	H	8.5	147.49	8
2	H	9.0	147.35	5
3	H	9.1	157.29	6
4	H	8.0	112.76	6
5	H	8.5	136.57	5
6	M	8.7	133.62	
7	M	8.4	103.57	
Total de puestas				30

En la Figura 2 se puede observar el número de puestas de masas de huevos por organismo, el máximo número de puestas lo obtuvo el organismo 8 y el mínimo lor organismos 2 y 7.

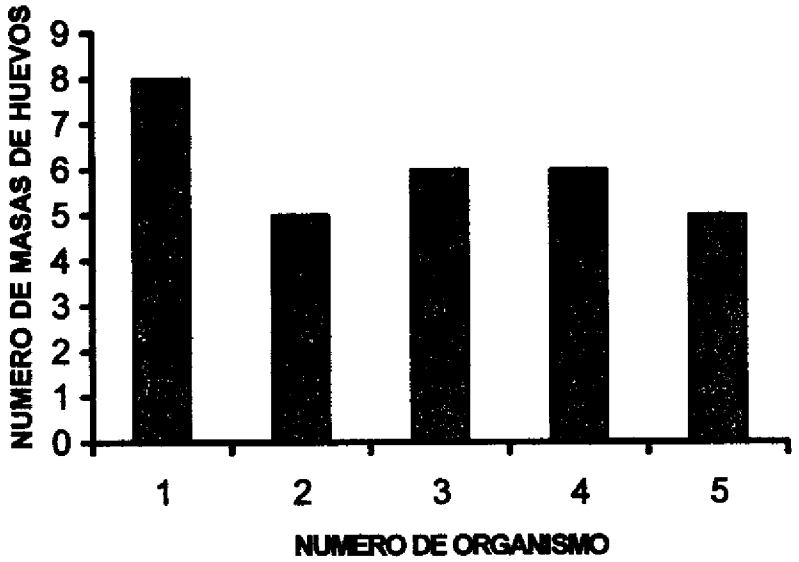


Figura 2. Número de puestas de masas de huevos por organismo en *Strombus pugilis* (L) de Septiembre de1999 a Junio del 2000 bajo condiciones de laboratorio.

La Figura 3 nos muestra el número de puestas de masas de huevos obtenidas en el laboratorio por mes, empezando por el mes de Septiembre en el cual se obtuvo 13 puestas de masas de huevos, posteriormente se detiene a partir del mes de Noviembre en donde no se obtuvo puestas, luego se presentó un pico a partir del mes de Abril y por último se observa una disminución duarante el mes de Mayo debido a problemas de solventes en el laboratorio.

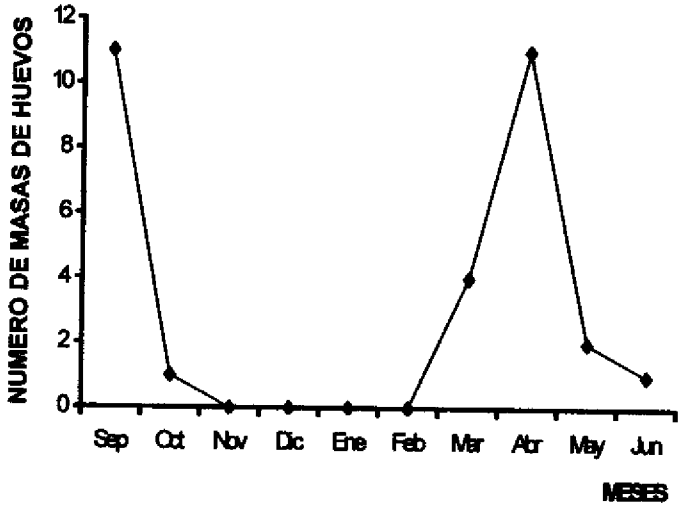


Figura 3. Número de puestas de masas de huevos en *Strombus pugilis*, obtenidas en el laboratorio por mes.

Con los datos anteriores se estimó el número total de embriones obtenidos por mes (Figura 4), el número total de embriones obtenidos de *S. pugilis* en el sistema de recirculación fue estimado por mes en base a la relación del peso de la masa de huevos de una sola hembra (1.031) y el número de embriones contados en toda la masa de huevos (157 500). La longitud total de la masa de huevos fue de 11.24 m, el número promedio de embriones encontrados en 2 cm fueron de 264, obteniendo un total de 157 500 embriones en toda la masa de huevos.

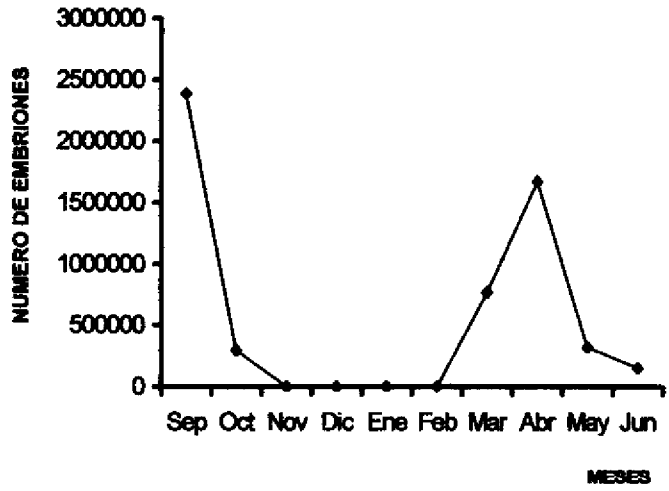


Figura 4. Total de embriones de *S. pugilis*, obtenidos en el laboratorio al mes.

DISCUSION

La tabla 1 nos muestra que no existe una relación entre el largo y peso del organismo con el número de puestas de masas de huevos, cada organismo ovopositó más de una puesta,obteniendo un total de 30 puestas de masas de huevos, obteniendo dos picos máximos de puestas de masas de huevos en el mes de Septiembre y en el mes de Abril, en tanto que los meses de Noviembre a Febrero no se obtuvo ninguna masa de huevos, cosa muy similar a lo reportado por Shawn en el campo, esto pudo ser atribuido primeramente a que los organismos ya tenian una acumulación de esperma cuando fueron transportados al laboratorio, pero posteriormente las hembras fueron fecundadas dentro del sistema de recirculación de los progenitores, los cuales fueron colocados en el laboratorio mediante parámetros controlados.

Con respecto a la alimentación los organismos no se alimentaron durante el primer mes, pero posteriormente fueron alimentados con "pellets", sobre todo se pudo observar a las hembras alimentandose, después de ovopositar.

Por lo que se puede concluir que este sistema de manteniminto y recirculación de los progenitores es excelente tanto para la reproducción de los progenitores como para la obtención de las masas de huevos bajo condiciones controladas.

La Tabla 2 nos muestra las diferencias que existen entre algunas lspecies de Strombus, tanto en el número total de embriones por puesta como en la longitud total de la masa de huepos en metros y el número de embriones por mm.

Tabla 2. Diferencias entre algunas especies del Género Strombus con relación al número estimado de embriones por puesta y por longitud en mm, así como la longitud total de la masa en metros.

Especie	Número de embriones	Longitud de la masa	Número de embriones/mm	Autor
S. gigas	300,000 -750,000	24 - 37 m	12 -15 mm	Hahn
	480,000	29.8 m		D'Asaro
	385,000 -430,000	22.6 m	17 -18 mm	Robertson
S.costatus	185,000 -210,000	13.2 - 15 m	14 mm	Robertson
S.raninus	400,000 - 460,000	20 m	20 - 23 mm	Robertson
S.tricornis	1,800 - 2,800	3 - 4 m	6 - 7 cm	Eisawy y Sorial
S.gallus	80,000	3.8 m		D'Asaro
S.luhuanus	112,000 - 317,000	4.4 - 8.0 m	225 - 396 cm	Kuwamura y Fukao
S.fasciatus	157,000			
S.pugilis	157,500	11.24 m	11 mm	Rodríguez y Góngora

CONCLUSION

Tanto las condiciones empleadas, como el tipo de mantenimiento, resultaron ser excelentes para la obtención de las masas de huevos desde el laboratorio, así como la sobrevivencia de los progenitores bajo condiciones controladas. Estos resultados ayudarán a mejorar el manejo de las masas de huevos de *S. pugilis*, proporcionar una descripción detallada de la morfología externa y comportamiento, poder relacionar

el desarrollo morfológico con la temperatura del agua. Con base en esta información se puede decidir cuando transferir las masas de huevos de los estanques de incubación a los de cultivo larval, así como el conocimiento de su biología básica, el efecto de la temperatura sobre el desarrollo embrionario, fisiología energética, bioquímicos y para el manejo adecuado de las masas de huevos y larvas en el cultivo de *S. pugilis*; en la práctica de su maricultura con la finalidad de recuperar el recurso aunado a la regulación pesquera. Un punto muy importante si se desea efectuar estudios sobre el cultivo de esta especie, es contar con un laboratorio específico, libre de solventes o productos químicos, para evitar mortalidad de los progenitores.

LITERATURA CITADA

Berg, C.J. 1981. Proceedings of the queen conch fisheries and mariculture meeting. The Wallace Groves Foundation. Freeport, Bahamas. 46 pp.

D'Asaro, C.N. 1965. Organogenesis, development, and metamorphosis in the queen conch *Strombus gigas,* with notes on its breeding habits. *Bulletin of Marine Science* **15**(2):359-416.

D'Asaro, C.N. 1970. Egg capsules of prosobranch mollusks from south Florida and the Bahamas and notes on spawning in the laboratory. *Bulletin of Marine Science* **20**:414-440.

Eisawy, A. y A. Sorial. 1968. The egg-masses, development and metamorphosis of *Strombus* (*monodactylus*) *tricornis* Lamarck. Institute of Oceanography and Fisheries, Al-Gardaga, United Arab Republic. *Proceedings of the Malacological Society of London* **38**:13-26.

Góngora, A.M. 1999. Efecto de la temperatura sobre el desarrollo embrionario del caracol marino *Strombus pugilis* (L).Tesis Licenciatura, Univ. Autón. Yuc. 38 pp.

Hahn, K. O. (ed.) 1989. Culture of queen conch, *Strombus gigas,* in the Caribbean. Pages 317-330 in: *Handbook of Culture of Abalone and Other Marine Gastropods*. CRC Press. Boca Ratón, Florida USA.

Kuwamura, T., R. Fukao, M. Nishida, K. Wada y Y.Yanagisawa 1983. Reproductive biology of the gastropod *Strombus luhuanus* (Strombidae). *Publ. Seto Mar. Biol.* **28**:433-443.

Pillsbury, K.S. 1985. Relative food value and biochemical composition of five Phytoplankton diets for queen conch, *Strombus gigas* (L) larvae. *Journal of Experimental Marine Biology and Ecology* **74**:241-257.

Robertson, R. 1959. Observation on the spawn and veligers of conch (*Strombus*) in the Bahamas. *Proceedings of the Malacological Society of London* **33**(4): 164-171.

Rodríguez, L.A. 1986. Desarrollo embrionario y metamorfosis del caracol rosado *Strombus gigas*. M. Sc. Tesis. CINVESTAV-Mérida, 43 pp.

Rodríguez, L. A. 1990. Cría del caracol rosado, *Strombus gigas* (L) en dos sistemas diferentes. *Proceedings of the Gulf and Caribbean Fisheries Institute* **43**:4-9.

Rodríguez, L.A. 1994. Análisis de la evolución de la pesquería del caracol en dos estados de la Península de Yucatán, México y en una cooperativa de pescadores. Paginas 113-136 en: I Congreso Latinoamericano de Malacología. Fundación Científica Los Roques, Venezuela.

Rodríguez, L.A. 1995. *Biochemical Composition of Larval Diets and Larvae Related to the Life History and the Induction of Metamorphosis in the Milk Conch, Strombus Costatus (G).* Ph. D. Thesis. Univ. of Puerto Rico, Mayaguez, Puerto Rico. 140 pp.

Rodríguez, L.A. 1995 a. Eclosión del caracol de leche, *Strombus costatus* basado sobre el desarrollo embrionario. *Revista del Centro de Graduados e Investigación. I.T.M* **23**:1-18.

Siddall, S.E. 1979. Temporal changes in the salinity and temperature requirements of tropical mussel larvae. *Proceedings of the World Mariculture Society* **9**:546-566.

Solís, R.M. 1994. Mollusca de la península de Yucatán, México. Recursos faunísticos del litoral de la Península de Yucatán. Universidad Autónoma de Campeche. 2-32 pp.

Re-Initiation of the Marine Recreational Fishery Statistics Survey in the U.S. Caribbean in 2000

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ABSTRACT

The Marine Recreational Fishery Statistics Survey (MRFSS) was begun by the National Marine Fisheries Service (NMFS) in 1979 to provide nationwide statistically valid and consistent estimates of saltwater recreational fishing catch, effort, and participation. The MRFSS was based on research conducted in the 1970's and consists of two complementary surveys: a telephone survey for effort and an intercept survey for catch. The MRFSS was conducted in the U.S. Caribbean territories in 1979 and in 1981; however, in 1982 insufficient funding caused that sampling to be discontinued. In 1999, the NMFS began planning to re-initiate the MRFSS in the U.S. Caribbean for calendar year 2000. Planning was conducted in a cooperative manner with the territorial fisheries resource agencies of Puerto Rico (PR) and the U.S. Virgin Islands (USVI). The Caribbean Fisheries Management Council (CFMC) and NMFS Southeastern Regional staff were also consulted to ensure federal management needs unique to the U.S. Caribbean were considered. Telephone sampling began December 1999 in both territories while intercept sampling began January 2000 in PR and March 2000 in the USVI. Sampling results and preliminary estimates are provided and lessons learned from the re-initiation of the MRFSS are discussed. The MRFSS staff expects that the survey will continue into 2001, which will allow continued improvement and adaptation to local conditions.

KEY WORDS: Recreational fishery, Fishery-dependant surveys, U.S. Caribbean

INTRODUCTION

Detailed information on marine recreational fishing is required to support a variety of fishery management and development purposes and is mandated by the Sustainable Fisheries Act, Public Law 94-265. In 1979, NMFS began the comprehensive Marine Recreational Fishery Statistical Survey (MRFSS) to provide such information on a national basis. Although the recreational harvest is only about six percent of the total U.S. harvest of finfish for the contiguous 48 states (O'Bannon 1999), it is important to managers because the fishing activities of millions of marine anglers are directed at relatively few species. Data collected through the MRFSS show that recreational fisheries have tremendous impacts on many recreationally important species and for some species recreational landings surpass commercial landings.

The MRFSS consists of an intercept survey of anglers in the field and a telephone survey of coastal county households. Numerous NMFS methodological studies indicated that a national survey should be structured around this data collection approach (Brown 1977, Brown et al. 1977, Chandler 1977, Chandler and Brown 1978, Hiett and Ghosh 1977, Hiett and Worrall 1977, Metze 1977). The studies showed that a telephone survey could be used to collect reliable data on recreational fishing effort. Data on fishing trips became less reliable beyond a two month period due to recall problems. Information on the actual catch such as species identity, number, and size of fish caught could not be reliably collected by telephone. Catch data are obtained from anglers intercepted by trained interviewers stationed at fishing access sites. The MRFSS surveys are stratified among geographic subregions, states, and two-month time periods ('waves'), and the intercept survey is also stratified by fishing mode (shore, private/rental boat, and charter/head boat).

From calendar years 1979 to 1981 the MRFSS was conducted in the U.S. Western Pacific and Caribbean territories and in all coastal states except Alaska, although the Caribbean was not surveyed in 1980. Due to insufficient funding throughout the 1980s and early 1990s, MRFSS coverage was dropped from Hawaii and the U.S. Territories in 1982, and from the Pacific coast (Washington through California) from 1990 to 1992. Sampling coverage during winter months was also curtailed on the Atlantic and Gulf coasts during various years, including the present. Coverage was dropped in relation to the relative magnitudes of the recreational fisheries, with smaller fisheries dropped first. Funding has gradually improved since 1992, allowing re-establishment of the MRFSS on the Pacific coast in 1993, the U.S. Caribbean in 2000, and Hawaii in 2001.

Planning for re-establishment of the survey in the Caribbean began the summer of 1999 and was done in cooperation with the PR Department of Natural and Environmental Resources and the USVI Division of Fish and Wildlife. The territorial agencies provided critical input on local fishing conditions, management information needs, preliminary listings of fishing access sites and estimated fishing pressures, numbers of charter boats, sources for census data needed for expansion of the estimates, review of Spanish-language questionnaires, and recommendations of interviewer hiring sources. PR also proposed using their own staff to increase intercept sample sizes above the base level that NMFS could afford. The Caribbean Fisheries Management Council (CFMC) and NMFS Southeastern Regional Office were also consulted to ensure federal management needs unique to the U.S. Caribbean were considered. Input from the SERO resulted in the use of the flexible questions option on the telephone survey to collect recreational shell-fishing data for lobster, whelk, and conch.

Telephone sampling began December 1999 in both PR and the USVI, while intercept sampling began in January 2000 in PR and in March 2000 in the USVI. Sampling has been completed through wave 5 (September-October) of the 2000

survey and some preliminary results through wave 4 (July-August) are now available. Telephone sampling was conducted by the current MRFSS telephone and intercept contractor, ORC Macro (Macro), one of the ten largest survey research companies in the world. Intercept sampling was conducted by Macro in the USVI and by a combination of Macro and PR staff in PR.

METHODS

The telephone survey collects data on the number of marine fishing trips. For the 1979-1981 Western Pacific and Caribbean surveys, personal interviews at individual homes were conducted instead of a telephone survey of households, due to the low percentage of telephone ownership. Although the contact method was slightly different for this survey component, other survey details and estimation procedures were similar to the routine MRFSS. For the 2000 survey, it was determined that telephone ownership rates (land-lines, not cell-phones) had increased enough to use the routine telephone survey, which is more affordable and logistically simpler, and allows larger sample sizes.

The MRFSS telephone survey estimates the total number of marine recreational fishing trips made by permanent residents of coastal county households with telephones. The sample frame for this survey is the residential household telephone directory for a designated coastal zone in each coastal state. For PR and the USVI the coastal zone includes all of the islands. The survey uses random-digit dialing (RDD) to select an approximately random sample of residential households with phones in each sampled county. The RDD method ensures that all residential phone numbers have an equal probability of being selected in the telephone survey sample for a given county. The sample allocation among counties in a state are based on the square root of the population, which helps ensure that rural counties with small populations are represented in at least some of the sample. For PR and the VI, there are municipalities and islands, respectively, instead of counties; however there is no census data available for these divisions, nor are there distinct telephone exchanges by municipality (PR) or island (USVI), therefore the telephone survey is a simple random sample within each territory.

Over 250,000 telephone households are contacted each year on the Atlantic, Gulf, and Pacific coasts. Samples typically are proportionally allocated to each state and wave based on relative historical distributions of estimated fishing effort. The 1979 and 1981 MRFSS Caribbean estimates were examined to determine their applicability to allocations but were extremely variable. Prevalence rates in the 1979 - 1981 surveys showed that 3 - 4% (PR) and 7 - 8% (USVI) of all households engaged in marine recreational fishing in the last two months, therefore sample sizes for each territory were set at 2,000 (PR) and 900 (USVI) households per wave. This is equivalent to state levels in the southeast U.S. which are the highest in the nation. Dialing for each wave's telephone survey was completed by contractor personnel during the two-week period which included the last week of the wave and the first week of the next wave.

If any of the permanent residents of a contacted household participated in marine recreational fishing within the last two months, all recreational saltwater fishermen in that household who fished during that period are interviewed. Fishermen are asked to provide the number of days, or day-trips, spent fishing in each fishing modes in the past two months. Next, the interviewer asks the respondent about each day-trip, starting with the most recent day of fishing and working back two months. For each trip, the fisherman is asked for the date of the trip, the state and county (municipality for PR and island for USVI) from which it was taken, the mode of fishing, the primary water body fished (ocean or inland waters), the type of access used (private or public), and the time of return.

The intercept survey gathers catch and demographic data from marine recreational anglers who have just completed fishing from shore, private/rental boats, or charter/head boats. In PR and USVI there are no head boats, so that mode is charter boat only. Over 80,000 fishermen interviews are conducted in coastal states on the mainland each year. Intercept sampling is stratified by state, mode, and wave with a minimum of 30 intercepts in each stratum. Beyond this minimum, samples are allocated in proportion to relative historical distributions of estimated fishing effort from the three previous survey years. The 1979 and 1981 MRFSS Caribbean data were too variable to provide practical guidance, therefore sample sizes were set equivalent to state levels in the Southeast U.S., but modified by preliminary estimates of the numbers of charter boats, and the numbers, distributions, and expected pressures by mode of fishing access sites. The 1979 and 1981 data showed high variability on seasonality between the two survey years, therefore sampling allocations were set equal for all waves for 2000 (Table 1).

Lists of access sites for marine recreational fishing were provided to MRFSS staff by PR and USVI in 1999 and modified by ORC Macro to include all MRFSS variables. These lists are updated prior to each wave's sample selection. Sites are chosen for interviewing assignments by randomly selecting from among the listed sites but weighting by estimates of expected fishing activity. The intent of the weighting is to sample so that each angler trip has an equal probability of inclusion in the sample, except that low pressure sites are down-weighted relative to medium and high-pressure sites to increase efficiency. Sampling historically has been distributed among weekdays and weekends (including holidays) based on a 60/40 split. Based on advice from PR, that was modified to a 50/50 split for that territory.

Anglers are intercepted, screened, and interviewed at assigned access sites upon completion of their fishing trips. Each interview consists of an introduction to the survey and information on the Privacy Act of 1974, an oral interview concerning the fishing trip just completed, collection of phone ownership and residence location, thorough examination of the respondent's catch, and measurement of lengths and weights from all of (or if necessary, a random sample) the fish of each species in the respondent's catch.

Table 1. Sample target goals for the Marine Recreational Fisheries Statistics Survey intercept interviews of fishermen by mode and territory for 2000.

Territory Sample Goals	Fishing Mode		
	Private Boat	Charter Boat	Shore
Puerto Rico			
MRFSS Base Target	200	90	130
PR Add-on Target	292	61	227
U.S. Virgin Islands			
MRFSS Base Target	150	80	100

Catch is divided into three categories – fish that were caught and landed whole or in such manner that they are available for identification, enumeration, weighing and measuring by trained MRFSS field personnel (type A); fish that are reported by the angler because they were filleted, released dead, given away, or disposed of in some way that interviewers can not verify the species, sizes, or numbers reported (type B1); and fish that were reported as released alive (type B2).

Effort estimates generated directly from the RDD telephone survey are the number of individual fishing trips taken by individual fishermen from households with phones in coastal counties. Trips are estimated for each state, wave and mode at the county level and then summed to state (territorial) level. For PR and the USVI the estimate is made for each territory as a whole, since county-type data for expansion are unavailable. The number of trips per all contacted household for each fishing mode during each wave is multiplied by the number of permanent, full-time occupied households in the coastal county (Bill Communications, Inc., 1999) to estimate total number of fishing trips in each mode by coastal county residents. Population estimates were obtained for PR from the Center for Income Registration or CRIM (1998 estimates were 1,225,400 households). Telephone ownership (78%) for PR was obtained from the PR Departamento de Comunicaciones. Population and telephone ownership estimates were obtained for the USVI from the Virgin Islands Population and Housing Survey, Eastern Caribbean center, University of the Virgin Islands (1995 estimates were 36,400 households with 90% telephone ownership). The variance associated with the average number of fishing trips per household is calculated using the model for a stratified simple random sample. The estimate of coastal resident trips is adjusted to cover trips not included in the sampling frame. For the U.S. Caribbean, it is adjusted by ratios obtained from the intercept survey for trips taken by out-of-state residents and for trips made by people who live in households without telephones. The total number of trips is then post-stratified into primary fishing area (inland, state territorial sea, and EEZ) by the distribution of intercept trips.

The catch of each finfish species is estimated for each subregion, state, wave, fishing mode, primary fishing area, wave, and catch type. The total number of fish for each stratum is estimated from the estimated number of fishing trips taken in that stratum, and the mean number of fish caught per trip in that stratum.

Estimation of the variances associated with the average catch and weight of catch estimates obtained from the intercept survey is based on the assumptions that the primary sampling unit was a fishing trip by an individual angler and that there is no clustering effect due to the collection of groups of interviews at each visited site. These assumptions were empirically verified in pilot surveys. Therefore, the variance is estimated using the standard variance equation for a stratified random sample. Combination estimates of total fishing effort, the numbers of fish caught, the weight harvested, and others are all produced by multiplying together the appropriate basic estimates, therefore the basic formula for the variance of a product of two random variables is used for those calculations (Goodman 1960). The total catch estimates are not necessarily normally distributed; however, simulation experiments indicated that a normal approximation is satisfactory for construction of 95 percent confidence intervals around the estimated total catch. More detailed information on the methodology and estimation procedures and access to the data are available on the Fisheries Statistics and Economics web page (www.st.nmfs.gov/st1).

RESULTS

Telephone quotas were met in all waves. Prevalence rates (the percent of coastal households with phones with 2-month marine recreational fishing activity were lower than historical rates (Table 2).

Table 2. Marine Recreational Fisheries Statistics Survey telephone sample sizes, percent of marine recreational fishing households, and number of marine recreational fishing households by wave and territory for sampling waves 1 - 4, 2000, in the U.S. Caribbean.

Territory	Sampling Wave			
	1	2	3	4
Puerto Rico				
Sample Size (households)	2,011	2,001	2,004	2,010
% Saltwater Fished	1.5	2.0	2.1	2.83
Saltwater Fishing Households	30	41	42	57
U.S. Virgin Islands				
Sample Size (households)	908	903	907	909
% Saltwater Fished	5.2	4.8	5.7	5.6
Saltwater Fishing Households	47	43	52	51

Based on historical rates, the sample sizes were expected to provide approximately 60 active fishing household interviews per wave and territory. Instead, prevalence rates ranged from 1.5 to 2.8 percent for PR and 4.8 to 5.7 percent for USVI, providing approximately 40-50 households with fishing activity per wave in each territory.

Intercept sample sizes have generally improved since the beginning of the survey in Puerto Rico but have been zero to minimal in the USVI (Table 3). For PR the sample sizes were lower than the MRFSS base target level for private/rental boats in waves 1-3, but exceeded the base in wave 4. For PR charter boat and shore fishing, the sample sizes were higher than the base target for all waves except wave 2 and wave 1, respectively. For the Virgin Islands, no intercept samples were obtained for waves 1 and 4, and for waves 2-3 were minimal.

Effort estimates for PR for waves 1-4, 2000, exceeded the total estimates for the 1979 and 1981 MRFSS, while USVI effort estimates were lower than the 1979 estimate and much higher than the 1981 estimates (Table 4). PSE's were similar to 1979-1981 for PR but better for the USVI. Shore fishing effort for PR was similar in all years, while private/rental boat effort has increased slightly (Figure 1). Charter boat effort was low relative to the other modes in all years. Effort by mode for the USVI was extremely variable between the 1979 and 1981 surveys (Figure 2). In 2000, effort was almost evenly split between the private/rental boat and shore fishing with only a trace of charter boat fishing. All effort estimates are preliminary and may be subject to change.

Table 3. Actual intercept interviews of fishermen obtained by the Marine Recreational Fisheries Statistics Survey by fishing mode and territory for 2000.

Territory	Waves 1-4, 2000		Waves 1-6, 1979 & 1980	
	Angler Trips	PSE	Angler Trips	PSE
Puerto Rico	807,100	13.8	1979-639,200 1981-592,900	@16
U.S. Virgin Islands	104,633	35.7	1979-163,800 1981- 26,100	@62

Table 4. Marine Recreational Fisheries Statistics Survey effort estimates and their proportional standard errors (PSE) for the U.S. Caribbean for waves 1-6 of 1979 and 1981, and waves 1- 4 of 2000.

Territory	Waves 1 - 4, 2000		Waves 1 - 6, 1979 and 1980	
	Angler Trips	PSE	Angler Trips	PSE
Puerto Rico	807,100	13.8	1979-639,200 1981-592,900	@16
U.S. Virgin Islands	104,633	35.7	1979-163,800 1981- 26,100	@62

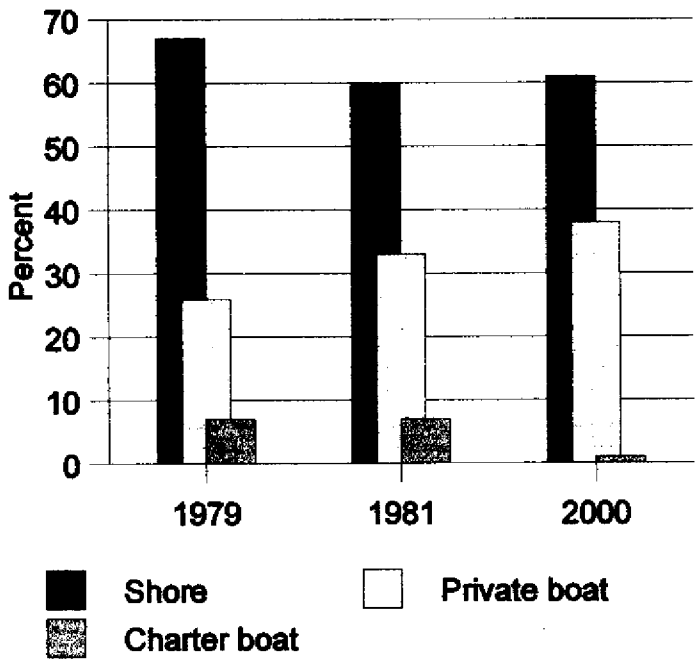


Figure 1. Marine Recreational Fisheries Statistics Survey effort estimates by mode for Puerto Rico for 1979, 1981 and 2000.

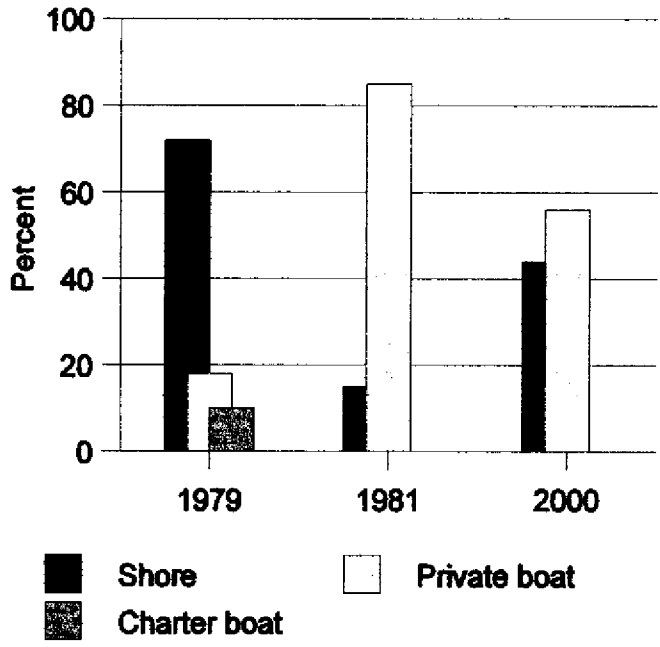


Figure 2. Marine Recreational Fisheries Statistics Survey effort estimates by mode for the U.S. Virgin Islands for 1979, 1981 and 2000.

Preliminary catch estimates are available for PR but not for the USVI due to the inadequate numbers of intercept samples obtained. Preliminary estimates for total catch (A+B1+B2) for PR are lower than the estimates from 1979 and 1981 but may reach the 1979 levels when the year is completed (Table 5). The percent of fish released is only seven percent. The top ten species groups of finfish harvested, in order, are herrings, snappers, dolphins, sea basses, mullets, jacks, tunas/mackerels, grunts, drums, and triggerfishes/filefishes. All catch estimates are preliminary and may be subject to change.

DISCUSSION

While two-month marine recreational fishing prevalence rates were lower than expected for the telephone survey, the large sample sizes ensured adequate numbers of active surveys, as shown by the PSE of 14 for Puerto Rico effort estimates. The PSE for the USVI effort estimates were negatively affected by the inability to obtain adequate intercept samples for the adjustments for out-of-state households.

Table 5. Marine Recreational Fisheries Statistics Survey harvest and released alive estimates of the numbers of fish and their proportional standard errors (PSE) for the U.S. Caribbean for waves 1-6 of 1979 and 1981, and waves 1-4 of 2000.

Type of Catch	Numbers of Fish	PSE	% of Total Catch
Harvest (A+B1)	1,842,000	23	93
Released Alive (B2)	142,000	21	7
Total Catch	1,984,000	22	100
Historical Total Catch		1979-2,664,000 1981-4,261,000	

The contractor has had difficulty in recruiting, hiring and retaining intercept samplers in the U.S. Caribbean, especially in the USVI. In PR, finding and hiring qualified interviewers was more difficult and took longer than expected prior to and during wave 1 of the survey. Without PR Department of Natural and Environmental Resources staff it is doubtful that sample sizes would have approached target levels in the earlier waves. The situation there has improved through the persistant efforts of the contractor and we expect sample sizes to continue to grow as the contractor-hired staff begin to obtain the base levels and the PR staff-collected interviews become true add-ons. Recruiting, hiring, and retaining staff in the USVI remains a problem, although the contractor successfully hired three new interviewers in October and they should be able to begin obtaining the target levels of interviews in wave 5. The interviewer problems is not a result of inactivity on the contractor's part, rather there just doesn't seem to be much interest by the populace in this type of part-time work. For example, a recent hiring effort resulted in 25 positive responses by phone, yet only three people actually show up for the testing and training sessions. In another case, a female interviewer was hired and sent a packet of assignments and forms, but her husband did not want her working so he hid the packet, and she missed the entire sampling period. We will continue to work with the contractor to explore remedies to these types of problems.

There have been other difficulties in attaining target levels of intercepts, including interviewer tardiness. The contractor has had difficulties in getting hired and trained interviewers to report back in a timely fashion and then to send in completed data forms. Without timely reporting of quotas, the contractor can not reschedule missed assignments or make additional assignments to make up for lower productivity levels. With-holding payment for completed assignments until completed packets are received doesn't seem to have much affect.

Lower productivity levels than expected has also resulted in not reaching target sampling goals. Productivity is affected by a variety of factors. Many of the fishing access sites have very low pressure, and there are relatively few very busy sites, which makes it more difficult and expensive to obtain samples. Subsistence fishing also seems to be affecting productivity as fishermen are excluding themselves due to the wording of our screening questions. These fishermen are using recreational methods, and many may be taking the fish home for the table so the catch is not being captured through monitoring of commercial fishing, yet these trips are not being captured by the MRFSS. We are considering changes to the screener for 2001 to allow categorization of the fishermen, while disposition of the catch questions will let us parse out fish that will enter commercial channels. Another factor causing low productivity is simply inexperience. The site registers and sample draws are working much better now that experienced interviewers have been in the field long enough to make better judgements on the expected pressures at access sites. More experienced interviewers also become more efficient and better at getting people to agree to be interviewed.

The survey estimation procedures are working well, although they could be improved if more recent information on household populations and phone ownership were available. Sampling could also be made more efficient if there were data on household populations by municipality in PR and by island in the USVI.

We currently expect that our budget will allow continued sampling in the U.S. Caribbean at least through 2001. This will allow us to continue to improve the survey and adapt to local conditions. Data and experience gathered through the 2000 survey will be used to fine tune sampling operations and we hope to provide full effort and catch estimates for the United States Virgin Islands as well as Puerto Rico for calendar year 2001.

LITERATURE CITED

Bill Communications, Inc. 1999. *Sales and Marketing Management: 1999 Survey of Buying Power.* Bill Communications, Inc., New York, NY USA. 290 pp.

Brown, G.L. 1977. A review of literature in selected areas relevant to the conduct of marine recreational fisheries surveys. Human Sciences Research, Inc., McLean, VA USA. 28 pp.

Brown, G.L., R.L. Hiett, and D.N. Ghosh. 1977. Evaluation of the door-to-door personal interview method as a technique for collecting marine recreational fishing statistics. Human Sciences Research, Inc., McLean, VA USA. 39 pp.

Chandler, K.A. 1977. A methodological study of on-site intercept surveys of marine recreational fishermen on the West coast. Human Sciences Research, Inc., McLean, VA USA. 60 pp.

Chandler, K.A., and G.L. Brown. 1978. A pretest of an approach to collection of marine recreational fishing data on the East and Gulf coasts. Human Sciences Research, Inc., McLean, VA USA. 175 pp.

Goodman, L.A. 1960. On the Exact Variance of Products. *Journal of the American Statistical Association* 55:708-713.

Hiett, R.L., and D.N. Ghosh. 1977. Recommended approach to the collection of marine recreational finfishing and shellfishing data on the Pacific coast. Human Sciences Research, Inc., McLean, VA USA. 57 pp.

Hiett, R.L., and J.W. Worrall. 1977. Marine recreational fishermen's ability to estimate catch and to recall catch and effort over time. Human Sciences Research, Inc., McLean, VA USA. 22 pp.

Metze, B.C. 1977. Evaluation of the telephone interview method as a technique for collecting marine recreational fishing data. Human Sciences Research, Inc., McLean, VA USA. 63 pp.

O'Bannon, B. (ed.) 1999. *Fisheries of the United States, 1999.* Current Fishery Statistics No. 9800, National Marine Fisheries Service, Silver Spring, MD USA. 130 pp.

Trip Tickets in Mississippi

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ABSTRACT

Trip tickets are increasingly being used to collect commercial landings information. A trip ticket is a form completed by a fisherman or seafood dealer on an individual fishing trip at the point of first sale. Though commercial landings information has been collected for years, there is a need for more specific and accurate information. Trip tickets are a relatively new method for collecting commercial landings data for most coastal states. The Atlantic states have been operating under the Atlantic Coastal Cooperative Statistics Program (ACCSP) since 1998. The Pacific states have been using trip tickets since 1981. In the Gulf of Mexico, Florida began a commercial landings data collection program utilizing trip tickets in 1984. Louisiana began a program in January 1999, and most recently Alabama implemented trip ticket use in August 2000, while Texas is currently in the developmental stages. Mississippi implemented a working scannable trip ticket for its oyster program in January 2000. Currently, Mississippi is in the process of developing a trip ticket program for other segments of its fisheries. The information collected provides per trip catch and the associated effort by species and gear. This data provides the basic trip information, and when coupled with biological data (i.e. length and age), makes for sound management regulations. In addition, trip tickets provide an overall view of the number of participants in a fishery, and along with the participants' history, can aid in establishing proof of involvement in a fishery for any possible limited entry system. Trip tickets can also provide the economic worth of a particular fishery.

KEY WORDS: Data collection, fisheries management, trip tickets

INTRODUCTION

A variety of commercial fisheries data collection programs have been used in the past, many of which continue to operate through state and federal agencies. A comprehensive and cooperative data collection program will be invaluable to fisheries managers. The development of a trip ticket program for fisheries management will provide information that is long-term in scope, timely and comprehensive (FIN Committee 1996).

A trip ticket program is a method to collect commercial seafood landings and associated fishing information for individual fishing trips. A trip ticket is a form usually completed by a fisherman or seafood dealer on an individual fishing trip at the point of first sale. The information that is recorded on a trip ticket includes the fisherman or dealer's license number, vessel registration, and the date, state, county, and port landed. Also recorded are the area fished, gear type, species caught,

quantity, count or market size, and the price per unit. When combined with the total quantity caught, effort information by gear type can be obtained by recording the actual time fished. Catch and effort statistics are fundamental for determining the influence of fishing on fishing stocks. Detection of population trends requires statistically consistent data collected over the geographic range of the stock for a time period that is several times longer than the lifespan of the animal (FIN Committee 1996).

Trip tickets are quickly becoming the standard method of marine commercial landings collection throughout the United States. Individual trip information provides fishery scientists with gear and area specific catch information that will improve the accuracy of stock assessments. It will also provide information on the impact of environmental changes and catastrophic events, such as hurricanes, on the fishery (LDWF 1998). These data collected provide the basic information, when coupled with biological data (i.e. length and age) for sound management decisions. In addition, trip tickets provide an overall view of the number of participants in a fishery and, along with the participants' history, can aid in establishing proof of involvement in a fishery for any possible limited entry system. Trip tickets can also provide the economic worth of a particular fishery.

HISTORY OF TRIP TICKET DEVELOPMENT

The collection of statistics for commercial fishing in the United States began in the late 1800s with the start of the Bureau of Commercial Fisheries. These early statistics were composed mostly of monthly landings for broad market categories of marine and some freshwater species (FIN Committee. 1996).

Efforts by state and federal agencies to develop a cooperative statistic program (CSP) for the collection of commercial and recreational data in the Southeast region began in the mid to late 1980s. In 1994, the National Marine Fisheries Service (NMFS) began a formal process to collect and manage commercial fishery statistics by outlining a strategy and schedule for developing the program and completing a strategic plan. It emphasized a cooperative program in conjunction with state and federal fishery management agencies, regional fishery management councils, interstate marine fishery commissions and other marine fishery management organizations (FIN Committee 1999).

The Atlantic Coastal Cooperative Statistics Program (ACCSP) is a state-federal cooperative system designed to improve the collection and management of fisheries data. The program began in November 1995 with the signing of a Memorandum of Understanding (MOU) by 23 Atlantic coast fisheries management agencies. A detailed Operations Plan was approved and used over the next two years to design the details of the ACCSP commercial, as well as recreational and for-hire data collection programs and the ACCSP data management system. The Atlantic states have been operating under this system since 1998 (ACCSP. 1998).

The Fisheries Information Network (FIN) established a state-federal cooperative program to collect, manage and disseminate statistical data and

information on the commercial and recreational fisheries of the Southeast Region (FIN Committee. 1999). The ACCSP and the FIN will collect and manage fishery data for the management of fishery resources in the Atlantic, Caribbean and Gulf regions. One of the goals is to eventually establish a national program consisting of the ACCSP, FIN, and the Pacific Finfish Information Network (PacFIN), to which all members will contribute and have access. PacFIN has had a trip ticket program in place since 1981.

There are two programs under FIN, the Commercial Fisheries Information Network (ComFIN) and the Southeast Recreational Fisheries Information Network (RecFINSE). The Southeast Cooperative Statistics Committee (SCSC) developed a MOU and framework plan for ComFIN. The mission of the ComFIN is to:

> " cooperatively collect, manage, and disseminate marine commercial and anadromous fishery data and information for the conservation and management of fishery resources in the Southeast Region and to support development of an inter-regional program" (FIN Committee. 1996).

The trip ticket program is the backbone of ComFIN. The first step to its implementation is the initiation of trip ticket programs in each state in the Gulf of Mexico to ensure that all landings are captured (FIN Committee 1999). Florida was the first state to implement a trip ticket program, followed by Louisiana and recently Alabama. Mississippi has an established trip ticket program for oysters and is currently working on implementing trip tickets for the remaining fisheries. T exas is also developing a trip ticket program in their state.

Florida's commercial landings data collection program began in 1984 with the advent of a marine fisheries trip ticket program. Before this, monthly landings summaries were collected by the NMFS from dealers on a voluntary basis. In 1985, both programs were used to make sure the data was comparable. Licensed wholesale and retail seafood dealers are required to send trip information on a monthly basis, weekly for those species that are regulated under state or federal quotas (FDEP, 1995).

The Louisiana Legislature established Louisiana's trip ticket program in 1991. Funding for the program became available in 1998, and the program began January 1, 1999. The trip ticket program replaced the monthly dealer reporting system. A trip ticket and monthly submission sheet must be filled out by dealers that buy fish from commercial fishermen and by commercial fishermen that sell their catch to someone other than a dealer. The monthly submission sheet documents the number of trip tickets filled out each time they are sent to the Louisiana Department of Wildlife and Fisheries. If no trips are taken, a sheet is still required indicating that no transactions took place (LDWF 1998).

Alabama's trip ticket program is similar to Louisiana's but began August 1, 2000. As in Louisiana, trip tickets are due by the 10th of the month for the preceding month. They have a Trip Ticket Summary Sheet (similar to Louisiana's monthly submission sheet) that must be submitted with each trip ticket mailing. Obtaining trip

tickets is the responsibility of the dealer, processor or commercial fisherman. They are assigned to a specific entity and cannot be shared with others (AMRD 2000).

REGULATORY ASPECTS

For trip tickets to work and achieve a balance between obtaining needed catch, effort and economic information and protecting the sources of the data, several federal mandates, state statute and ordinance regulations have been enacted. In 1981 the Shrimp Fishery Management Plan for the Gulf of Mexico was approved under the authority of the Magnuson Fishery Conservation and Management Act. The management plan contains provisions for the collection of shrimp catch and made the NMFS responsible for developing and implementing a data collection program. This data collection program made upon request reporting shrimp catch, effort, price, and license information mandatory. Before this time, data collection was under a voluntary reporting program (50 CFR Part 658). To assist state and federal port agents working in the CSP the Mississippi Commission on Wildlife Conservation (MCWC) adopted Ordinance 111:

> "An Ordinance to Establish Statistical Reporting Requirements and the Confidentiality of Statistical Data for Marine Fisheries in the State of Mississippi", in 1982.

Ordinance 111 has been modified over the years and currently exists as the Mississippi Commission on Marine Resources (MCMR) Ordinance 9.002; however, the general reporting provisions of this ordinance have not changed substantially. This ordinance authorizes and empowers the port agents to obtain, upon request, catch, effort, price, and license information for each trip landed in Mississippi.

To protect the confidentiality of the information collected, the National Oceanic and Atmospheric Administration (NOAA) set forth, under administrative order, prescribed policies and procedures. This order requires that before data is collected by the state, under the CSP, the state must have authority to protect the confidentiality of the data comparable to, or more stringent than, NMFS. The provisions of Mississippi law that provide proprietary information submitted to the state is exempt from public disclosure are the Public Records Act of 1983, Miss. Code Ann. § 79-23-1 (1972) and Ordinance 9.002. These laws protect the sources (dealer, processor or fisherman) from public disclosure of information that may harm their business. Catch information may be published, however, it must be in an aggregate form that cannot be traced to a specific source.

MISSISSIPPI'S OYSTER TRIP TICKET

Currently, Mississippi only uses trip tickets for data collection in the oyster fishery. In the early 1980s, enforcement personnel at oyster check stations obtained data on oyster catch from fishermen. At this time the main purpose of the check

station was to collect the shell retention fee for the oyster sacks. Oyster fishermen were and still are required to report to these stations with their catch in order to buy tags for their oyster sacks. The money obtained from the sale of the oyster sack tags was and is being used to plant cultch material on the public reefs. The only information recorded during this time was the name of the fisherman, sacks harvested, sequence numbers of the tags sold and money collected.

In 1991 the oyster division staff of the Department of Marine Resources (DMR) manned the check stations and what could be considered a true trip ticket (Figure 1) was instituted. The trip ticket was designed to collect information on oyster catch and effort on specific reef areas in Mississippi. In addition, the trip ticket was used to record the shell retention fees (shell tax) collected and harvester license data.

OYSTER TRIP TICKET NUMBER: 32652

MISSISSIPPI DEPARTMENT OF WILDLIFE, FISHERIES & PARKS
BUREAU OF MARINE RESOURCES
OYSTER TRIP TICKET

DATE:	TIME OUT:
LICENSE #:	TIME IN:
HARVESTER'S NAME:	
BOAT NAME:	
REG. NO.:	
INTENDED HARVEST AREA:	
CHECK IN LOCATION:	
INSPECTOR:	
GEAR: TONG DREDGE	OTHER
TYPE HARVEST: COMMERCIAL	RECREATIONAL
HARVEST AREA(S):	
SACKS PER AREA:	
TOTAL SACKS:	SHELL TAX: $
TAG SEQUENCE:	
NUMBER OF FISHERMEN:	
DESTINATION OF CATCH:	

THIS TICKET MUST REMAIN WITH CATCH!!

MISSISSIPPI DEPARTMENT OF WILDLIFE, FISHERIES & PARKS
BUREAU OF MARINE RESOURCES
2620 BEACH BLVD.
BILOXI, MISSISSIPPI 39531
(601) 385-5860

Figure 1. Unscannable trip ticked utilized from 1991 - 1999

Mississippi's oyster catch increased dramatically during the mid 1990s causing the number of trip tickets to increase from a low of 4,900 in 1992 to 15,000 in 1998. Because these tickets are entered manually it utilized at least four people to enter the information in a timely manner. To enter the large amount of information gathered from oyster harvesting, a scannable trip ticket was proposed in 1999 and instituted in January of 2000.

The oyster fishery scannable trip ticket contains four pages of carbonless forms. These forms were designed to collect the catch, effort, shell retention fee and economic information for each trip in the oyster fishery. The first form, designated OTT-1 (Figure 2) is filled in by check station personnel and brought back to the office to be scanned. The second form, OTT-2 (Figure 3) is taken to the dealer by the harvester and is filled in by the dealer. Form OTT-2 is required to be at the Department of Marine Resources office to be scanned no later than the 10th of the following month from the month the transaction took place. These two forms are linked together by a unique trip ticket number. The other two forms serve as receipts for the harvester and the dealer.

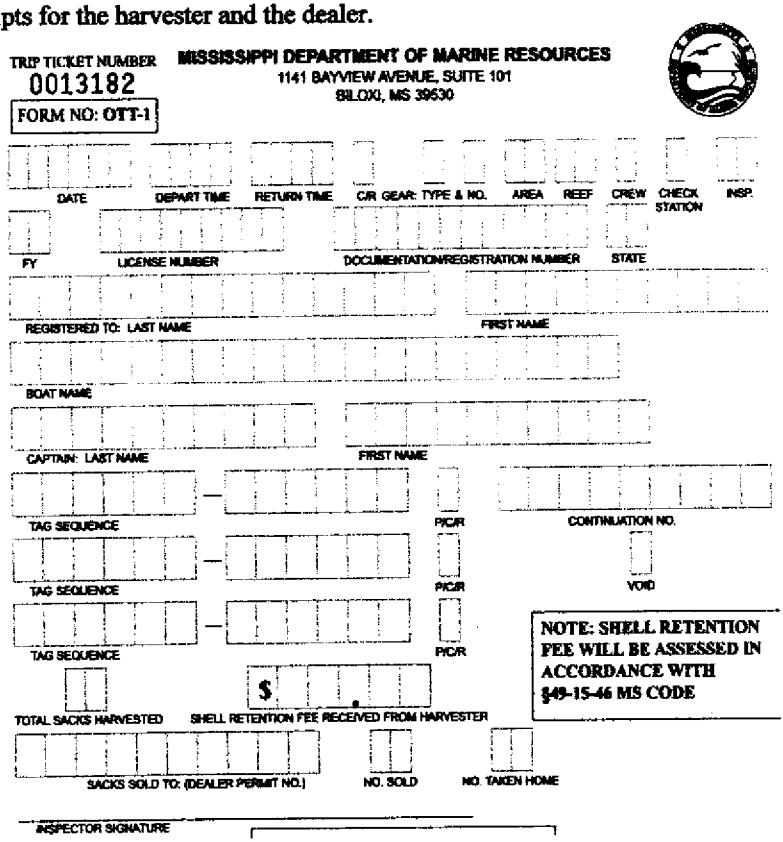


Figure 2. Scannable form OTT-1 completed by DMR personnel at oyster check stations.

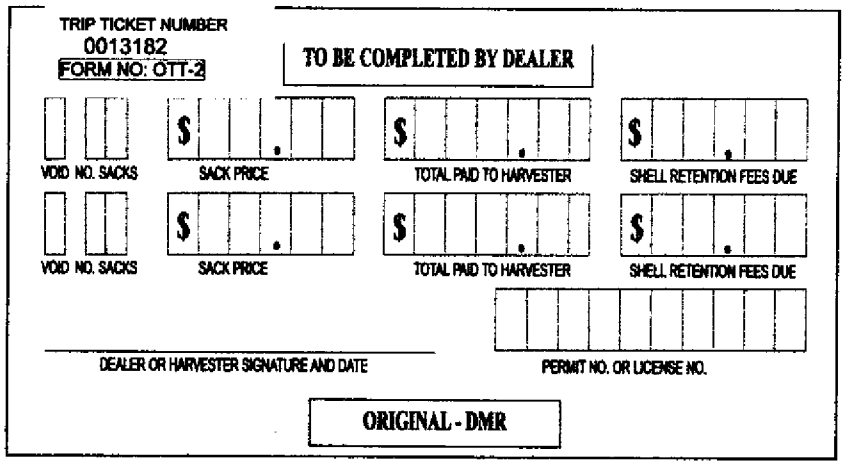


Figure 3. Scannable trip ticked form OTT-2 completed by seafood dealer.

Oyster trip tickets are scanned with a Canon DR-5020 high-speed scanner tied to a Pentium personal computer running a Windows NT Operating System. The software used to scan the data is Cardiff Teleform Version 6.2, character recognition software. The scanner's software allows a batch scan of 75 trip tickets per minute. To verify scanned information each field has a data validation process and the data is visually cross-referenced from the hardcopy to the screen. The data is downloaded to a Microsoft Structured Query Language (SQL) Version 7.0 multiple user database. In the event of scanner failure, personnel have the ability to manually enter the trip ticket information utilizing a front-end Microsoft Access 2000 entry form. With the institution of the scannable trip ticket, data is entered in a timely manner with fewer data entry personnel (two employees on a part time basis).

Data from the oyster trip tickets is scanned, with few exceptions, the following day. Specialized queries were developed in SQL to track catch, effort and shell retention fees owed to the state by fishermen and dealers. This provides oyster managers with timely data for informed reef management decisions and for bookkeeping purposes. For example, overall catch per unit effort per day (Figure 4) can be graphed with the previous day's harvest information.

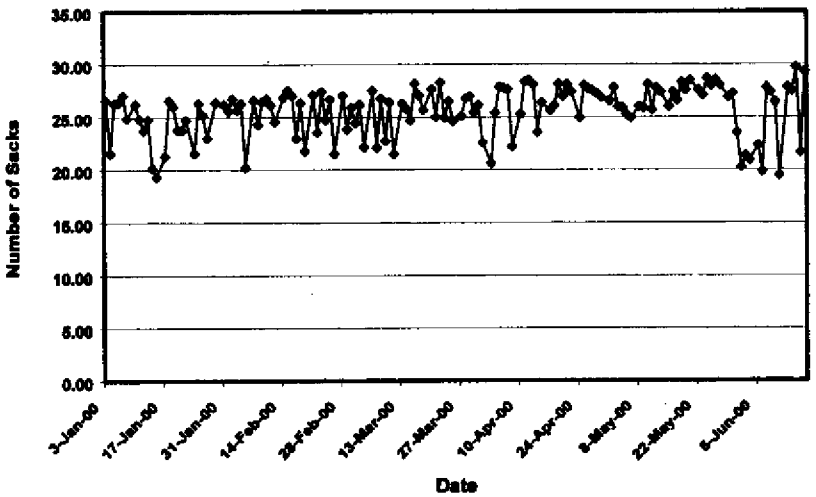


Figure 4. Daily catch per trip for all gear types

PROBLEMS

The development of any new type of data collection and management system will have problems. Most of the problems (i.e., cooperation in completing the form or filling out the form correctly) with Mississippi's oyster trip ticket program are alleviated by virtue of the fact that DMR personnel complete the harvester information portion of the trip ticket (OTT-1) at the check station. While the dealer portion of the trip ticket (OTT-2) is not very long and requires a minimum of information, there have been a number of complaints and compliance problems associated with completing this form. The most common problem is a reluctance to give price information. Although information about the value of a fishery is important and the data will be confidential it is difficult to convince some individuals. They believe that this data may be used against them, either through a competitor obtaining the price information or the Internal Revenue Service (IRS) utilizing the data for tax purposes. Other complaints generally deal with the extra paperwork

involved and the possibility of the dealer having to hire additional manpower to meet the extra workload.

There were some initial problems with the trip ticket itself. Because of time constraints the forms were not developed in Cardiff but with Microsoft Word 2000. This led to a tedious process of getting Cardiff to recognize the individual field placement within the trip ticket. In order to avoid any complications with form development, it is recommended that the forms be developed in the software designed to read them.

FUTURE DEVELOPMENTS

The Mississippi oyster trip ticket is currently under modification. Some of the data fields that deal with harvester information, such as harvester name and boat name, are being removed from the trip ticket. This data will be obtained by linking the DMR license database with the trip ticket database. Consequently, the workload of the check station personnel will be reduced.

Trip tickets have been promulgated for the other marine fisheries in the state and are currently under review and refinement. Other future developments include exploring the possibility of electronic transfer of trip ticket information.

LITERATURE CITED

Alabama Marine Resources Division. 2000. *Trip Ticket Manual*. Alabama Department of Conservation and Natural Resources. Mobile, Alabama USA. 39 pp.

Atlantic Coastal Cooperative Statistic Program. 1998. ACCSP Program Design Document. Atlantic States Marine Fisheries Commission. 1:1-3.

Fisheries Information Network Committee. 1996. *Framework Plan for the Fisheries Information Network*. Gulf States Marine Fisheries Commission. No. 36. 35 pp.

Fisheries Information Network Committee. 1999. Annual Report of the Fisheries Information Network in the Southeast Region (FIN). Gulf States Marine Fisheries Commission 77:1-3,B-61 –B-63.

Florida Department of Environmental Protection. 1995. Florida's Trip Ticket System: An Improved Method of Collecting Commercial Landings. Florida Marine Research Institute.

Gulf of Mexico Fisheries Management Council. 1981. Fishery Management Plan of the Gulf of Mexico, United States waters (revised November 1981). Gulf of Mexico Fishery Management Council. Tampa, Florida USA.

Louisiana Department of Wildlife and Fisheries. 1998. *Trip Ticket Procedures Manual*. Louisiana Department of Wildlife and Fisheries 1:1-3.

Recreational Chartered Fishing Activity in the U.S. Caribbean

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ABSTRACT

Recreational chartered fishing activity has been increasing in the U.S. Caribbean. Charters were identified from the telephone book, tourism guides, and sports fishing and boating magazines. Most of the information summarized was derived from advertisement and the logbook data of the United States Virgin Islands (USVI). No data from fishing charter operations were available from Puerto Rico (PR). A telephone survey conducted by the Caribbean Fishery Management Council during 2000, aimed at:

i) Identifying these charter operations for PR and corroborating the information from the USVI,
ii) Collecting information on the number of potential fishers using the resource,
iii) Documenting the number of fishing trips per week,
iv) Identifying the species targeted and caught by the charter operations, and
v) Establishing the operational costs of the charter operations.

Preliminary results indicated that there were over 35 year-round fishing charter operations in the area comprised of Puerto Rico and the United States Virgin Islands. Although the survey is not completed, 46 of these operations (60 charter boats) have been identified. Most charter operations target the seasonal migrations of pelagic species including marlin, sailfish, dolphin fish, tuna, jacks, mackerels, barracuda, and wahoo. Inshore fishing for bonefish, snook, permit, and tarpon now also includes reef fish. Most of these recreational fisheries do not require anchoring by fishing vessels. It is not known if those charters that advertise for reef fish fishing (groupers and snappers) do or do not anchor their boats.

KEY WORDS: Recreational fishing, charters, sportsfishing

RESUMEN

La actividad de la pesca recreacional con botes de alquiler, ha aumentado en el Caribe americano de acuerdo a información obtenida de guías turísticas, telefónicas, revistas de botes y pesca deportiva. La mayor parte de la información sobre las embarcaciones de alquiler se obtuvo de anuncios publicitarios y del diario de

navegación (bitácora) de las Islas Vírgenes Americanas. No se consiguió data alguna en Puerto Rico (PR) sobre las actividades de las embarcaciones de alquiler. Durante el año 2000, el Consejo de Aministración Pesquera del Caribe condujo una encuesta telefónica dirigida a:

i) Identificar las operaciones de alquiler de botes de pesca en PR y corroborar la información de las Islas Vírgenes Americanas (USVI),
ii) Recopilar información de la cantidad potencial de pescadores que utilizan este recurso,
iii) El número semanal de viajes de pesca,
iv) Identificar las especies que persiguen y pescan los operadores de alquiler, y
v) Determinar el costo de las operaciones de alquiler.

Los resultados preliminares indican que en el área que comprende a Puerto Rico y las Islas Vírgenes Americanas había mas de 35 operaciones alquilando durante el año entero. A pesar que la encuesta no se ha completado, (de 46 operaciones de alquiler) 60 botes han sido identificados. La mayoría de éstos negocios de alquiler se enfocan en la temporada migratoria de especies pelágicas que incluyen el pez aguja, pez vela, dorado, atún, jureles, sierra, picúa y peto. La pesca en aguas cercanas a la costa que incluía capturas de macaco, róbalo, pómpano y sábalo, ahora también incluye los peces de arrecife. La mayoría de estas pesquerías recreacionales no requieren anclaje de las embarcaciones. Se desconoce si los botes de alquiler que se anuncian para la pesca de peces de arrecifes (meros y pargos) anclan sus botes o no.

PALABRAS CLAVE: Pesca recreacional, operadores de alquiler, pesca deportiva

INTRODUCTION

Recreational fishing activities, contrary to artisanal commercial fishing activities are not actively and continuously monitored, nor regulated, in the U.S. Caribbean. Among the recreational user groups of marine resources are the free and SCUBA divers, sportfishers, shoreline fishers and the chartered fishing operations.

Management of marine resources is usually exercised over commercial fishing activities in the U.S. Caribbean. This is so because most of the data available to determine the status of stocks and the impacts from fishing on these stocks, and fish habitat, are from the commercial fishing sector. Recreational fishing related activities that have direct and indirect impact over marine resources includes boating, cruising, anchoring of vessels, trampling, and harvesting, among others. Most of the information available from the recreational fishing activities is derived from big game fishing (e.g., fishing tournaments) or shoreline fishing (Adams et al., 1995). Except for tournament data in the USVI, most other data are collected through special or short-term projects.

Chartering in the U.S. Caribbean has been taking place for over 50 years. There has been no continued effort on monitoring the development of the charter fleet.

Although there are a number of studies that inventoried the fleet (names of captains/owners; U.S.V.I. Marine Recreational Services and Facilities Directory, 1986 - 1987, Griffith et al. 1988, Chaparro 1992) and provided information on the clientele of these operations (Chaparro 1992), no detailed description of the local charter operation exists (e.g., effort, size, spatial distribution, operation costs, etc.).

In order to establish a baseline database on the chartered fishing activities, this study focused on a telephone survey of the charter operations in the U.S. Caribbean during 2000. This survey, in addition to identifying and documenting these year-round local operations, aimed at collecting information on:

i) The number of potential fishers using the resource,
ii) The number of fishing trips per week,
iii) The species targeted and caught or released by the charter operations, and
iv) Operational costs of the charter operations.

METHODS

Fishing charter operations were identified from the local yellow pages for Puerto Rico and the U.S. Virgin Islands (St. Thomas, St. John and St. Croix). Local tourist guides (e.g., Que Pasa and Sports Planners (PR), St. Thomas This Week, What to do in the U.S. Virgin Islands, etc.), newspapers, specialized magazines and the Internet were searched for information on charter operations. The local government offices were contacted (e.g., PR Tourism Co., PR Department of Natural and Environmental Resources, USVI Department of Planning and Natural Resources) for information on the chartered fishing activities.

The survey conducted included questions to corroborate the information obtained from the sources mentioned above. This information included name of business and captain, address and phone numbers, type of fishing, seasonality of the target species, type of fishing trips available (four, six, or eight hours per day), name and size of the vessel(s), and cost per trip. In addition, respondents were questioned about the area of fishing, the number of people and fishing lines taken per trip, the number of trips taken per week, and the type of bait used. Additionally, respondents were asked to estimate their operating costs that included fuel per trip, insurance, docking expenses, etc. The answers of the respondents were taken at face value.

The same person conducted the telephone interviews, and each lasted about 20 minutes unless the respondent provided additional comments or requested information. Most respondents have offered partial information only. Calls were made throughout the day since the survey was conducted during the low season.

RESULTS

The number of charter boat operations identified in the U.S. Caribbean totaled 46, with 27 in the USVI and 19 in Puerto Rico (Table 1). The number of charter boats identified was 60 since 11 operations have two (2) boats and one has 4 boats that are chartered for fishing. The overall effective response rate based on 46

charter operations identified was 52%, with a response of over 58% from St. Thomas. Chaparro (1992) reported 30 charter boats from St. Thomas (15 in this study), 17 in St. Croix (15 in this study), none for St. John (two in this study), and seven (7) from Puerto Rico (28 in this study). Of these, three, four and one were repeats between 1992 and 2000 for Puerto Rico, St. Thomas, and St. Croix, respectively. This is an indication of the rapid turnover in the charter business. Chaparro (1992) also reported most boats centered in San Juan, PR. In 2000, most charter operations are found on the East coast of Puerto Rico.

The present study only surveyed the year-round local charter fleet, but it is generally known that there are numerous charters and private recreational fishing boats that fish in the U.S. Caribbean during the peak season (June-September) for blue marlin. More than 70 boats have been reported in St. Thomas (Adams et al. 1995).

Most fishing charters are offshore charters, but many with vessels under 35 ft offer both offshore and inshore fishing. Figure 1 shows that the greatest number of boats is less than 35 ft, the average boat size in Puerto Rico being 36 ft (range 16 to 58 ft) and 35 ft in St. Thomas (range 15 to 48 ft).

The number of years in business for these charter operations ranges from one to 49 in Puerto Rico (13 years average) and two to 32 in St. Thomas (16 years average). Typically, the St. Thomas fleet had been one of larger boats and less dedicated to inshore fishing, a trend that seems to be changing but was not analyzed in this study. There was no correlation between the number of years in business and the size of the charter boat for either Puerto Rico or St. Thomas (Figure 2).

The USVI have been monitoring the fishing tournaments since the 1970's and establishing a voluntary log book system for data collection from the recreational fishing sector in the 1990's.

Charter boats operate during half day (four hours in the morning or four hours in the afternoon), ¾ day and full day trips and charge by trip (ranging from US$85 to US$1,300) rather than by person. However, inshore trips might charge per person instead of per trip. More information is needed to further define the differences between inshore and offshore fishing trips.

One other objective of the study was to estimate effort and the potential impact on marine resources. Table 2 presents a summary of the estimated annual effort obtained for charter operations. The 60 charter boats identified, if making an average of 180 trips per year [calculated based on the proportion estimated by the owners or on a 50:50 high to slow season proportion by GGM], could be fishing 54,000 lines per year. The average number of lines fished per offshore charter boat was five. No specific information was requested on the percent composition of the catch but most of those interviewed commented on the practice of tagging and releasing the catch. The charter boats are taking an estimate of 43,200 people on fishing trips per year. No information was collected on the expertise of the visiting fishers.

Table 1. Number of charter boats and charter operations identified in the US Caribbean. Response rates are presented as number of answers

	St. Thomas	St. John	St. Croix	Puerto Rico	TOTAL
Number of Charter Boats	15	2	15	28	60
Number of Charter Operators	12	2	13	19	46
Number of answers	7	1	6	10	24
Percent	29.2	4.2	25.0	41.7	
Percent within Island	58.3	50.0	46.2	52.6	52.2
Number of tourists	1,935,300		289,500	3,396,115	
Charter Operators:					
Number boats 1	7	2	13	12	34(74%)
Number boats 2	3		2	6	11(24%)
Number boats 3					
Number boats 4				1	1(2%)
Number of boats dedicated to:					
Inshore	2		1	6	9(15%)
Offshore	5		7	11	23(38%)
Unknown	8	2	7	11	28(47%)

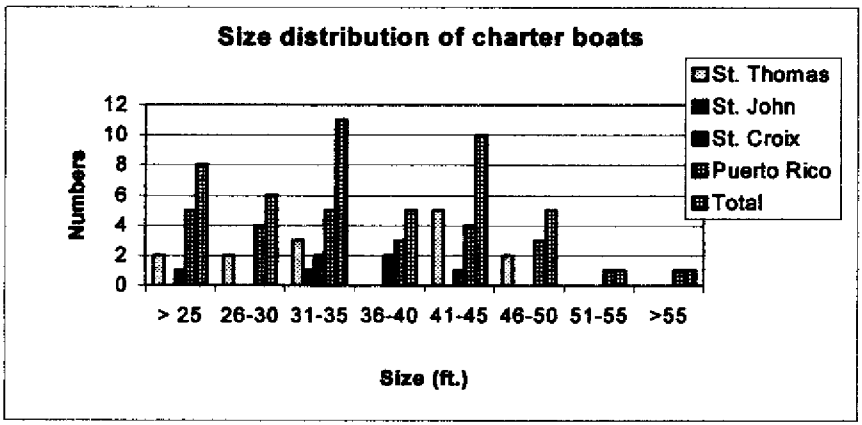


Figure 1. Size distribution of charter boats in Puerto Rico and the U.S. Virgin Islands.

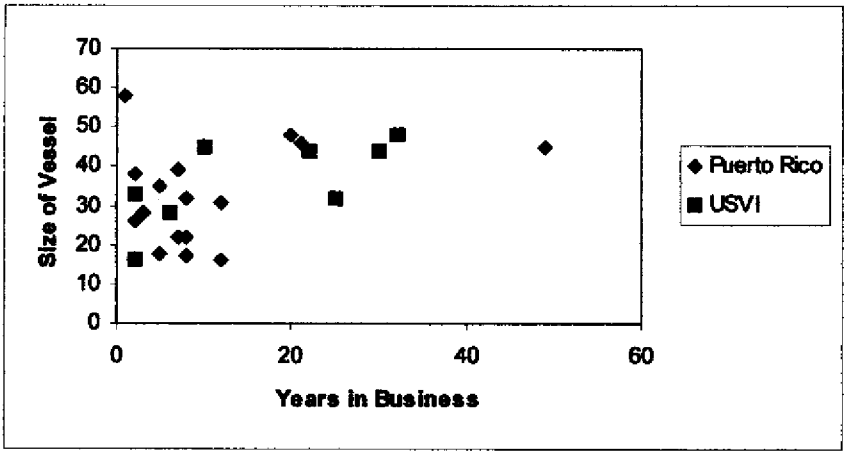


Figure 2. Charter boat size distribution as a variable of years in business.

The catch composition varies seasonally (Table 3) for the various species targeted. Most fishing is still carried out for pelagic species that are identified by common names. Inshore fishing for tarpon, snook, etc. is done per area and season (tourist season) although they are found in the area most of the year. The 'new' species targeted by the charter industry are the reef fish but these are lumped into a snapper/grouper category. Erdman (1959) identified months and areas when and

where there was best fishing for a number of species (over 70 species) of interest to the sport fisher. Adams et al. (1995) and others in the USVI and Puerto Rico have identified the numerous species harvested by recreational fishers. However, very little biological data have been obtained from the species harvested recreationally. Thus, the impact on the marine resources by the harvesting from the recreational sector cannot really be determined as it can be for the pelagic species harvested. However, the information on pelagics has been documented somewhere else (e.g., USVI/DPNR Data).

Table 2. Estimated effort in numbers of trips per year and lines fished per year for the charter operations in the US Caribbean

		Annual Average for Fleet	
Average number of trips per vessel per year	180	10800	Trips
Average number of lines fished per vessel per trip	5	54000	Lines Fished
Average number of people per vessel per trip	4	43200	Fishers*
Number of charter boats identified	60	120	Crew

The most difficult subject to approach was that of estimating the operational costs in the charter fishing industry. Table 4 summarizes the amounts, in U.S. dollars, estimated as operational costs for charters in the U.S. Caribbean for boats that range in size from 15 to 58 ft and are making from 1 to 14 trips per week. These estimates have not been weighted, normalized or standardized as of the writing of this paper. The least variable items in the operation costs were (1) insurance, (2) docking expenses (marina and utilities), and (3) the commission for agents.

DISCUSSION

A database has been established for charter operations in the U.S. Caribbean. A description of the charter operations that compliments those in existence (e.g., Griffith et al. 1988) has been documented and the direction of further investigation established.

The number of visitors to the U.S. Caribbean is estimated at over five million each year but not one percent of the total number of visitors partakes in the charter operations. Perhaps an underutilized business but, considering that most marine fish species are documented as overfished, what direction can be given to the industry? The impact on marine resources from the charter operation sector has not been determined thus caution must be exercised. The survey does not include information on other recreational fishing sectors such as privately owned boats used in recreational fishing, on-shore fishing, and others but offers information on only the chartered fishing operations.

Table 3. Seasonality of species availability and harvest in the U.S. Caribbean

Species	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Blue marlin	F	F	F	G	G	G	E				F	F
White marlin	F	F	F			NA	NA	NA	NA	NA	G	G
Sail fish	G	F	NA	NA	NA	NA	NA	NA	NA	NA		G
Dolphin			G	G	F	NA	NA	NA	NA	NA	G	G
Wahoo	NA	NA	NA	NA	NA	NA	NA	NA	F	G	G	G
Yellowfin tuna	G	G	G	F	F			F	F	F	F	G
Black fin tuna												
Bonito												
Albacore												
Mackerel		F	G	G	G	G	F	F	F	F	F	F
Jacks												
Yellowfin grouper	F	F	F	F	F	F	F	F	F	F	F	F
Red hind	F	F	F	F	F	F	F	F	F	F	F	F
Mutton snapper	F	F	F	F	F	F	F	F	F	F	F	F
Yellowtail snapper	F	F	F	F	F	F	F	F		F	F	F
Silk snapper	F	F	F	F	F	F	F	F	F	F		F
Snook												
Tarpon	E	E	E	E	G	G	G		G	G	G	G

Legend on Information	G	Good	North
Letters =Year 2000	F	Fair	South
Colors = Year 1959	E	Excellent	West
Cross = 1995-2000			All

Erdman, D.S. 1959. La Pesca Deportiva de Agua Salada en Puerto Rico. Agricultura al Dia. Septiembre-Octubre, 1959. 3p.
Thoemke, K. 2000. Puerto Rican Potpourri. Sport Fishing 15(4):6470.

Table 4. Estimated (average) operational costs per charter boat in the U.S. Caribbean. (In US dollars, US$)

Operation Costs	
Size of Vessel (Ft.)	39
Fuel Per Year	US$9822
Upkeep of Boat (Maintenance)	US$2550
Bait	US$669
Equipment	US$2000
Insurance	US$5356
Ice	US$523
Drinks Water Lunch	US$2458
Marina	US$4486
Utilities	US$350
Tackle	US$2048
Salaries	US$18021
Capt	US$10125
Crew	US$7598
Estimated Costs	US$33464
Commission For Agents	15%

The number of recreational fishers in the U.S. Caribbean is unknown since there is no requirement by the local or federal governments for a recreational fishing license. Recreational fishers could, and some do, have a commercial fishing license that would, and does, allow them to sell their catch. No attempt has been made yet to determine the number of fishers that charter or function otherwise as for-hire vessels that also have commercial fishing licenses.

The number of recreational vessels has been increasing (Figure 3) and it is expected that it will continue to increase in the future but no long time monitoring of the fishing activities, with funded analytical capabilities, is yet in place in the U.S. Caribbean. Comments from those interviewed also included the need to manage, not necessarily fishing activities or practices but the increasing number of people at sea, that is boaters, swimmers, walkers on reefs, etc. In addition, some commented on the need to conserve special places where fish aggregate as juveniles or for reproductive purposes – in other words protection of essential fish habitat (EFH) and most specifically habitat areas of particular concern (Magnuson-Steven Act, as amended). The Magnuson-Stevens Act, as amended, requires that EFH be defined for each fish species and that both fishing and non-fishing impacts on habitat and stocks be described. It also requires that fishing communities or communities affected by fishing activities be identified and described. Most of the information

available is on the commercial fishing sector. Questions regarding the number, distribution and activity patterns, and the overall impact on fisheries and EFH by the recreational fishing activity are still unanswered.

One fishing charter boat was found to carry 7 to 10 people per fishing trip. There are no head boats identified as such yet in the area but the possibility of these increasing in number is real.

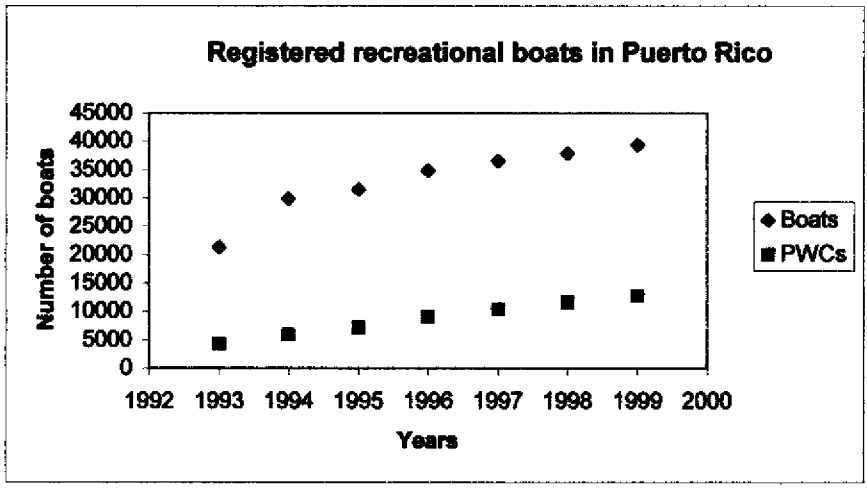


Figure 3. Registered boats in Puerto Rico between 1993 and 1999. PWCs are personal water crafts or jet skies. Data from PRDNER, Ramon Martinez.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Adams, A., S. Caseau, S. Meyers, B. Kojis, and B. Dalmida-Smith 1995. Activity and harvest patterns in the U.S. Virgin Islands recreational fishery 1991-1995. Final Report to the U.S. Fish and Wildlife Service Sport Restoration Program. 18p.

Chaparro, R. 1992. Developing strategies to enhance charter boat fishing operations in Puerto Rico and the United States Virgin Islands. NMFS-Southeast Office (contract No. NA89WC-C-HSK040).

Erdman, D.S. 1959. La pesca deportiva de agua salada en Puerto Rico. Agricultura al Día. Septiembre-Octubre, 1959. 3pP.

Griffith, D.C., M. Valdés Pizzini, J.C. Johnson, J.D. Murray, R. Chaparro 1988. Developing marine recreational fishing in Puerto Rico and the U.S. Virgin Islands. Final Report NOAA/NMFS NA86W-C-H-06108.

Thoemke, K. 2000. Puerto Rican Potpourri. *Sport Fishing* **15**(4): 64-70.

The Economic Impact of Charter and Party Boat Operations in the Gulf of Mexico

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ABSTRACT

In this paper we report upon the financial characteristics of charter boat operators in a five-state U.S. Gulf of Mexico study area. Revenues and expenditures provide a breakdown for a typical enterprise. This is used in conjunction with the IMPLAN (IMpact analysis for PLANning) model to estimate economic impacts generated by charter and party boat operations. Because the charter and party boat industry is too small to be identified specifically as a separate sector in the IMPLAN model, the collection of the aforementioned more detailed data was necessary. The IMPLAN model was customized by developing specific output and purchasing relationships for these industries, to enable indirect and induced impacts to be estimated. Gulf of Mexico charter boat operations were estimated to have generated annual total (direct, indirect, and induced) output valued at $131.0 million, incomes of $60.3 million, and employment amounting to 3,116 jobs. The party boat industry generated annual total (direct, indirect, and induced) output valued at $18.5 million, incomes of $8.2 million, and employment amounting to 371 jobs. Practical implications of our research are numerous. Clearly, during times of policy change, this type of information provides a base of knowledge for informing government officials about the magnitude of industry impacts. At an individual level, boat operators can compare themselves to industry expenditure profiles. No one individual operator will likely match such an expenditure profile exactly but this information provides a basis for comparison, causing one to question reasons for large deviations from the norm.

KEYWORDS: Charter boats, party boats, economic impact

INTRODUCTION

Charter and party boat operators in the U.S. Gulf of Mexico are difficult to classify within a fisheries management framework. From one perspective, these operators may be viewed as part of the recreational sector because they provide a unique opportunity for anglers to fish offshore for recreation and food. From another perspective, charter and party boat operators may be viewed as part of the commercial sector because they operate a commercial service through which they earn their livelihood from fishing activity (albeit the fishing activity of others). Classification is further complicated because a certain number of these operators also use their boats for commercial fishing purposes. An alternative perspective is to view these operators as a sector unto themselves with ties to both the commercial and recreational sectors.

When implementing fishery regulations, it is important to understand the extent to which these regulations will impact the charter and party boat industry at various levels ranging from individual operators to the entire Gulf-wide industry. To disregard social and economic impacts to focus solely on stock assessment and recovery is to doom regulatory efforts to failure because management initiatives will be vigorously opposed in the political arena when people feel their livelihoods are threatened.

Business activity results in sales, employment, and income for individuals directly involved in the business. The sales by a business rely on the use of inputs to produce the goods and services desired by customers. Charter and party boats need fuel and oil, bait, ice, and a variety of other inputs to provide fishing services for their customers. As a result of the sales (output) of a charter or party boat business, other businesses make sales to charter and party boat operators. These other businesses then purchase inputs from additional businesses to produce their own products. This interaction between businesses leads to economic impacts that extend beyond the initial sale of a fishing trip by a charter or party boat.

Economic impact analysis provides measures of the interaction between businesses in particular regions, states or sub-state areas. In order to distinguish the sources of economic impact, three types of effects are commonly described. *Direct impacts* refer to the initial sales (output) of a business or a group of businesses contained within an industry. The direct impacts of sales by an industry cause *indirect impacts* as other businesses and industries provide goods and services. Finally, as employees earn income from the sales of businesses, the money these employees spend for goods and services for their households create additional *induced impacts* within the economy. The sum of the direct, indirect and induced impacts is the total impact of a business on an economy. These three impacts can be measured in terms of either output (spending), income or employment.

The total impact can also be used to determine *multipliers* that indicate how much additional spending, income, or employment would result from an increase (or decrease) in output in a particular industry in a region. Basically, the total economic impact of an industry is derived from the magnitude of the industry's direct expenditures and the multiplicative effect these have through re-spending in the

economy of concern. Economic multipliers are used to capture this re-spending effect. If no re-spending were to occur, the economic multiplier would have a magnitude of 1.0 and indicate that the only impact is the direct expenditure. This would imply that all re-spending by recipients of the initial expenditure (for goods and services used as production inputs) occurred outside of the region of concern. This unlikely event is termed "leakage" and it is unlikely because rarely would 100% of re-spending take place totally outside the region of concern. However, the greater the degree of leakage, the lower the economic multiplier will be for the region. For illustration, if the total economic multiplier were 1.5 we would estimate a total economic impact of $1.50 for each dollar of direct expenditure occurring in the regional economy ($1 x 1.5 = $1.50).

Our primary foci herein regard 1) mean costs, returns and gross revenues in order to develop a financial profile for charter and party boat fisheries by state and 2) the direct and indirect economic impacts associated with charter and party boat fishing in the five states making up the U.S. Gulf of Mexico's economy (excluding the Florida Keys). Previous studies by Ditton et al. (1989) and Holland and Milon (1989) and subsequent journal articles (Ditton et al. 1992, Holland et al. 1992, Gill et al. 1993) provide a baseline of relevant socio-demographic information for charter and party boat fisheries in the U.S. Gulf of Mexico.

METHODS

Charter boats are commonly defined as for-hire vessels that carry six or fewer passengers in addition to the crew, whereas party boats are usually defined as for-hire vessels that carry more than six passengers (up to about 150). During the course of compiling the sampling frame, however, it was found that a number of operations were advertised as charter boats with a capacity of up to 25 passengers. Further examination revealed that the best discriminators of party boats and charter boats are the base fee charged per trip and the number of passengers included in the base fee. For the purpose of this study, charter boats are defined as for-hire vessels operating primarily in Federal waters that have a base fee that is charged on a group basis (two or more passengers). Party boats are defined as for-hire vessels operating primarily in Federal waters that have a base fee which is charged on a per-person basis. Boats that did not solicit public business for offshore fishing trips were not considered for inclusion in the sampling frame. Based on these definitions, vessels classified as charter boats tended to be smaller, carry six or fewer passengers, and operate only when the vessel is chartered. Party boats tended to be larger, carry a larger number of passengers, operate on a schedule, and operate with as many passengers on board as possible to maximize income.

Previous study findings and methodological concerns were used to guide the development of the final interview schedule administered to boat operators. Because of previously-documented levels of attrition and turnover in the charter boat industry (Ditton and Loomis 1985, Ditton and Vize 1987), charter and party boat database files maintained by the Gulf States Marine Fisheries Commission and the National

Marine Fisheries Service, respectively, were subjected to careful scrutiny and verification using various sources of public information prior to selecting a sample in each state. New boats were identified as well and added to the overall population of charter and party boats to be sampled. Even with careful verification ahead of field interviews, some boats were found to be no longer in business or operators were not available for a variety of reasons necessitating the use of a standardized replacement procedure. For more detail see Ditton et al. (1999) and Holland (1999).

Charter and party boat operators in Alabama, Florida, Mississippi, Louisiana, and Texas were interviewed by trained interviewers between May and September 1998. Personal interviews covered 59 questions and lasted from 30 - 60 minutes. There is consensus today among the human dimensions research community that the personal interview approach is the most effective means for collecting data from charter and party boat operators. Besides providing an opportunity for more open-ended questions and deeper understandings, personal interviews are seen as the best means for asking sensitive business and economic questions. Operators had to be convinced their individual responses were going to be held in confidence and only be reported in aggregate. This was accomplished through a series of mail and telephone communications about the project and its importance followed by a face-to-face interview.

Methods for Impact Assessment

The primary data used for impact analysis were the revenue and cost information provided by respondents. Sample data were extrapolated to the population of charter and party boats based on the number of boats of each type in each state as reported in Ditton et al. (1999) and Holland et al. (1999).

The survey data were used in the IMpact analysis for PLANning (IMPLAN) input-output modeling framework to produce estimates of purchases by charter and party boats, employment, income, and the corresponding multiplier effects within each state. IMPLAN is a flexible software package that can be used to develop impact analyses for any industry in a state or subregion within a state.[1] Some industries, such as charter and party boat fishing, are too small to be identified separately in the output, employment, and income data for any state. Therefore it is necessary to develop specific output and purchasing relationships for these industries and use the IMPLAN impact analyses procedures to estimate the indirect and induced impacts of these businesses.

One of the primary ingredients of an input-output model is the classification of purchases by an industry from other industries. The percentage of the total expenses attributable to each expense category is the input requirement (production coefficient) of charter and party boats from that sector. These production

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[1] IMPLAN is a proprietary software package maintained by the Minnesota IMPLAN Group, Inc., Stillwater, MN.

coefficients for boats were used to modify the basic IMPLAN economic data for each state included in the survey in order to create distinct charter and party boat industries within each state. The production coefficients for each state were adjusted to account for differences in wages and salaries across the states. Also, due to the fact that only one party boat operated in Mississippi in 1997 and none in Louisiana, no party boat industries were developed for these states.

Another important element of economic impact analysis is identification of resident and nonresident shares of total operating revenues in each state. Nonresidents inject "new money" into a state that creates incomes that would not have existed without these expenditures. This new income is the source of *induced impacts* that occur in response to employees' purchases with this new income. Revenues from residents, on the other hand, do not create induced impacts because no new income within the state results from resident purchases[2]. A purchase of charter boat services in a state by one resident from another resident simply reflects a transfer of income along with payment to cover the expenses of providing the charter boat service. The distribution of charter and party boat trips by residents and nonresidents within the five Gulf states in 1997 was determined from secondary sources. No data were available for party boats because the only ongoing survey to determine the number of party boat trips in the Gulf of Mexico does not identify the state of residence of party boat customers.[3]

Finally it should be noted that this economic impact analysis only considers the revenues received by charter and party boat operators. Other sources of economic activity associated with charter and party boat trips such as customers' travel costs, lodging, etc., are not included in this analysis. The inclusion of these expenditures would increase the overall economic impact of charter and party boat operations.

RESULTS

Firm Financial Profile

Only 40% of the firms comprising the charter boat industry in the Gulf of Mexico are corporations while roughly 85% of party boats chose a corporate form of organization. Investment at the time of purchase and current age for fixed factors of production are shown in Table 1. As expected hull and superstructure is the highest expenditure item followed by engine investment. While reported separately, in many instances it is suspected that the hull and superstructure purchase included the engine and electronics. Notably, given their typically larger size, party boats have a much higher average cost for hull and superstructure.

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[2] This is true, unless one argues that the money would have been spent elsewhere if local (state) opportunities had not been available.

[3] Party boats surveys are conducted by the National Marine Fisheries Service.

Table 1. Fixed Factors of Production for Charter and Party Boats

		Florida[a]			Rest of U.S. Gulf of Mexico			PartyBoats
	Florida		Charter Boats		Party Boats		Charter Boats	
Hull and Superstructure								
Present Age	Mean		14.67		12.86		15.99	20.97
	Std. Error		0.66		2.44		1.05	2.64
Capital Investment	Mean	n=168	$90,989	n=19	$214,158	n=84	$97,128	$241,922
	Std. Error		$10,498		$35,749		$11,213	$37,918
Engine								
Present Age	Mean		8.15		3.36		4.3	3.81
	Std. Error		0.65		1.13		0.48	1.22
Capital Investment	Mean	n=75	$40,518	n=4	$40,000	n=39	$20,438	$18,000
	Std. Error		$13,513		$7,071		$2,842	$2,000
Electronics								
Present Age	Mean		4.54		3		4.78	4.56
	Std. Error		0.37		0.7		1.17	1.19
Capital Investment	Mean	n=82	$5,568	n=5	$5,560	n=66	$6,974	$13,000
	Std. Error		$698		$1,673		$891.73	$5,275
Other Equipment and Tackle								
Present Age	Mean		4.1		3		3.24	4.69
	Std. Error		0.42		0.82		0.22	1.81
Capital Investment	Mean	n=79	$5,878	n=6	$9,183	n=73	$8,797	$15,600
	Std. Error		$607		$4,421		$991.06	$3,795

[a] Includes boats in Atlantic, Keys, and Gulf Coast areas of Florida.

Current expenditures in 1997 are indicated for a common set of boats by actual amount and as a proportion of total expenses in Tables 2 and 3. Average input purchases for charter boats in Florida and across the remaining four Gulf of Mexico states included in this survey and the corresponding IMPLAN sector are shown for each purchase category.

Wages and salaries and expenses to purchase and maintain the boat were the largest input purchases (Table 2). Wages and salaries are classified as the income earned by the captain and crew of the boat. Expenses to purchase and maintain the boat are classified as purchases from IMPLAN sector 393 (Boat Building and Repairing) and sector 357 (Motors and Generators). Other large purchase categories were fuel and oil, insurance and docking fees. For party boats (Table 3), fuel and oil, wages and salaries, and expenses to purchase and maintain the boat were the largest expense items. The data in these tables provide firm operators useful information for comparative purposes.

Respondents reported annual gross revenues by choosing from equal sized categories ranging from "less than $10,000" to "$150,000 or more". For purposes of discussion and analysis here, these gross revenues were converted to approximate a continuous variable by using the mid-point of the equally sized categories ($155,000 was used for the highest category). The average charter boat gross revenue was $51,400 in the Gulf region of Florida and was $68,934 annually for the remaining Gulf states.

Since a limited number of trips were made for other types of recreational purposes (such as diving), only a small proportion of additional annual revenue is expected from these other sources. Further, a number of boat operators responded that they had received revenues from commercial fishing activities. To the extent that operators viewed these two sources of income as separate from the gross revenue they reported when queried about charter expenses and revenues, our estimate of gross revenue is an underestimate.

Overall, from the data collected, the typical charter boat business appears to exist at the margin. On the other hand, many might argue that there are non-monetary returns from the charter operator's style of life for which we are unable to account with these financial data. But, at the bottom line, an enterprise must be able to cover its basic expenses in order to survive.

Party boat gross revenues were $150,000 for Florida Gulf boats and $137,308 for the remaining states. A majority of the party boat sample respondents indicated that their gross business revenues were in the top category of $150,000 or more annually. This means that our estimates of gross revenues (which used $155,000 to represent this category) are likely to be severely understated which has implications for any discussion of their business profitability.

Table 2. Average Charter Boat Purchases in 1997 for Florida and the rest of the U.S. Gulf of Mexico

Expense Category	State of Florida Amount	Share	Rest of U.S. Gulf Amount	Share	IMPLAN Sector
Hull and Superstructure	$3,020.31	4.40%	$18,300.00	22.53%	Boat Building and Repairing (393)
Maintenance and Repair	$5,720.02	8.34%	$8,584.43	10.57%	Boat Building and Repairing (393)
Engine	$6,333.88	9.24%	$4,890.16	6.02%	Motors and Generators (357)
Electronics	$1,134.68	1.65%	$1,538.20	1.89%	Electronic Components, N.E.C.(378)
Fuel and Oil	$8,223.96	11.99%	$10,256.21	12.63%	Automotive Dealers and Service Stations (451)
Other Equipment and Tackle	$2,403.76	3.51%	$2,020.98	2.49%	Sporting and Athletic Goods, N.E.C.(421)
Bait	$2,021.85	2.95%	$2,753.03	3.39%	Sporting and Athletic Goods, N.E.C.(421)
Docking Fees	$4,604.04	6.71%	$3,034.28	3.74%	Water Transportation (436)
Food and Drink	$1,191.15	1.74%	$417.70	0.51%	Food Stores (450)
Ice	$823.75	1.20%	$1,028.28	1.27%	Manufactured Ice (101)
Bookkeeping Services	$1,388.98	2.03%	$892.95	1.10%	Accounting, Auditing and Bookkeeping (507)
Advertising and Promotion	$2,040.72	2.98%	$2,986.62	3.68%	Advertising (469)
Insurance	$2,970.40	4.33%	$3,799.10	4.68%	Insurance Carriers (459)
Permits and Licenses	$890.17	1.30%	$986.23	1.21%	State and Local Government – Non-education (523)
Wages and Salaries	$25,810.35	37.64%	$19,725.39	24.29%	—
Total	$68,578.02	100.00%	$81,213.56	100.00%	—

Table 3. Average Party Boat Purchases in 1997 for Florida and the rest of the U.S. Gulf of Mexico

	State of Florida		Rest of U.S. Gulf		
Expense Category	**Amount**	**Share**	**Amount**	**Share**	**IMPLAN Sector**
Hull and Superstructure	$3,333.33	2.46%	$23,076.92	8.68%	Boat Building and Repairing (393)
Maintenance and Repair	$13,384.61	9.86%	$26,919.46	10.12%	Boat Building and Repairing (393)
Engine	$9,450.00	6.96%	$15,153.85	5.70%	Motors and Generators (357)
Electronics	$182.35	0.13%	$8,869.23	3.33%	Electronic Components, N.E.C.(378)
Fuel and Oil	$18,020.00	13.28%	$61,366.77	23.07%	Automotive Dealers and Service Stations (451)
Other Equipment and Tackle	$291.66	0.21%	$8,538.46	3.21%	Sporting and Athletic Goods, N.E.C.(421)
Bait	$6,352.91	4.68%	$14,171.23	5.33%	Sporting and Athletic Goods, N.E.C.(421)
Docking Fees	$11,533.07	8.50%	$4,050.85	1.52%	Water Transportation (436)
Food and Drink	$0.00	0.00%	$1,999.85	0.75%	Food Stores (450)
Ice	$1,799.23	1.33%	$2,515.38	0.95%	Manufactured Ice (101)
Bookkeeping Services	$1,420.00	1.05%	$14,233.08	5.35%	Accounting, Auditing and Bookkeeping (507)
Advertising and Promotion	$7,242.30	5.34%	$8,321.23	3.13%	Advertising (469)
Insurance	$8,569.57	6.31%	$11,491.08	4.32%	Insurance Carriers (459)
Permits and Licenses	$2,157.69	1.59%	$1,238.46	0.47%	State and Local Government – Non-education (523)
Wages and Salaries	$52,000.00	38.31%	$64,064.69	24.08%	—
Total	$135,736.72	100.00%	$266,010.54	100.00%	—

ECONOMIC IMPACTS OF CHARTER AND PARTY BOAT INDUSTRY

The charter fishing industry has significant impacts on local economies (Table 4). We estimate the total direct, indirect, and induced economic impact of output, income, and employment of the charter industry in the Gulf section of Florida to be $88.3 million, $44.6 million, and 2,132 jobs and for the remaining four states in 1997 amounted to $42.7 million, $15.8 million, and 984 jobs, respectively. We should note that the economic impacts estimated in our study refer only to those impacts generated from fees paid directly to charter businesses for services rendered. Our study did not include measures of money spent by charter boat customers on other goods and services such as meals, accommodations, equipment, etc. related to their charter fishing trip. These additional expenditures are likely significant, especially in Alabama and Mississippi where the majority of charter boat customers are not residents of those states. Estimating the total economic impact of the charter fishing industry would require an additional survey of charter boat customers to estimate their total charter fishing-related expenditures.

We estimate the 1997 total direct, indirect, and induced economic impact for output, income, and employment of the party boat industry in the Gulf section of Florida to be $14.2 million, $6.1 million, and 278 jobs and for the remaining four-state study region amounted to $4.4 million, $2.1 million, and 93 jobs, respectively (Table 5). As with the charter industry, these estimates do not include impacts of money spent by party boat customers on other goods and services related to party boat fishing experiences.

DISCUSSION

The charter fishing fleet of the Gulf of Mexico consists of approximately 432 boats in the Gulf section of Florida and another 430 boats distributed throughout Alabama, Mississippi, Louisiana, and Texas. The average charter boat operator has invested over $100,000 to purchase the equipment currently used for the charter business and is taking in gross annual revenues of approximately $51,000 in the Gulf Florida region and $69,000 for the rest of the Gulf. After annual expenditures are accounted for, it appears as though most charter operations are not highly profitable.

The party boat fleet consists approximately of 35 boats in the Gulf section of Florida and 23 boats in the remaining Gulf. The average party boat operator has invested over $200,000 to purchase equipment used for the party boat business. We estimate the average operator is taking in gross annual revenues of approximately $140,000. We expect, however, that this estimate of party boat annual revenue is low because our method of collecting this information did not provide accurate data on operators who had annual revenues exceeding $150,000. Otherwise, given annual expenditures reported by party boat operators, most operations would be taking an annual net loss.

Table 4. Total Economic Impacts in U.S. Gulf of Mexico from Charter Boat Revenues by State

Category	Alabama	Florida Gulf Region	Louisiana	Mississippi	Texas	Total
Total "Output" Impact						
a) Direct	$9,011,530	$49,618,040	$3,167,500	$4,411,695	$13,280,410	$79,509,175
b) Indirect	$3,439,881	$19,545,935	$878,086	$1,576,259	$4,301,830	$29,741,991
c) Induced	$1,423,220	$19,144,765	$384,978	$676,680	$140,369	$21,770,012
d) Total	$13,874,631	$88,308,740	$4,450,564	$6,664,634	$17,722,609	$131,021,178
e) Multiplier (d/a)	1.54	1.78	1.40	1.51	1.33	1.65
Total "Income" Impact						
a) Direct	$2,858,350	$20,997,858	$1,101,827	$847,940	$3,594,117	$29,400,092
b) Indirect	$1,887,330	$11,403,814	$510,258	$886,103	$2,497,833	$17,185,338
c) Induced	$866,538	$12,187,729	$235,791	$401,156	$85,698	$13,776,912
d) Total	$5,612,218	$44,589,401	$1,847,876	$2,135,199	$6,177,648	$60,362,342
e) Multiplier (d/a)	1.96	2.12	1.68	2.52	1.72	2.05
Total "Employment" Impact (jobs)						
a) Direct	220	1,541	100	179	333	2,373
b) Indirect	28	305	12	21	50	416
c) Induced	22	286	6	11	2	327
d) Total	270	2,132	118	211	385	3,116
e) Multiplier (d/a)	1.23	1.38	1.18	1.18	1.15	1.31

Table 5. Total Economic Impacts in U.S. Gulf of Mexico from Party Boat Revenues by State

Category	Alabama	Florida Gulf Region	Louisiana	Mississippi	Texas	Total
Output						
a) Direct	$620,000	$9,568,552	n/a	n/a	$2,593,638	$12,782,190
b) Indirect	$212,945	$4,597,584	n/a	n/a	$932,613	$5,743,142
c) Induced	—	—	—	—	—	—
d) Total	$832,945	$14,166,136	n/a	n/a	$3,526,251	$18,525,332
e) Multiplier (d/a)	1.34	1.48	n/a	n/a	1.36	1.45
Income						
a) Direct	$239,000	$3,536,058	n/a	n/a	$1,125,558	$4,900,616
b) Indirect	$109,979	$2,568,687	n/a	n/a	$615,587	$3,294,253
c) Induced	—	—	—	—	—	—
d) Total	$348,979	$6,104,745	n/a	n/a	$1,741,145	$8,194,869
e) Multiplier (d/a)	1.46	1.73	n/a	n/a	1.55	1.67
Employment (jobs)						
a) Direct	13	211	n/a	n/a	65	289
b) Indirect	3	67	n/a	n/a	12	82
c) Induced	—	—	—	—	—	—
d) Total	16	278	n/a	n/a	77	371
e) Multiplier (d/a)	1.22	1.32	n/a	n/a	1.19	1.28

In this paper we have summarized estimates of the economic impacts associated with charter and party boat operations in the five states comprising the U.S. Gulf of Mexico. This information can be used to inform businesses as well as local, state, and federal officials about the economic contribution of charter and party boat operations to their respective state economies.

Another use of this information is to evaluate the economic effects of policies and/or events that change the revenues received by charter and party boat operations. For example, an output multiplier can be calculated from the ratio of total to direct output. In the case of charter boats in Alabama, the output multiplier is 1.54 ($13,874,631 ÷ 9,011,530). An event such as a hurricane that occurred during a peak season and resulted in a loss of $1,000,000 in charter boat revenues would have a $1,540,000 total output impact on the Alabama economy.

Other multipliers can also be computed to evaluate the effects of changes in output on employment and income. These multipliers, while simple to compute, should be used with caution. The use of multipliers to predict the impacts of changes in policies or events requires certain assumptions. One important assumption is that the policy or event does not change the cost structure of providing the service. Also, it is necessary to assume that the structure of the industries providing inputs does not change. For short term analysis (2 to 3 years) such considerations are not a problem but longer term evaluations may need to consider how changes may occur. Several other issues should be considered in using multipliers for impact analysis; the interested reader should consult more comprehensive sources (e.g., Miller and Blair 1985, Propst and Gavrilis 1987, Stevens and Lahr 1988)

Finally, it should be noted that the economic impacts described in this section apply to the entire state economies for the respective states. For this reason our total Gulf impacts are rough estimates in that they are sums of individual state results, not strictly legitimate. Likewise, and probably more so, it would be inappropriate to use the relationships (such as output multipliers) to evaluate impacts of charter and party boat operations on local economies such as one county or a group of two or three counties around a bay. Local economies will always have smaller impacts (and therefore smaller multipliers) of changes in output because there are more "leakages" from the local economy in the form of input purchases from other parts of the state. Impact analyses can be developed for these local economies using the IMPLAN framework if data are available on charter and party boat revenues in the local area.

LITERATURE CITED

Ditton, R.B., S. M. Holland, and D.A. Gill. 1992. The U.S. Gulf of Mexico party boat industry: activity centers, species targeted and fisheries management management opinions. *Marine Fisheries Review* 54(2):15-20.

Ditton, R.B. and D.K. Loomis. 1985. Examining business turnover in the Texas charter boat industry: 1975-1980. *Marine Fisheries Review* 47(1):43-47.

Ditton, R.B., J.R. Stoll and D A. Gill. 1989. The social structure and economics of the charter and party boat fishing fleets in Texas, Louisiana, Mississippi and Alabama. College Station, Texas A&M University. Final contract report for National Marine Fisheries Service, St. Petersburg, Florida USA. 259pp.

Ditton, R.B. and J.D. Viz.e 1987. Business turnover in the Texas charter fishing industry, 1975-85. *Marine Fisheries Review* **49**(2):162-165.

Gill, D.A., R.B. Ditton and S.M. Holland 1993. Charter and party boat operators in the U.S. Gulf of Mexico: A social structure perspective. *Marine Fisheries Review* **55**(3):16-20.

Holland, S.M., R.B. Ditton and D.A. Gill. 1992. The U.S. Gulf of Mexico charter boat industry: activity centers, species targeted and fisheries management opinions. *Marine Fisheries Review* **54**(2):21-27.

Holland, S.M., A.J. Fedler, and J.M. Milon. 1999. The operations and economics of the of the charter and party boat fishing fleets of the eastern Gulf of Mexico and South Atlantic Coasts. Gainesville, University of Florida. Final contract report for National Marine Fisheries Service, St. Petersburg, Florida, 284pp.

Holland, S.M. and J.W. Milon. 1989. The structure and economics of the charter and party boat fishing fleet of the Gulf Coast of Florida. Gainesville, University of Florida. Final contract report for National Marine Fisheries Service, St. Petersburg, Florida USA. 278pp.

Miller, R.R. and P.D. Blair 1985. *Input-Output Analysis: Foundations and Extensions*, PrenticeHall, Inc., Englewood Cliffs, New Jersey USA.

Propst, D.B. and D.G. Gavrilis. 1987. Role of economic impact assessment procedures in recreational fisheries management. *Transactions of the American Fisheries Society* **116**:450-460.

Stevens, B.H. and M.L. Lahr. 1988. Regional economic multipliers: definition, measurement, and application. *Economic Development Quarterly* **2**:88-96.

Sutton, S.G., R B. Ditton, J R. Stoll, and J.W. Milon. 1999. A cross-sectional study and longitudinal perspective on the social and economic characteristics of the charter and party boat fishing industry of Alabama, Mississippi, Louisiana, and Texas. College Station, Texas A&M University. Final contract report for National Marine Fisheries Service, St. Petersburg, Florida USA. 198 pp.

The New Marine Recreational Fishery Statistics Survey Method for Estimating Charter Boat Fishing Effort

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ABSTRACT

From 1997 through 1999, state and federal agencies cooperated to conduct a pilot study of an alternative method for estimating charter boat angler fishing effort in the Gulf of Mexico. Cooperating agencies included the Gulf States Marine Fisheries Commission (GSMFC), the marine fishery agencies of Florida, Alabama, Mississippi, and Louisiana, and the National Marine Fisheries Service which funded the pilot study. The new method sought to improve effort estimates by collecting trip data via weekly telephone interviews of a 10% random sample from a directory of charter boat owners/operators. Respondents reported the number of charter boat trips, numbers of anglers who fished, and primary areas fished. The existing Marine Recreational Fishery Statistics Survey (MRFSS) methodology utilizes a random-digit-dialing (RDD) telephone survey

of coastal households, which requires a large correction factor due to a significant percentage of charter anglers not residing in coastal counties. We compared the two methodologies and found that charter directory estimates were considerably more precise than RDD estimates with more than a 50% reduction in standard error. Total annual effort estimates did not differ significantly; however, the new methodology produced geographic and temporal distributions of charter fishing effort which were considered much more credible by the Gulf for-hire industry. The new methodology indicates fewer trips in the Exclusive Economic Zone, more trips in inland areas, and no significant difference in the number of charter trips in State Territorial Seas. The primary implications of the new methodology include:

i) More accurate fishing area data,
ii) Relatively low respondent burden,
iii) Increased cooperation and participation by the for-hire industry, and
iv) More precise and accurate data making it easier to identify changing trends in the for-hire fishery.

This new methodology has been officially adopted by the National Marine Fisheries Service as the new MRFSS method for the Gulf of Mexico from West Florida through Louisiana beginning with 2000. Dependent on funding, we hope to implement the new methodology nationwide by 2001-2002.

KEY WORDS: Charter Boat Fishery, methods, surveys

INTRODUCTION

Prior surveys of fishing effort and catch by the charter boat fishery have been inadequate for a variety of reasons. The National Marine Fisheries Service (NMFS) has conducted the Marine Recreational Fishery Statistics Survey (MRFSS) since 1979, which utilizes a random-digit-dialing (RDD) telephone survey of coastal residential households to estimate fishing effort and an access-point intercept survey to estimate catch-per-trip of finfish. The RDD survey is relatively efficient for estimating shore and private boat fishing effort, but it has been rather inefficient for estimating charter boat fishing effort. Charter boat fishing is relatively rare among residents of coastal residential households, and the coastal zone covered by the RDD survey includes only 20-30 % of the U.S. households with residents who fish on charter boats. Adjustment factors, which sometimes are large, are estimated from the MRFSS intercept survey to account for charter fishing trips by non-coastal residents. The low incidence of charter boat fishing trips in the MRFSS telephone survey sample and the relative instability of the large adjustment ratios have caused MRFSS estimates of charter boat fishing effort and catch to be very imprecise and highly sensitive to random measurement errors. A Voluntary Logbook Survey (VLS) conducted by the NMFS Panama City Lab in 1983-1996 was used to track general catch-rate trends in the charter boat fishery, but it's non-random method of sampling ruled

out its use for estimating total fishing effort or catch. Attempts to census charter boat fishing effort and catch through 100% mandatory logbook reporting (MLR) have traditionally encountered biases due to undercoverage and non-response. Furthermore, the respondent fatigue that can develop with MLR programs can lead to significant reporting and measurement errors (Pollock et al. 1994). Traditionally, logbook reporting programs for charter boats have not attempted to independently validate or measure reporting errors in the self-reported data they collect.

In 1997, the NMFS began a cooperative pilot study to test new methods of surveying fishing effort and catch by the charter boat fishery in the Gulf of Mexico. Participating agencies included the Gulf States Marine Fisheries Commission (GSMFC), the marine fishery agencies of Florida, Alabama, Mississippi, and Louisiana, and the National Marine Fisheries Service which funded the pilot study. The primary objective of the study was to test methods which would potentially be more efficient and more accurate in estimating effort and catch than the traditional methods used by the NMFS Marine Recreational Fishery Statistics Survey (MRFSS). Two sampling survey methods based on the development and use of a vessel directory as a sample frame were tested in comparison with the traditional MRFSS methods. Both a vessel-directory telephone survey and a vessel-directory logbook survey were tested as alternative methods for estimating the number of angler fishing trips on charter boats. Due to concerns over the potential inaccuracy of self-reported data, the pilot study also tested an independent validation survey as a means of estimating possible errors in the reporting of fishing effort by vessel operators. This report describes the new Vessel-Directory Telephone Survey (VDTS) methods and preliminary results, and compares them with the traditional MRFSS methods and estimates.

The MRFSS consists of two independent surveys which are stratified among geographic subregions, states, and two-month time periods (or 'waves'). The MRFSS telephone survey was designed to estimate the total number of marine recreational fishing trips made by permanent residents of coastal county households with telephones. The sample frame for this survey was the residential household telephone directory for a designated coastal zone in each coastal state. The survey used a technique called random-digit dialing (RDD) to select an approximately random sample of residential households with phones in each sampled county. The telephone survey dialing sample for each state was stratified by state, two-month wave, and county. Samples were proportionally allocated to each state and wave to match relative historical distributions of estimated fishing effort. The RDD method ensured that all residential phone numbers had an equal probability of being selected in the telephone survey sample for a given county. Dialing for each wave's telephone survey was completed by contractor personnel during the two-week period which included the last week of the wave and the first week of the next wave.

If at least one permanent resident of a contacted household participated in marine recreational fishing within the last two months, each recreational saltwater

angler in that household who fished during that period was interviewed. The anglers were asked to provide the number of days, or day-trips, that he/she spent fishing in each of three different fishing modes – shore, private/rental boat, and charter boat. Next, the interviewer asked the respondent questions about each day-trip, starting with the most recent day of fishing and working back through the wave. For each trip, the angler was asked for the date of the trip, the state and county from which it was taken, the mode of fishing, the primary water body fished (ocean or inland waters), the type of access used (private or public), and the time of return.

The RDD sample frame used by the MRFSS telephone survey has both overcoverage and undercoverage problems with respect to surveying charter boat fishing effort. Sample frame overcoverage refers to the inclusion of ineligible respondents in a survey sample frame, whereas sample frame undercoverage refers to the exclusion of eligible respondents from a survey sample frame.

The extreme overcoverage of the MRFSS RDD sample frame (Figure 1) with respect to charter boat fishing made it very difficult to obtain the effective sample sizes needed to make reasonably precise estimates of coastal resident fishing effort for each geographic region and two-month period. In addition, less than 0.5% of the residential households contacted by the telephone survey actually had residents who report that they took charter boat trips during the two-month sampling period (Figure 2). Effective sample sizes for estimating numbers of charter boat fishing trips by coastal residents were so small that "zero" effort estimates were common during low activity time periods and "non-zero" estimates were usually very imprecise even during relatively high activity periods.

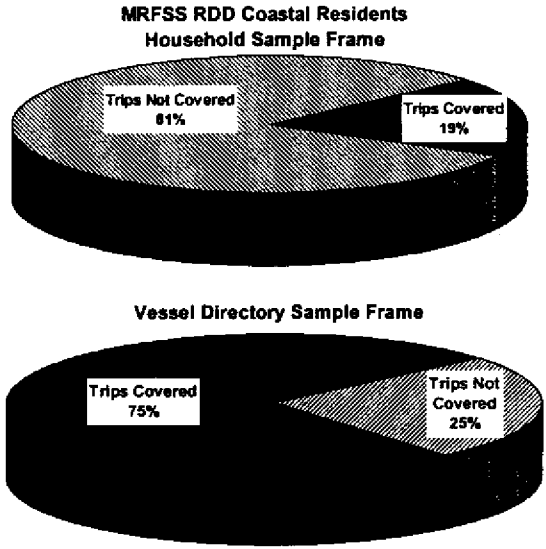


Figure 1. Sample frame coverage of Charter Fishing Trips by the traditional MRFSS RDD telephone survey and the pilot VDTS charterboat study.

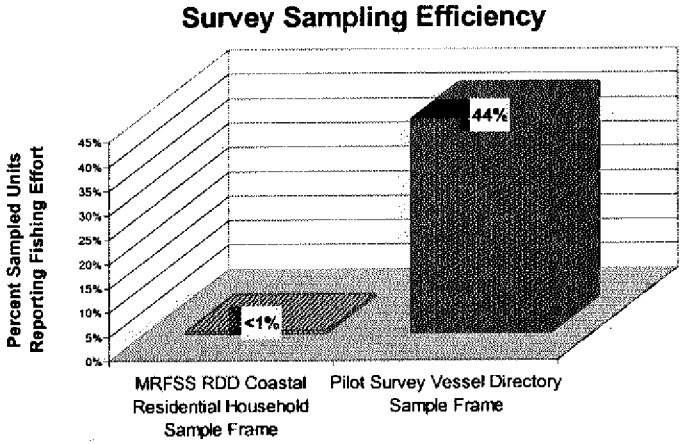


Figure 2. Sampling efficiency for Charter Fishing Trips by the traditional MRFSS RDD telephone survey and the pilot VDTS charterboat study.

The MRFSS telephone survey only covered about 20% of the anglers who fish from chartered boats. Most of the anglers who fish from chartered boats resided outside of the coastal zone covered by this survey. In order to correct for the approximate 80% undercoverage of the RDD sample frame, the MRFSS used angler residency data collected by the intercept survey to estimate an undercoverage correction ratio (UCR). The UCR varied greatly among geographic areas and time periods around a mean ratio of about 5:1. Correction ratios that high are very difficult to estimate precisely from intercept survey data, therefore the corrected total charter boat effort estimates were usually considerably more imprecise than the charter boat effort estimates for coastal residents.

MRFSS estimates of charter boat angler fishing effort were generally too imprecise to be useful in tracking temporal or geographic trends in the fishery. In order to get more precise estimates of charter boat fishing effort for a given geographic area or two-month sampling period, the MRFSS pools data collected during that time period with data collected in the four previous years for the same time period prior to calculating the estimates. Although pooling in this case increased the reliability of the estimates, it may have also introduced a bias if fishing effort was steadily declining or increasing over the five-year period. In addition, the estimates produced from the 5-year pooled data cannot be used to track year-to-year trends in the charter boat fishery.

The MRFSS obtained information about the distribution of trips by primary area of fishing (inland waters, state territorial seas, EEZ), state and county of residence, type of residence, and presence/absence of telephone in the household from the intercept survey. These data were used to post-stratify estimates of

total fishing effort into one of the three fishing areas, and to calculate adjustments for trips made by non-coastal county residents, those anglers not living in private households, and anglers living in households without a telephone. Data from the intercept survey was used for the area fish post-stratification because it was hard to get reliable data on the area of charter boat fishing trips directly from the telephone survey interviews of coastal household residents. Typically, charter anglers do not know specifically where they fished or may have trouble recalling the details of the trips taken up to two months prior to the interview. In addition, the large undercoverage of the MRFSS telephone survey suggested that its sample of trips was not likely to be fully representative of all trips. This post-stratification method relies heavily on the assumption that the area distribution of trips profiled by the intercept survey sample is truly representative of all charter fishing trips within the sample period and region.

METHODS

The pilot VDTS method tested in this study depended on the existence of a relatively complete list of boats used to take marine recreational anglers fishing for a fee. In order to use such a list as a sample frame for a telephone survey, a unique identifier for each vessel, as well as a telephone number and a designated representative for each vessel was required. Prior to the start of the pilot survey, additional information on each listed boat which could be used to facilitate successful survey contacts with boat representatives or to characterize the boat's fishing capacity and location was obtained. For each listed vessel, its name, its state or Coast Guard registration or license number, its length, and its principal county and port of operation was compiled. State personnel attempted to determine whether the boat was usually trailered and launched at public ramps or whether it was usually moored at a private dock, private marina, or public marina. They also obtained telephone numbers and mailing addresses for as many as three captains or owners of each boat. Through telephone contacts and mailings, state agency staff attempted to verify the vessel directory data. In addition, they asked vessel captains or owners to specify a particular person as the primary representative for reporting of the boat's fishing effort. Each boat was randomly assigned a survey identification number which could be used as an anonymous identifier of all data collected for that vessel in the pilot telephone survey databases.

In order to determine which of the listed boats should be considered for inclusion in the pilot survey, sample frames for each state and state subregion, the cooperating agencies used information reported by respondents to classify boats as either "active", "inactive", or "ineligible". "Active" boats were boats known to be taking fishing passengers for a fee. Unless otherwise indicated by a vessel representative, all listed boats were assumed to be active. "Inactive" boats were those reported to be temporarily out of operation as a guide, charter, or party boat. "Ineligible" boats were those reported to be used strictly for commercial or

private recreational fishing, as well as those known to be covered by the NMFS Southeast Headboat Survey, or some other non-fishing activity. Ineligible boats were not removed from the directory, but they were flagged so that they would not be used on the pilot survey sample frames. Boats for which representatives refused to supply data were identified in the directory as "not willing to participate" and were not included in pilot survey sample frames. Information on eligibility, activity status, and survey participation status was updated as new data were collected by interviewers conducting the MRFSS intercept survey or the pilot telephone survey.

Sampling for the pilot VDTS was stratified by state or state subregion (Louisiana, Mississippi, Alabama, and three subregions of Florida), MRFSS two-month wave, and week. The Gulf coast of Florida was divided into three distinct geographic strata. Boats with principal ports located in Escambia through Dixie Counties were assigned to the Panhandle Region; those located in Levy through Lee Counties were assigned to the Western Peninsula Region; and those located in Monroe County were assigned to the Keys Region. The sample frames used for the VDTS were developed from the vessel directories prepared for the three states and the three Florida subregions. Only boats in the directory that had at least one unique identifier (name, registration or licensce number), a valid telephone number, a county of operation, and a representative's name listed were chosen for each sample frame. Boats previously identified as ineligible and boats previously reported to be inactive for the entire sampling wave were not included in the frame. Also, boats whose representatives identified themselves as not willing to participate were not included. Inactive boats projected to become active at some time during the sample wave were included in that wave's sample frame. Sample frames were constructed and all sample draws were made for a given wave at least two weeks prior to the start of the wave. The same sample frame was used to draw telephone calling samples for all weeks of a given wave in each state or state subregion.

For each week, a 10% sample of boats was selected by stratified, systematic random sampling from each state or state subregion sample frame. Prior to selecting the sample, the program used randomly sorted the boats in the sample frame and then sorted the "shuffled" list of boats by county of principal port and boat length category. Boats for each county were separated into short (less than or equal to 28 feet in length) or long (greater than 28 feet in length) categories, with boats of unknown length comprising a third size category. We sorted in this manner to assure a consistent proportional representation of boats among weeks with respect to boat size and geographic area of port. We randomized the start point and set the sampling interval such that every 10th boat was selected on one pass through the entire list. Since we randomly sorted boats within the geographic/boat-size strata prior to each week's sample draw, we assumed simple random sampling of boats for each week.

Gulf States Marine Fisheries Commission (GSMFC) staff mailed pre-contact letters and optional data forms to representatives of the boats included in the

weekly telephone interviewing samples. The letter was mailed at least two weeks in advance of the telephone interviewing attempts, and an optional data form which explained the type of information sought was included in the mailing so that the captains or owners would know what to expect. In addition, it was provided so that the respondents could use it to record their fishing effort data for the week to be surveyed. Representatives of boats for which a correct mailing address had not been obtained obviously did not receive the mailings.

Calling for the VDTS was completed by state agency personnel during the week following each designated sampling week. Callings started on Monday and continued until representatives of all boats in the sample had either been successfully contacted or called without contact at least five times. Repeated calling attempts for particular boat representatives were made at different times of day and on different days to increase the likelihood of a successful contact. If a contact was made but the designated vessel representative was not available then more callbacks were attempted to contact the appropriate person. The outcomes of all calling attempts were recorded and the final result for each vessel was coded at the end of the week. The final results of calling attempts included "successful contact", "line busy", "no answer", "answering machine or service", "wrong number", "not available", "not in service", "refusal", "communication problem", and "fax/computer response". Once telephone contact was made with a given vessel representative, the respondent was asked to specify a preferred day and/or time of day for subsequent survey interviews. This information was entered into the vessel directory for later reference.

Respondents were interviewed about their boat's fishing activity during the prior full week. Initial screening questions verified that the person contacted was an eligible representative of the selected boat. The interviewer then asked the respondent to report the number of dock-to-dock trips taken by the selected boat during the prior week, as well as the number of those trips which were for the purpose of marine recreational fishing. For each recreational fishing trip, starting with the most recent, the interviewer asked the respondent to report the mode of the trip (charter, headboat, or private), the number of anglers who fished on the trip, the primary area fished (inland or ocean waters), and, if ocean, the distance from shore (< 3 miles or > 3 miles in AL, MS, and LA; < 10 miles or > 10 miles in Florida). In addition, they asked for the number of hours fished, the primary and secondary fishing methods used, the return time, and both the county and specific site of fishing access. For each boat fishing trip reported the interviewer also recorded both the date and day of the week on which it occurred. At the end of each interview, interviewers asked additional questions to update information listed for the boat in the vessel directory, if needed.

A random 10 % sample of the completed interviews were selected and a second call was made later in the week to allow the respondent to verify the data recorded from the interview. This "post-validation" procedure was implemented to build confidence in the quality of the data collected and minimize possible

recording errors made by the interviewers. Post-validated interviews were flagged in the final database.

An independent survey was conducted to determine whether or not respondents were accurately reporting their fishing effort data on the VDTS. Using the sample drawn for a given week, state personnel attempted to visit the principal port identified for each boat on at least one day during the sample week. The time of validation visits was chosen to coincide with the time of day when boat fishing activity could most readily be confirmed. Observers usually visited boat slips during the morning hours between 9:00AM and 1:00PM. If the boat was observed to be out of its slip, then the observer recorded the boat as "out". If the boat was observed to be in its slip, then the observer recorded that the boat was "in". For the first two waves of the VDTS (September - Dececmeber 1997), boats that were "out" were assumed to be fishing that day. Starting in January of 1998, validation observers attempted to confirm the fishing status of boats. If a boat was observed to be out of its slip, then the observer recorded the boat as "out" and attempted to determine whether the boat was fishing by asking a marina operator or other knowledgeable people present at the site. If the boat was determined to be fishing, then the boat's status was recorded as "out, fishing confirmed". If the observer was unable to confirm that the boat was fishing that day, then he/she recorded the status as "out, fishing not confirmed". In order to estimate reporting errors, we matched validation observations with fishing effort data reported during the subsequent VDTS interview. This allowed direct comparisons of observed fishing effort with reported fishing effort for a given boat and day. The results of these comparisons were used to estimate reporting errors which were stratified by state, or state subregion, and wave.

RESULTS

Estimates of Gulf charter boat fishing effort from September 1997 - December 1999 derived from the pilot VDTS followed a seasonal trend with peak activity in May/June of 1998 and 1999 (Figure 3). Adjustment estimates were relatively small each wave except for some unexpectedly large adjustments for unlisted boats in Nov/Dec 1998 and Mar - Jun 1999, and an unusually large adjustment for reporting errors in Nov/Dec 1998 (Figure 3). Relative to estimates derived from the traditional MRFSS RDD telephone survey the pilot VDTS estimates were more precise (smaller 95% confidence intervals) and demonstrated an expected seasonal trend of fishing activity in the Gulf of Mexico (Figure 4).

The relative precisions of the pilot VDTS wave estimates were greater that those of the traditional MRFSS estimates, were more consistent from wave to wave, and were independent of the magnitude of the estmates (Figure 5). The Gulf charter boat pilot VDTS effort estimated by fishing area was significantly lower in the EEZ and significantly higher in Inland waters than the estimates

derived by the traditional MRFSS RDD telephone survey for corresponding areas (Figure 6).

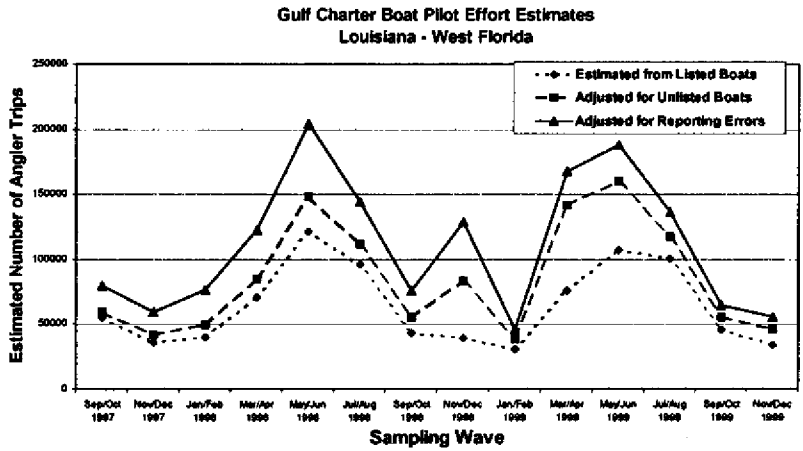


Figure 3. Gulf charter boat effort estimates and adjustments by wave from pilot VDTS study.

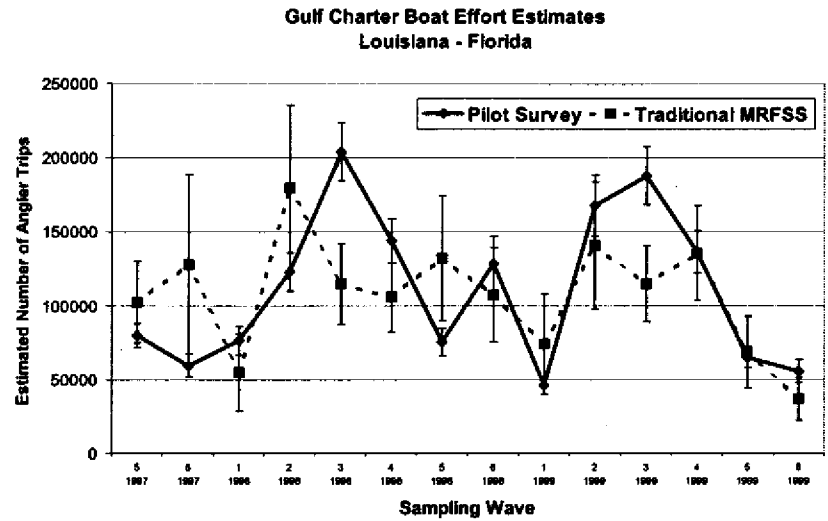


Figure 4. Gulf charter boat effort estimates and 95% confidence intervals by wave from pilot VDTS study and trational MRFSS RDD telephone survey.

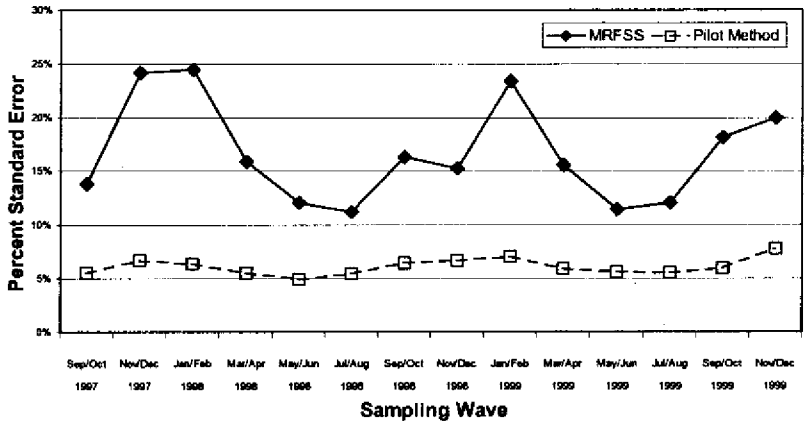


Figure 5. Precision of estimated angler effort (trips) by pilot VDTS and traditiional MRFSS methods [PSE = (Std. Error of Estimate/Estimate) x 100].

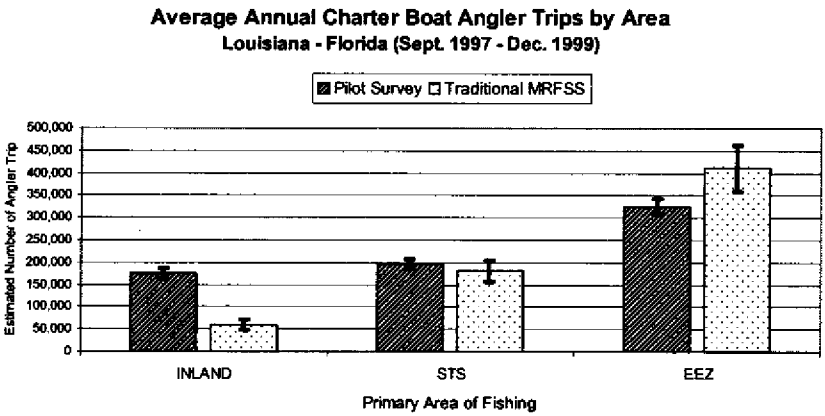


Figure 6. Annual charter boat angler trips estimated by the pilot VDTS and the trational MRFSS methods.

DISCUSSION

The pilot vessel directory telephone survey produced significantly more efficient, precise, and credible charter angler effort estimates than the traditional MRFSS method. This was primarily due to better coverage of Gulf charter angling activity, collecting the data from vessel representatives rather than their customers, and excellent cooperation rates from the charter fleet. Although there

was no significant difference in the annual Gulf of Mexico and state level effort estimates, the new methodology generally showed higher charter angler effort in inland waters and lower charter angler effort in the exclusive economic zone (EEZ). The pilot study also indicated a significantly different seasonal distribution of charter angler effort relative to the traditional MRFSS distribution, which the Gulf charter fleet considered more realistic.

Participating agencies were pleased by the preliminary findings. The NMFS adopted the pilot survey as the new MRFSS charter method in the Gulf of Mexico starting in 2000 and hopes to implement it nationwide in the near future.

LITERATURE CITED

Pollock, K.H., C.M. Jones, and T.L. Brown. 1994. *Angler Survey Methods and their Applications in Fisheries Management.* American Fisheries Society, Bethesda, Maryland USA. 371 pp.

The Economic Impacts of Sport Divers Using Artificial Reefs in Texas Offshore Waters

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ABSTRACT

Dive charter boat operators along the Texas coast were asked to provide names and addresses for a representative sample of their diving customers. A random sample of 1,059 sport divers was selected from dive charter boat records; 614 divers took trips to the Flower Gardens Banks National Marine Sanctuary and 445 divers in proportion to the known number of non-Flower Gardens trips by coastal region. An 11-page mail questionnaire was used to collect social and economic data from the sample of divers. Of the 1,059 questionnaires mailed, 528 were returned usable for an overall effective response rate of 56.2%. About 256 (56% of those who went diving in Texas marine waters in the previous 12 months) indicated they took one or more trips in the previous 12 months to artificial reefs in Texas offshore waters. This paper will focus on the group of sport divers who used artificial reefs. Artificial reefs included manmade materials deployed as bottom reefs, wrecks, and standing oil and gas platforms. Most divers participated in activities such as night diving (81%), underwater photography (53%), wreck diving (52%), and marine identification (52%); only 25% participated in spear fishing. Two estimates of sport diver offshore trip days (1,985 and 5,953) were multiplied by the average per trip expenditure for Texas residents ($162) yielding estimated total expenditures (direct economic impact) in coastal communities of $261,439 to $784,106. Total expenditures in coastal communities by non-residents of Texas were considerably less ($58,885 to $176, 606). The overall economic impacts of artificial reef diving in Texas where dive charter boats were used to access offshore reefs are presented in terms of changes in total output, income, and total employment. This paper excluded private boat divers who used artificial reefs offshore and charter and private boat divers accessing the Flower Gardens Banks National Marine Sanctuary. The overall economic impact of sport diving in Texas would be higher if these other segments were included. Finally, the paper will emphasize methods and address methodological difficulties involved in studying this particular group of marine resource users and their activities.

KEY WORDS: Artificial reefs, economic impact, sport diving

INTRODUCTION

The total number of sport divers worldwide was expected to be 14 million by the year 2000 (McCawly and Teaff 1995). As the number of divers increases, the need for additional dive sites also can be expected to increase. Natural reefs can only account for a certain amount of diving activity where allowed due to carrying capacity concerns for sustainability. Not all shipwrecks are sited to facilitate sport diving use. Offshore oil and gas platforms in the Gulf of Mexico provide temporary diving resources so long as hydrocarbon production continues. These structures must be removed once production ceases. In many areas of the world, the construction and maintenance of artificial reefs is an effective means for increasing the number of dive sites, particularly where opportunities to satisfy diver demands are otherwise limited. Instead of losing diver clientele to other markets in the region, the Texas Artificial Reef Program administered by the TPW has sought to create additional diving sites along the Texas coast. This is seen as having a positive impact on the charter dive boat industry, related infrastructure, as well as coastal communities. The Texas Artificial Reef Program was authorized by the Texas Artificial Reef Act of 1989 and is implemented as per the Texas Artificial Reef Plan. In this paper, artificial reefs included man-made materials deployed as bottom reefs, ship wrecks, and standing oil and gas platforms.

Previously, artificial reefs have been created and sited primarily to increase fish biomass. Siting is typically carried out to met state and federal statutory requirements in the most cost-effective way (Gordon and Ditton 1986). Where fishing and diving use was intended, it was usually assumed that dive sites with high fish biomass and diversity will meet the needs of and attract participants to the reefs. In other words, "If we build it, they will come". Recently, however, there has been a paradigm shift toward understanding and planning for users and their recreation experiences rather than simply being concerned with biological improvements. Accordingly, reef siting is being linked with human population and tourism densities and the expressed demand for scuba diving -related resources. The reasoning is that if artificial reefs are well sited from a market perspective, use will be encouraged, and social and economic benefits will be forthcoming. Understanding direct and indirect economic impacts of expenditures by resident and non-resident sport divers using artificial reefs provides decision makers with useful feedback on previous reef deployments and a baseline for future reef deployment.

The economic impacts of artificial reef diving use need to be described in terms of changes in total output, income, value-added, and total employment. Total output is the dollar value of goods and services produced to satisfy final demand foods and services associated with sport diving and the inter-industry transactions to produce them. Final demand is the dollar value of purchases from producing industries for final consumption. Value-added is equivalent to gross regional product, namely, payments to labor, capital, and taxes or the value of total output minus input purchases.

The goal of this paper was to characterize the sport diver constituency that use dive charter boats to access Texas offshore waters and to provide estimates of their

direct and indirect economic impacts on coastal communities and at the state level. We discuss methodological difficulties associated with diver studies and the implications of results for future artificial reef development and management in Texas.

METHODS

We used a stepwise approach to better understand the human dimensions of the offshore sport diving industry in Texas. First, the population of dive boats and operators was identified in an effort to know more about the extent of their offshore diving activity and use of artificial reefs (Ditton et al. 1995). Next, we invited dive boat operators to provide us with access to their customer names and addresses for sampling purposes. A social survey research protocol was then used to collect data from dive boat customers using a mail questionnaire.

In 1997, charter dive boat operators on the Texas coast reported 289 offshore trips in the previous 12 months where artificial reefs were used; these trips accounted for 1,985 diver trip days. For comparison purposes, the Flower Garden Banks National Marine Sanctuary (FGBNMS) accounted for 77 trips and 2,350 diver trip days. This information was derived directly from logs or data bases maintained by the operators.

Our goal was to sample 1,200 sport divers: 600 divers from boats known to take divers to the FGBNMS and another 600 divers in proportion to the known number of charter boat dive trips offshore in the previous 12 months by region of the Texas coast. We were able to achieve our sampling goals with regard to FGBNMS divers, but we were unable to achieve sampling goals with the other group of divers due to a lack of cooperation by dive boat operator. Planned and actual numbers of divers in the sample for South Padre Island were 148 (222), Port Isabel 15 (0), Corpus Christi/ Port Aransas 99 (97), Port O'Connor 45 (57), Freeport 173 (69), Galveston 83 (0), and Port Arthur 37 (0), respectively. Overall, cooperation was greater on the lower coast from Port O'Connor south. To maintain adequate sample size, we over-sampled in other areas where operators were willing to cooperate. Accordingly, we over-represented divers taking trips with operators on the lower Texas coast and under-represented divers taking trips with dive boat operators on the upper Texas coast. The study focuses on sport divers who had gone diving in Texas offshore waters using a charter dive boat in the previous 12 months. Therefore, this study excludes those divers making trips offshore on privately-owned boats because we could not identify a sampling frame of boats used one or more times a year for sport diving purposes.

An 11-page self-administered mail questionnaire was developed to collect data from sport divers. The questionnaire contained questions proven effective in previous studies of sport divers, birders, and anglers conducted by the Texas A&M University (TAMU) investigators. The questionnaire was pre-tested with sport divers from the TAMU Scuba Diving Club and several questions were modified as a result. In addition to questions about overall diving activity and experience, we

asked divers about their overall diving participation in Texas offshore waters and specifically about their "last dive trip" to the Texas coast, including their personal trip expenses by category and by location of expenditure made (in coastal communities, elsewhere in Texas, and out of state. Finally, a social and economic profile of sport divers was sought using questions regarding age, gender, race, ethnicity, education, income, and residence location.

The Salant and Dillman (1994) survey methodology was used. The first mailing explained the study purpose and solicited their cooperation. This was followed with a questionnaire one week later, followed by a reminder/ thank you post card the next week. Two weeks later, non-respondents were sent a second questionnaire. Mailings were sent using TPW letterhead and envelopes with postage-paid envelopes addressed to TAMU.

Of the 1,059 questionnaires mailed to divers, 528 were returned usable. An overall effective response rate of 56.2% was achieved; this takes into account questionnaires returned but non-usable (9) and non-deliverable addresses (103). The response rate achieved was below what Dillman (1978) reports should be achieved using his "Total Design Methodology" and well below the range (61.5% - 71.8%) achieved previously by the Human Dimensions of Fisheries Lab in angler surveys completed for TPWD. There were several possible reasons for the lower than expected response rate:

i) Divers may not have been artificial reef users and hence did not understand why the TPW wanted their survey input,
ii) Divers may have felt that TPW shouldn't be involved in what is generally considered a private sector recreation activity,
iii) The sampling frame contained the names and addresses of persons other than those taking dive trips in the previous 12 months, and
iv) The survey was conducted during the summer months due to difficulties in acquiring diver names and addresses from operators. This is not one of the best time periods for conducting mail surveys because people are busy with recreation activities during the summer vacation period (Brown et al. 1989).

Surveys can yield inaccurate results when the effects of non-respondents are not accounted for in mail surveys (Fisher 1996). An 11-item telephone interview was developed so we could test for statically significant differences between respondents and non-respondents on the selected items. Since no phone numbers came with diver addresses, we used the internet to get telephone numbers for non-respondents, telephone numbers were located for only 254 non-respondents. After two attempts to reach these individuals, only 13 interviews could be completed. Besides divers not being home and occasional refusals, many numbers were out of order or had answering machines. The number of completed interviews was insufficient for ascertaining the extent of non-respondent bias in the data set. From previous studies, we would expect non-respondents to have fewer years of experience and participate less frequently than respondents; accordingly, the activity probably has less salience to the former group explaining their non-response to the mail survey

(Filion 1980). Based on this, we would expect survey respondents to report more days of diving participation in the previous 12 months, more years of diving experience, and more dive boat trips in the previous 12 months than non-respondents. Because of the likely differences between respondents and non-respondents, we cannot generalize from respondents to the population of divers who use charter dive boats to access offshore waters. In the following analysis, we are assuming no difference between groups in charter boat trip costs. No matter how salient diving may be to individuals, or how frequently they participate in diving, per person trip costs are likely to be the same for each group.

Direct economic impact was estimated at the coastal community and state levels. Trip expenditures by respondents were extrapolated to the population of sport divers using charter dive boats on the Texas coast in 1997. Economic impact multipliers for the Texas coast derived by Tanyeri-Abur et al. (1998) were applied to estimate the economic impacts of sport diving in coastal communities or at the state level. They used IMPLAN to calculate these multipliers, which show the impact of an increase in output in one sector on other sectors of the economy. From their understandings of the total impacts of recreation activities on the Texas coast, they concluded on average that each dollar of expenditure resulted in $1.81 of total input, $0.75 in personal income, and $1.15 in value added on the Texas coastal economy. They reported an employment multiplier of about 37 jobs per $1 million of expenditures. At the state level, the economic impact multiplier was slightly higher at $1.90 of total economic output, $0.78 in personal income, and $1.20 in value-added on the state's economy. Total economic impact was estimated for the entire Texas coast and not on a community by community basis due to lack of sample size at the community level and because there was no data for communities on the Texas coast.

RESULTS

Of the 528 diver respondents, 461 reported diving activity in the previous 12 months (Figure 1). Of these, 256 (55.5%) had taken one or more diving trips using artificial reefs in Texas offshore waters in the previous 12 months. A larger percent of these divers (74.6%) had taken one or more diving trips to the Flower Gardens National Marine Sanctuary in the previous year. This is a natural reef area approximately 110 miles offshore from Texas made up of bioherms, or salt domes, with corals growing on top. The remainder of results presented in this paper will be from the 256 (55.5%) diver survey respondents who reported using artificial reefs on one or more trips in the previous 12 months.

Most (75%) artificial reef divers were male. Most (90%) categorized themselves as Anglo or white, while only 9% reported themselves to be of Spanish/ Hispanic origin. Divers averaged 39 years of age, with most between 21- 40 years of age. Most (81%) sport divers reported a current Texas residence. Of these, most (70%) lived in five urban metropolitan areas: Houston (32%), San Antonio (11%), McAllen (11%), Austin (10%), and Corpus Christi (6%). For non-resident sport

divers, whether they were attracted to dive in Texas offshore waters or came to vacation in Texas and went diving while they were here is not known. Fifty-three percent of divers had household incomes before taxes of between $10,000 and $69,000; the median household income category was $60,000- $69,999. Most (64%) sport divers had four or more years of college education.

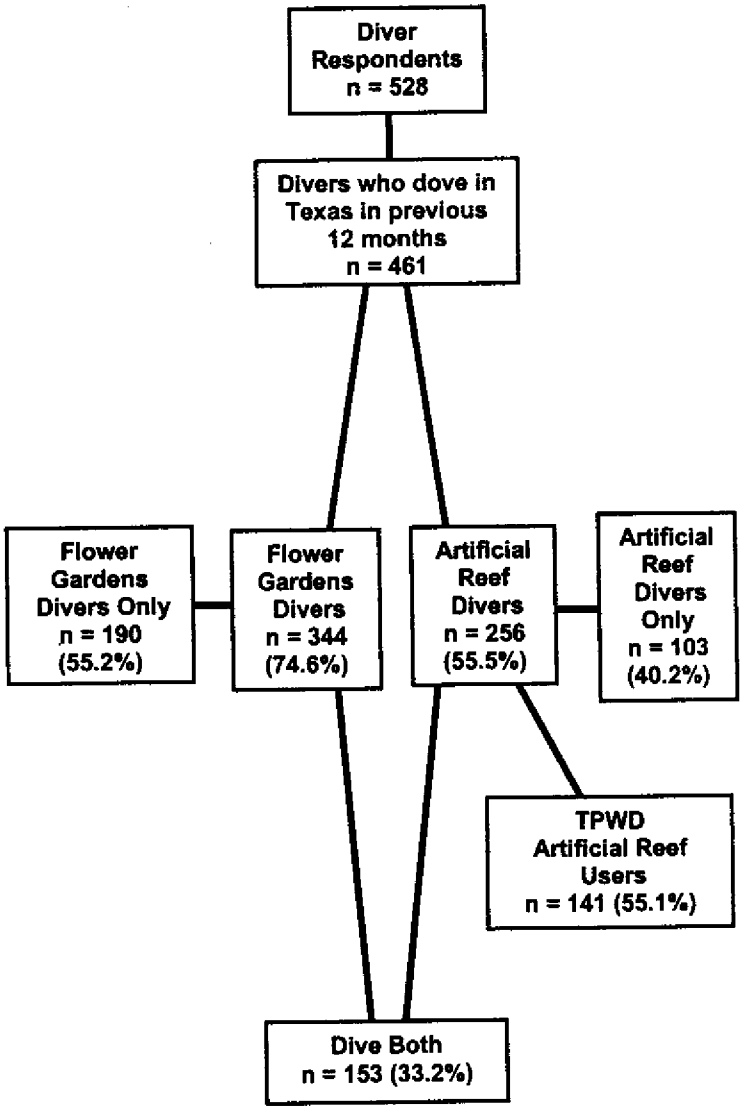


Figure 1. Distribution of diver respondents by location of charter boat diving trips (one or more trips) in the Gulf of Mexico offshore from Texas in 1996.

Most artificial reef divers reported they participate in night diving (81%), underwater photography (53%), wreck diving (52%), and marine identification (52%). Only 26% of this group participated in spear fishing (Table 1). When divers were asked to indicate which of the identified diving activities they participated in most often in the previous 12 months, they indicated a tie between underwater photography and marine identification.

Table 1. Number and percent of artificial reef divers by the diving activities they participate in and those they participated in most over the previous 12 months.

	Participate		Participate Most	
Activity	N	%	N	%
Underwater photography	135	52.7	61	26.1
Marine identification	133	52.0	61	26.1
Cave diving	31	12.1	2	0.9
Wreck diving	134	52.3	18	7.7
Spear fishing	65	25.4	24	10.3
Decompression/NITROX diving	56	21.9	9	3.8
Night diving	207	80.9	33	14.1
Other[1]	43	16.8	26	11.1
Total			234	100.1
Missing Cases			22	

In order to establish a frame of reference for dive trip expenditures, divers were asked about their last trip to the Texas coast where they went scuba diving and used a charter dive boat to do so. Most indicated this trip took place between July 1-December 31, 1996 (58%) with a one-way travel distance of 200 miles or less (69%) from home. There was an average of 21 people onboard (excluding captain and mate) the dive charter boat on this last trip. Most of the trips described by divers were devoted almost exclusively to sport diving activity. Their last trip to the Texas coast for sport diving where they used a dive charter to access offshore waters averaged 2.8 days; of this, they reported they spent an average of 2.2 days diving.

Overall, artificial reef divers reported spending an average of $287 in the coastal community they visited to go scuba diving (and used a charter dive boat to access offshore waters) plus an additional $116 "elsewhere in Texas" in preparation for or during their last trip to the coast (Table 2). Their total average trip expenditure was $403. Since their last trip averaged 2.8 days with 2.2 days of diving, each diver's trip consisted of 2.2 charter dive boat trips from shore. Accordingly, divers spent an average of $131 per person per day diving in coastal communities in Texas. As expected from previous expenditure studies of other outdoor recreation activities, most (73%) of the sport divers' expenditures in destination communities were for charter fees, lodging, and restaurant meals (Table 2). Most (53%) expenditures "elsewhere in Texas" were for automobile transportation costs and dive boat fees paid to dive shop providers (some of which finds its way back to the charter dive boat operator and the coastal community); food and lodging expenditures could have been made in route to the diving destination community or else divers may have chosen to stay elsewhere to reduce their trip costs (Table 2).

Table 2. Number and percent of artificial reef divers making dive trip related expenditures on their last dive trip to the Texas Coast; average expenditures for those making each expenditure and overall.

Expenditure Category	n	Percent of Divers with Expenditure on Item	Average Expenditure per Diver Who Purchased Item	Average Expenditure for Item for All Divers
Amount in the Coastal Community:				
Automobile transportation to the Texas coast (fuel, rental car, taxi, etc.)	207	83.8	$23.10	$19.40
Other transportation to the Texas coast (airplane, etc.)	160	64.7	18.30	11.90
Dive boat fees	209	84.6	178.30	150.90
Tips	207	83.8	20.90	17.50
Lodging	186	75.3	41.90	31.50
Restaurant meals	199	80.6	34.30	27.70
Groceries, drinks, ice	196	79.4	18.00	14.30
Rental of diving gear	187	75.7	8.30	6.30
Anything else for this diving trip	35	14.2	54.70	7.80
Total			$397.60	$287.30
Amount Elsewhere in Texas:				
Automobile transportation to the Texas coast (fuel, rental car, taxi, etc.)	159	64.4	$35.90	$23.10
Other transportation to the Texas coast (airplane, etc.)	123	49.8	18.30	9.10
Dive boat fees	116	46.9	80.20	37.70
Tips	111	44.9	8.20	3.70
Lodging	120	48.6	25.10	12.20
Restaurant meals	137	55.5	26.30	14.60
Groceries, drinks, ice	127	51.4	12.50	6.40
Rental of diving gear	130	52.6	12.40	6.50
Anything else for this diving trip	24	9.7	23.60	2.30
Total			$242.50	$115.60

To understand the economic impacts of diving activity on local and state level economies, it is necessary to know where divers reside. We separated expenditures by Texas divers from those from other states to estimate the state level impact of artificial reef diving. State level expenditures are determined by new monies coming into the state and being re-spent. Similarly, expenditures made by divers from coastal communities in Texas need to be separated from those of other Texas divers. Only three of the 256 divers in the sample were from Texas coastal communities. The assumption here is that they would have made other expenditures locally if they were not able to go diving. Thus, local economic impacts were determined by new monies coming into coastal communities and being re-spent there.

Texas resident divers spent an average of $255 in coastal communities on their last trip to the Texas coast. When divided by the mean number of days diving on this last trip (1.57), this yields an average of $162 spent in coastal communities per sport diving trip day. They spent an additional $49 per sport diver trip day elsewhere in Texas traveling to or from the coast. Non-residents spent about $459 in coastal communities on their last trip (2.70 days of diving) for an average of $170 per sport diver trip day. While non-residents spent nearly $200 more than state residents on their last trip to the Texas coast, they spent about the same per person per diving day on these trips. Non-residents spent an additional $81 per sport diver trip day elsewhere in Texas on their trip to the coast.

We made two estimates of sport diver trip days taken offshore. A low estimate (1,985) was based on dive charter boat operator self-reports of the number of trips made times the number of divers onboard (mean = 6.8); a higher estimate (5,953) was based on the average number of divers (excluding captain and made) on board charter dive boats (20.6) as reported by sport divers in their questionnaire responses times the number of trips reported by dive boat operators.

When these two estimates of sport diver trip days for the Texas coast are multiplied by the average per trip expenditures for Texas residents, estimated total expenditures (direct economic impact) in coastal communities ranged between $261,439 to $784,106 (Tables 3 and 4). Total expenditures in coastal communities by non-residents were considerably less. Overall, non-residents spent between $87,121 and $261,293 on their last trip to the Texas coast to go diving; these were new monies to the Texas economy.

The estimated $320,323 to $960,713 in direct expenditures made by non-residents of coastal communities for local goods and services generated an additional 259,738 to $779,026 in economic output, resulting in a total output of $581,994 to $1,745,559 with 12 to 35 jobs in this sport diving sector (Table 5). The total value-added associated with this increased level of output is estimated at between $371,561 and $1,114,413. This is smaller than the level of total output because it represents only the amount of income and taxes retained in the coastal communities where charter dive boats operate. Many of the inter-industry inputs such as labor, capital, wholesale supplies, etc. must be purchased outside of the coastal margin. Each of these purchases represents a leakage from the local economy. The more leaks in the economy, the smaller will be the overall economic impacts from changes

in final demand. A component of the total value added impact of sport diving activity is the impact on total income, which was estimated to range from $242,169 to $725,866.

Table 3. Total Expenditures (Direct Economic Impact) made by artificial reef divers by residence location using data provided by dive boat charter operators

Residence	Dollars spent in coastal community	Dollars spent elsewhere in Texas	Total
Coastal community residents	1,941	0	1,941
Texas residents (not coastal community)	261,439	78,351	339,790
Non-residents	58,885	28,237	87,121
Total	320,324	106,588	426,911

Calculated based on data provided by 12 dive charter boat operators for number of trips taken offshore for sport diving and number of divers carried offshore in 1996.

Table 4. Total Expenditures (Direct Economic Impact) made by artificial reef divers by residence location using data provided by divers and dive boat charter operators

Residency	Dollars spent in coastal community	Dollars spent elsewhere in Texas	Total
Coastal community residents	5,821	0	5,821
Texas residents (not coastal community)	784,106	234,990	1,019,096
Non-residents	176,606	84,687	261,293
Total	960,713	319,677	1,280,389

Calculated based on data provided by 12 dive charter boat operators for number of trips taken offshore for sport diving in 1996 and diver questionnaire responses regarding the number of persons on board (excluding captain and mate) on their last trip to the coast where they went scuba diving and used a charter dive boat.

State level economic impact results are notably different because only a small number of non-residents come to Texas to go diving and make use of artificial reefs using dive charter boats. The total output (direct and indirect impacts) associated with this group of sport divers ranged between $166,349 and $498,913 with 3 to 10 jobs. Total statewide effects from indirect and induced spending are likely spread over a wider range of sectors including manufacturing, retail, and services sectors. The total value-added dollars generated by the increased level of output is estimated to be between $104,563 and $313,604.

Table 5. Coastal community and statewide impacts of artificial reef divers by economic impact variable

Economic Impact Variable	Total Impacts			
	Local		State[1]	
	Low	High	Low	High
Direct Impact	$322,256	$966,533	$87,121	$261,293
Output	$581,994	$1,745,559	$166,349	$498,913
Personal Income	$242,169	$725,866	$67,769	$388,104
Value-added	$371,561	$1,114,413	$104,563	$313,604
Employment (jobs)	12	35	3	10

[1] State level economic impacts are derived from local as well as statewide direct expenditures by non-resident sport divers. They are usually larger in magnitude because they include secondary and tertiary impacts outside of coastal communities but within the state of Texas.

DISCUSSION

Artificial reefs are provided by the TPW in an effort to enhance offshore diving experiences. Since divers and dive boat services are not required to pay for using offshore artificial reefs, there is a general expectation there will be a positive economic impact on coastal communities and even statewide from reef deployment. Economic impact assessments are useful to agency decision makers for determining whether local and statewide economic development goals are being met. As a result of this analysis, community leaders have a baseline understanding of local impacts associated with this outdoor recreation and tourism sector. With additional private sector promotion of offshore artificial reef diving, particularly in out-of-state markets, we are likely to see substantial increases in the impact figures presented here. The situation mirrors a similar case with the Texas charter sport fishing industry where only 3% of their customers come from other states (Sutton et al. 1999). In Mississippi, Alabama, and Louisiana, charter boats derived 62%, 57%, and 33% of their fishing customers from other states, respectively. If increasing local and state level economic impacts are important components of the Texas Artificial Reef Program, then private sector educational and outreach efforts need to be encouraged.

It should be remembered that this study focused on the expenditures and total economic output of only one segment of the Texas sport diving industry. Not included here are those who used private boats to go diving offshore artificial reefs or those who use private or charter boats to dive the FGBNMS. Nevertheless, sport diving is probably only a small portion of the coastal and marine recreation sector which is estimated to involve expenditures of about $866.65 million with a total economic output of $1.56 billion (Tanyeri-Abur et al. 1998). This doesn't mean that sport diving is unimportant but rather a reflection of the low rate of participation

(percent that participate) in diving compared to other outdoor recreation activities which cost less and hence are more popular.

This paper focuses on the coastal community and state level economic impacts of sport divers using dive charter boats to reach offshore artificial reefs in Texas offshore waters. This perspective is but one of several studied in this overall research project (Ditton et al. 1999). Overall, we found little available literature on the social and economic aspects of sport diving use of artificial reefs, not to mention on the offshore dive charter boat industry or sport diving in general. There are several possible reasons for this:

i) Sport diving has fewer participants than many other outdoor recreation activities and hence has not yet received the same research attention from public sector marine resources management agencies,
ii) Since sport diving is by and large a private sector outdoor recreation activity, previous research has been completed but it is proprietary,
iii) Lists of diver names and addresses are maintained by dive certification organizations and are not available for sampling purposes by public sector natural resource management agencies, and
iv) Artificial reefs appear to have been planned more for recreational fishing than for diving. If public-sector agencies are to be responsive to the wants and needs of divers as well as effective in managing their marine resource impacts, there will need to be many more social and economic studies of statewide, area, and mode-specific diver populations.

LITERATURE CITED

McCawley, R. and J.D. Teaff. 1995. Characteristics and environmental attitudes of coral reef divers in the Florida Keys. Pages 40-46 in: General Technical Report INT-GTR-323 U.S. Department of Agriculture, Forest Service Intermountain Research Station, Missoula, Montana USA.

Gordon, W.R., Jr. and R.B. Ditton. 1986. A user-resource planning framework for offshore recreational artificial reefs. *Coastal Zone Management Journal* 13 369 – 395.

Ditton, R.B., Finkelstein, L.D., and J. Wilemon. 1995. Use of offshore artificial reefs by Texas charter fishing and diving boats. Technical Report #HD-604. Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas USA. 38pp.

Salant, P. and D.A. Dillman. 1994. *How to Conduct Your Own Survey*. John Wiley and Sons. New York, New York USA.

Dillman, D.A. 1978. *Mail and Telephone Surveys: The Total Design Method*. John Wiley and Sons, New York, New York USA.

Brown, T.L., D.J. Decker, and N.A. Connelly. 1989. Response to mail surveys on resource-based recreation topics: a behavioral model and empirical analysis. *Leisure Sciences* 11:99-110.

Fisher, M.R. 1996. The effect of nonresponse bias on angler surveys. *Transactions of the American Fisheries Society* **125**:118-126.

Filion, F. 1980. Human surveys. Pages 441-453 in: *Wildlife Management Techniques Manual, 4th ed. (revised)*. The Wildlife Society, Washington, D.C. USA.

Tanyeri-Abur, A.L. Jones, and H. Jiang. 1998. Economic impacts of recreational activities and commercial fishing on the Texas Gulf coast: Executive Summary. Report prepared for the Texas Water Development Board, Austin, Texas USA. 31pp.

Sutton, S.G., R.B. Ditton, J.R. Stoll, and J.W. Milon. 1999. A cross-sectional study and longitudinal perspective on the social and economic characteristics of the charter and party boat fishing industry of Alabama, Mississippi, Louisiana, and Texas. Report #HD-612. Report prepared for the National Marine Fisheries Service. Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas USA. 220 pp.

The Socio-economic Characterization of Tournament Anglers in Barbados

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ABSTRACT

Information on social and economic characteristics of eighty tournament anglers in Barbados was obtained by interviews covering social and economic profiles of anglers; fishing patterns and angler expectations; attitudes towards commercial fisheries and interactions with them; and attitudes towards fisheries management and management measures. Tournament anglers are mostly white males who seek large pelagic fish, especially dolphinfish and billfish, which are also targeted by commercial fishermen. Dolphin are prized for consumption, and billfish particularly for the sporting challenge. Anglers sell their fish at local markets, and report both catch and non-catch motives for fishing. The importance of non-catch reasons, such as relaxation, was greater and catch motives. Anglers supported the introduction of fisheries management measures such as size/length limits, catch and release, closed areas, and fishery closures. Due to the multi-species nature of the fisheries, and reasons for targeting these fish, anglers did not support bag limits or catch and release for the more marketable species. There are few conflicts between tournament anglers and commercial fishermen, but a major concern is the dwindling numbers of billfish caught. This is blamed on commercial longlining in Caribbean waters. Fisheries management planning in Barbados has ignored tournament anglers. This study facilitates their inclusion in management planning.

KEY WORDS: Anglers, Barbados, socio-economics

INTRODUCTION

Most fisheries development efforts in the Caribbean, and efforts to acquire information for marine fisheries management, have focused on commercial fishing. Less attention has been paid to Marine Recreational Fishing (MRF), also called game-fishing or sport-fishing. This includes the tournament angling about which this paper is concerned.

In Barbados most sport fishermen report that fisheries managers lack an appreciation for the importance of MRF. This perception is strengthened by the fact

that the Barbados 1997-2000 Fisheries Management Plan (FMP) pays little attention to MRF, even though the 1993 Fisheries Act makes provision for the inclusion of sports fishing in fisheries management and development.

The tournament aspect of MRF in Barbados is believed by some anglers to be still at an early stage of development, but with potential to grow. An indicator of this growth has been the increase in the popularity of sport-fishing among locals and visitors, as reflected in an increase in the number of charter boat operators who provide recreational fishing experiences, mainly for tourists.

As MRF grows, there is concern that the harvest pressure applied, in addition to that of the commercial fishery, could lead to over exploitation of valuable target species. If the development of the fisheries sector is to be managed effectively, the MRF component needs to be incorporated into the whole planning process. The planning process requires knowledge not only of the biological status of the fisheries concerned, but also the social and economic components of the fishery. In Barbados, according to fisheries officers, information on the human element involved in MRF is scarce, and this has made it difficult to formulate policies and programs needed to guide its development.

In anticipation of the further development of MRF in Barbados, information on the human dimensions of the fishery is important. This entails assessing the attitudes, beliefs, motives, and preferences of people involved in MRF. Such information could help fisheries managers understand the variety of stakes that people have within the fishery in order to guide coordinated management and development of fisheries policies and plans in Barbados.

Furthermore, an understanding of MRF could be vital in regional planning for recreational fishing if, for example, coordinated and joint marketing of the fisheries were attempted in the context of conventional tourism or eco-tourism. Especially intriguing are the prospects of recreational fisheries that are structured and marketed in such fashion that angler satisfaction is not measured by catch rate or size of fish, and that fish caught are released with a high rate of survival. It is the human dimension that may determine whether or not such responsible recreational fisheries are feasible. This paper describes tournament anglers in Barbados in relation to:

i) Social and economic profiles of individuals and their activities,
ii) Fishing participation patterns and angler behavior,
iii) Attitudes towards the commercial fisheries and interactions with them, and
iv) Attitudes towards fisheries management and management measures.

METHODS

A sample of 80 tournament anglers resident in Barbados was obtained from the membership list of 150 current members of the Barbados Game Fishing Association (BGFA). This is the principle body that organizes and regulates all game fishing competitions on the island. Most local tournament anglers are members of this association.

Since very little literature existed on tournament angling in Barbados, the researcher conducted two separate sets of interviews. In-depth interviews with key informants (7 male, 2 female) provided the background on tournament angling and for the second round of shorter interviews. Surveys were conducted between November 1999 and January 2000 as a graduate research project.

RESULTS

Social and Economic Profile of Anglers

Tournament anglers in Barbados comprise four ethnic groups, the largest of which is white (73.8% of the sample). The other anglers were of mixed race (16.3%), black (7.5%), and Indian (2.5%). The anglers in the sample were all male, and 63.8% were married. Anglers in the age group 26-35 years dominated the sample. The mean age was 33 years old. All the anglers interviewed had received formal education with just over half (58.5%) having attained secondary school or post-secondary school training. The majority (97%) of the anglers are employed within the private sector.

The modal annual income before taxes of the anglers ranges US$20,000-$30,000 and the annual income before taxes ranged between US$10,000-$40,000 for the entire sample. The modal (33.8%) annual expenditure of anglers on fishing was US$500-$2,500. Of the monies spent on fishing, about 75.1% of the anglers spend half or greater locally. On further analysis, comparing annual income earned with ethnicity and age, results showed that more than half of the white anglers earned between US$20,000-$45,000. Black anglers were clustered at both extremes of the income spectrum.

Relating age to income, and income spent on gamefishing, most anglers in the dominant age group (26-35 years) earn between US$20,000- $30,000, and spend less than $2,500 annually on fishing. Most (75%) of the anglers who are 36-45years old earn over $15,000 annually, and close to a third (28%) spend over $8,000 annually on fishing. All anglers 46-55 years old earn over $30,000, and the majority (87%) of them spend $3,000-$7,500 annually on fishing.

Fishing Participation Patterns

The majority (71.3%) of the tournament anglers fished regularly for sport 37 days per year, with an average of 10 days spent participating in organized competitions. Close to half of the anglers (48.8%) are involved in the sale of their catch and spend an average of 16 days fishing commercially (Table 1).

When anglers listed their three favorite target fish species in order of decreasing preference, dolphin was indicated as first choice (41.3 %), wahoo as second choice (35%), with billfish third (23.8%). Pelagic fish are preferred over demersal species. As reasons for targeting dolphin, 47.5% of fishermen cited the challenge of catching the fish, others (28.8%) mentioned the palatability of the fish, while 7.5% associated

with sale of their catch. All anglers who indicated marlin as a first choice (28.8%) gave reasons to do with the challenge of the catch.

Table 1. Fishing days per year by type of fishing activity.

Types of fishing activity	Mean no. of days fishing
Game-fishing (in general)	40
Occasional (once in a while for fun)	3
Regular (often for fun)	37
Tournament (organised competition)	10
Charter boat (hired fishing tour)	6
Commercial (sale for income)	16
Others*	3
No. of respondents = 80	

*Other types of fishing include; spin fishing, spear fishing, and pot fishing.

Those that sold their catch did so due to the need for income to offset the cost of maintenance and replacement of fishing paraphernalia, such as rods, reels, lures, hooks and maintenance of the fishing boat. Most of the fish sold is disposed of at dockside, at local fish markets, or sold from home. Most anglers who sell fish have regular customers. Dolphin, wahoo, and marlin, which dominate as fishes of choice, are also important to commercial fishing in Barbados.

For the majority (85%) of the anglers, their fishing activity started generally before the age of 15 years old. The mode of introduction into game fishing was mainly by family (55%) and friends (43%). Just over half (58%) of the anglers own a fishing vessel. Of these, 21% own a moses (dinghy), 20% own a pirogue, and 16% own cabin cruisers. The experience of going fishing in other parts of the world is important amongst Barbadian tournament anglers, as a majority (81%) have gone fishing in other countries. Of this group 76% have fished elsewhere in the eastern Caribbean, while 21% have also fished in the northern Caribbean.

Anglers' Motives and Attitudes

Anglers were asked to rank nine motives for fishing according to their degree of importance. Three of these reasons were related to non-catch aspects of fishing while the other six were catch related. Overall, two non-catch related motives were rated most important. These were "relaxing with family and friends", which was rated slightly to extremely important by 98.5%, and "getting away from their daily routine" rated by 95.8% as slightly to extremely important.

The two most important catch related motives for fishing were, "to catch fish big or small" and "catching fish to eat" (Table 2).

Anglers were asked the extent to which they agreed or disagreed with statements on attitudes towards fish exploitation (Table 3). Most anglers agreed (either agreed or strongly agreed) to "the more I go fishing, the happier I am" (75%) and "a fishing trip can be successful even though no fish are caught" (87.6%). Fish

size and retention were important to about half of the sample. However while anglers were happy to release species such as marlin, they prefer to keep dolphin and wahoo.

Most anglers disagreed (disagreed or strongly disagreed) with the statements, " I want to keep all the fish I catch", "if I thought I would not catch anything, I would not go fishing", and "when I go fishing, I am not satisfied unless I catch something".

Table 2. Tournament anglers' reasons for fishing

Reasons for fishing	Extent of agreement/ disagreement (%)*					
	1	2	3	4	5	Total
To catch fish big or small		6	13	24	25	33 100
Relaxing with family		1	4	8	21	66 100
Obtaining a trophy or prize fish		4	6	15	25	50 100
To get away from the daily routine		5	7	9	23	57 100
Challenge or sport		3	9	13	43	34 100
Seeking the thrill of fishing		0	0	19	44	38 100
To develop skill		1	23	24	16	19 100
		9				
Catching fish to eat		5	21	19	31	24 100
Catching fish to sell		2	26	19	16	11 100
		8				
To catch fish big or small		6	13	24	25	33 100

No. of respondents = 80

*1= Not at all important, 2 = Slightly important, 3 = Moderately important, 4 = Very important, 5 = Extremely important

Attitudes Towards Commercial Fisheries and Interactions with Them

When anglers were asked about the ways in which game fishermen and commercial fishermen cooperated, 58.8% indicated assisting each other in times of distress. Other responses included providing each other bait (43.8%), informing each other about fishing area locations (41.3%), and informing each other about currents and tides (10%). About conflict with commercial fishermen, 72.5% indicated hostility while fishing around debris that aggregates fish, locally called riffles.

Other cases of friction between game and commercial fishermen include the destruction of unmarked or inadequately marked fishing gear, such as fish traps and fishing lines, by the game fishing boats and competition for sale of fish. Some anglers were also concerned about the impacts of commercial fishing, and foreign longlining in particular, on fish stocks.

Table 3. Tournament anglers attitudes towards fish exploitation

	Extent of agreement/ disagreement (%)*					
Attitude statements	1	2	3	4	5	Total
The more I fish the happier I am.	27.5	47.5	12.5	11.3	1.3	100
A fishing trip can be successful even though no fish is caught.	38.8	48.8	2.5	6.3	3.8	100
I would rather catch one or two big fish than ten small ones.	23.8	40.0	12.5	18.8	5.0	100
It does not matter to me the kind of fish I catch.	8.8	43.8	3.8	32.5	11.3	100
The bigger the fish I catch the better the fishing trip.	20.0	33.8	12.5	32.5	1.3	100
I am happy if I don't keep the fish I catch.	16.3	37.5	21.3	16.3	8.8	100
I want to keep all the fish I catch.	6.3	5.0	7.5	70.0	11.3	100
If I thought that I would not catch any fish I will not go fishing.	7.5	22.5	1.3	43.8	25.0	100
When I go fishing I am not satisfied unless I catch something.	5.0	6.3	3.8	58	27.5	100
No. of respondents = 80						

*1 = Strongly agree, 2 = Agree, 3 = Uncertain, 4 = Disagree, 5 = Strongly disagree

Attitudes Towards Fisheries Management and Management Measures

Anglers were asked to indicate the extent of support or opposition for the use of four management tools for MRF. The majority of the anglers indicated support for the use of all management tools, with the exception of bag limits. For the latter 52.5% opposed use while 36.3% supported bag limits.

Comparing responses on bag limits with the responses on "catching fish to eat", 75% of those who considered eating their catch unimportant supported the use of bag limits, while much less (75%) opposed its use. Of the anglers that considered "catching fish to eat" important for going fishing, 53.94% opposed the use of bag limits, while 36.25% supported its use. When "catching fish to sell" was compared with opinions on the use of bag limits 53.45% of the anglers who considered the sale of fish important opposed the use of bag limits, while 34.48% supported it. Relating bag limits to fish of first choice, of those who chose marlin as a first choice, 52.1% supported use of bag limits. For those that chose dolphin 60.6% opposed the use of bag limits while only 21.2% supported the use of this tool.

DISCUSSION

Social and Economic Profiles

Tournament angling, like commercial fishing in Barbados and fishing generally, is primarily a male activity. Specific reasons for the low level of female involvement in tournament angling were not pursued, but some women have been champion anglers and held executive positions in the Barbados Gamefish Association.

The social and economic results partially support the popular stereotyping of game fishing as a recreational pastime for rich white Barbadians. Sections of the white community in Barbados, though in minority, are affluent and have a higher probability of participation in gamefishing on the basis of income alone since deep-sea tournament fishing is expensive. Income, however, may not be a major barrier to wider participation in tournaments, especially if boat ownership is excluded, since the level of incomes reported by anglers are earned by a wide ethnic cross-section of Barbadians. Low cost participation is possible in several of the local tournaments.

The process of socialization amongst family and friends, occuring in the context of colour and class groups, is also likely to be important. This is supported by the results showing that family introduced 55% of the tournament anglers to fishing while friends introduced 43%, but is only one perspective on a complex socioeconomic situation.

When sports fishing becomes better integrated into the fisheries management plan, fisheries authorities must deal with a greater diversity of clientele than they presently do now. However, the present relative lack of interaction between the BGFA and Fisheries Division suggests that these new clients may be more independent and need less assistance than those in commercial fisheries.

Fishing Activity and Expectations

Tournament anglers in Barbados mostly target large oceanic pelagic fish of commercial importance, such as billfish, dolphin, and wahoo. Dolphin is the fish of choice for challenge and because it is rated high as a food fish that sells easily. Billfish, the prize game fish in other parts of the world, is rated second.

The sale of fish is a common practice amongst the Barbadian tournament anglers. Sales subsidize the cost of fishing, especially of fuel, which is the main expense. The sale of tournament fish does not usually impact on the commercial fishery because the quantities sold are small due to the limited size of the MRF fleet and number of days deep-sea fishing. However, an implication for fisheries management is that such practices have the potential to produce conflict between the fisheries, particularly in times of heavy landings from both sources which may leave markets in glut. Mike and Cowx (1996) report that, in Trinidad and Tobago, on several occasions sales from MRF have caused commercial fishers to dump their catch when some markets become locally saturated.

On the other hand many of the local game fishers hold the view that selling fish caught by MRF serves to meet part of the public demand for fish and lessens

dependency on fish importation into Barbados. It is important that the Fisheries Division obtain information on the quantity, composition and disposal of tournament landings. The Fisheries Act of 1993 makes provision for regulations to address these management requirements.

Motive and Attitudes Towards Fishing

Motives for fishing are related to the satisfaction derived from catch and non-catch aspects of angling and its related activities (Knopf et al. 1973, Driver and Knopf 1976, Fedler 1984, Holland and Ditton 1992). The dimensions considered most important are the non-catch aspects of fishing related to relaxation, reflection-nostalgia and enjoying nature (Knopf et al. 1973, Buchanan 1983). However, Graefe and Fedler (1986), suggest that catch related motives are often more important in determining satisfaction and dissatisfaction amongst anglers. Results of this study show that, overall, anglers rate the non-catch reasons more important than the catch-related motives for fishing. However, when the reasons for fishing were grouped with species of first choice in Barbados, those who chose billfish were motivated more by the challenge aspect, while those who chose dolphin and wahoo were oriented towards consumption and sale of fish.

In studies conducted by Fedler and Ditton (1994) in the United States, when anglers were grouped by mode of fishing or target species, the relative importance of catch-related motives increased dramatically. In looking at the attitudes that anglers have towards exploitation, the majority of anglers were more interested in catching a few big fish than several small ones. This should be positive for management in that juvenile dolphin or wahoo are less likely to be sought after if the fishing is selective, but it emphasises the possibilities of interactions with the commercial fishery.

Attitudes towards commercial fishing

Presently, the conflicts between tournament anglers and commercial fishers are minimal. Most of the friction occurs while fishing around debris where the target species are concentrated. However, despite the minimal conflict, there is need to resolve and manage for the existing situation before it escalates to broader conflict, especially if there is an increase in either tournament anglers or commercial fishermen. The Fisheries Division should encourage the BGFA and fisherfolk organisations to establish a process for conflict management. The Division could then facilitate or mediate rather than arbitrate unless there was no alternative.

Anglers were unhappy and concerned with their dwindling catches of billfish. They attribute the decline to the by-catch of longlining, and especially foreign tuna and swordfish longliners. To address this issue, a collaborative effort is needed in fisheries management and research among Caribbean countries to investigate these observations and perceptions with the aim of maintaining or improving the quality of angling experience. The matter of measuring the impacts of foreign fishing is an interest likely to be shared with the commercial fishery, and collaboration or information exchanges between the fisheries could serve to establish more common

ground. Another consideration is the trade-off between promoting an unregulated local longline fishery, as at present, and regulating billfish harvesting so as to enhance the recreational fishery, which could be steered more towards catch and release. These options should be considered in the Fisheries Management Plan.

Attitudes Towards Fisheries Management

As the marine fisheries in Barbados continue to grow, tournament anglers appreciate that increasing pressure is exerted on the fishery resources, and therefore, precautionary management strategies and measures may be required via the implementation of various angling rules and regulations. They have witnessed the incorporation of more IGFA rules in their own tournaments and have instituted minimum retention weights.

With respect to catch and release, a large proportion of the anglers were uncertain about support for this because of the different reasons for targeting each species, a problem encountered more with multi-species than single-species fisheries. Anglers who agreed to the release of fish preferred to catch marlin. Those that preferred dolphin mostly disagreed with catch and release.

Similarly with bag limits, which received least support, the rationale for opposition relates to the consumption of fish as an important reason for fishing. Those that considered the sale of fish important or had dolphin as first choice were most opposed to the use of bag limits. These relationships point to consumption and sale as important elements to be considered in the management of MRF in Barbados for some species especially.

By examining motives and attitudes together with various management options for resource conservation, fisheries managers can devise comprehensive management and development programs to meet the anglers' and government's objectives for responsible fisheries. For example, for those who prefer to target billfish high emphasis should be placed on catch rates but low emphasis on retention. Such conservation practices may facilitate an ecotourism perspective (Holland et al. 1998). For fisheries managers to provide programs best suited for anglers, information is required on the different components of a fishing experience that contribute to angler satisfaction (Ditton 1996).

Caution should be exercised when generalizing results from motivation studies to provide programs for anglers because aggregate profiles may be misleading and obscure the diverse interests of anglers. As Shafer (1969) reminds, there is no such thing as an average angler. We should expect diversity in motivations and attitudes, and hence, there is a need to prioritise and compromise amongst angler and management objectives. In conclusion, this paper illustrates for fisheries management the importance of human dimension information about tournament anglers.

LITERATURE CITED

Buchanan, T. 1983. Towards an understanding of variability in satisfactions within activities. *Journal of Leisure Research.* **15**:39-51.

Ditton, R.B. 1996. Understanding the diversity among largemouth bass anglers; implications for managers. Pages 135-144 in: L.E. Miranda and D. R. Devries (eds.) *Multidimensional Approaches to Reservoir Fisheries Management.* American Fisheries Society, Symposium 16, Bethesda, Maryland USA.

Driver, B.L and R.C. Knopf 1976. Temporary escape; one product of sports fishing management. *Fisheries* **1**(2):24-29.

Fedler, A.J. 1984. Elements of motivation and satisfaction in the marine recreational fishing experience. *Marine Recreational Fisheries* **9**:75-84.

Fedler, A.J, and R.B. Ditton. 1994. Understanding motivation in fisheries management. *Fisheries* **19**(4):6-13.

Fisheries Division. 1997. *Barbados Fisheries Management Plan.* Ministry of Agriculture and Rural Development, Government of Barbados. 68 pp.

Graefe, A.R. and A.J. Fedler. 1986. Situational and subjective determinants of satisfaction in marine recreational angling. *Leisure Science* **8**:275-295.

Holland, S.M. and R.B. Ditton. 1992. Fishing satisfaction: A typology of anglers. *North American Journal of Fisheries Management* **12**:28-33.

Holland, S.M., R.B Ditton and A.R. Graefe. 1998. An ecotourism perspective on billfish fisheries. *Journal of Sustainable Tourism* **6**(2):97-116.

Knopf, R.C., B.L. Driver and J.R. Bassett. 1973. Motivations for fishing. *Transactions North American Wildlife and Natural Resource Conference* **38**: 191-204.

Mike, A. and I.G. Cowx. 1996. A preliminary appraisal of the contribution of recreational fishing to the fisheries sector in north-west Trinidad. *Fisheries Management and Ecology* **3**:219-228.

Shafer, E.J. 1969. The average camper who does not exist. Research Paper NE-142. Upper Darby, Pennsylvania: USDA Forest Service, Northeast Forest Experiment Station.

Participatory Processes for Involving Fisherfolk in Barbados Fisheries Management Planning

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ABSTRACT

A bottom-up approach to planning was implemented for the formulation of the 2001 to 2003 Fisheries Management Plan for Barbados. Rather than seek public participation through obtaining comments on an existing draft, this process sought wide stakeholder input without prepared text. The main initiative was a series of fish landing site community consultations aimed at identifying issues and recommending actions for inclusion in the draft management plan. Fishing industry organisations and the Fisheries Division of government collaborated in this process. Industry issues focused mainly on immediate problems with landing site infrastructure and constraints affecting income-generating activities. Conservation was mentioned primarily in the context of fisheries known already to be in crisis. Most of the actions recommended placed responsibility for fisheries management principally on government, with relatively little responsibility shared by the fishing industry. This paper examines the inputs and outputs of the participatory process prior to drafting the 2001-2003 Fisheries Management Plan for Barbados.

KEY WORDS: Barbados, participatory, planning

INTRODUCTION

The first Fisheries Management Plan (FMP) for Barbados was approved in 1997 following an introductory planning process that emphasised the role of a multi-stakeholder Fisheries Advisory Committee (FAC) with later input from individuals in the fishing industry through a series of public meetings (McConney and Mahon 1998). The legislation to give effect to the agreed upon management measures became law in 1998 as regulations under the Fisheries Act of 1993. Prior to this process the majority of people in the fishing industry and the general public were unfamiliar with the concept of fisheries management planning (McConney 1997). The first plan, for the three-year period 1997 to 2000, was intended primarily as a communication and education document (Fisheries Division 1997).

During the preparation of the 1997 - 2000 FMP few organisations existed in the fishing industry. The absence of fisherfolk organisations may have impacted as much on the contents of the Plan as it did on the process. The latter was more of an

exercise in the promotion of participation than it was in the technical and scientific aspects of fisheries management planning (McConney and Mahon 1998). However, in implementing the 1997-2000 FMP, the government of Barbados has encouraged a co-management approach to fisheries governance. The government assisted in establishing and strengthening fisherfolk organisations through a two-year Fisherfolk Organisation Development Project (FODP) reported on in McConney et al. (1998). The project was moderately successful in terms of creating or facilitating conditions that favour co-management (McConney in press). Several examples of attempted co-management exist in the Caribbean Community (Brown and Pomeroy 1999), and this form of partnership is seen as one of the more positive options for reforming fisheries governance in the region (Chakalall et al. 1998).

Although fisherfolk organisations have been formed through the FODP, several of them are still weak. One of the most significant problems has been that many of the organisations lack effective leadership to interest and sustain the involvement of members (McConney et al. 1998). The government's intention for the planning the new 2001 - 2003 Fisheries Management Plan is to involve fisherfolk organisations more in the process. This may help to strengthen both fisheries management planning and fisherfolk organisations in Barbados through information exchange and the demonstration of important roles that the industry organisations can play. An important aspect of developing the 2001 - 2003 FMP will be encouraging co-management and stakeholder participation that will strive towards a bottom-up, as opposed to the more conventional top-down, approach to planning.

There will be questions as to whether top-down consultation, or the encouragement of bottom-up participation, is more appropriate in Barbados at this time due to the present lack of awareness about fisheries management and the emergent development stage of the fisherfolk organisations. Indeed the role of government in the process of engineering co-management can also be brought under scrutiny (Pomeroy and Berkes 1997, Jentoft et al. 1998). However, it is generally thought that social partnerships will continue to play a key role in fisheries management planning in Barbados and throughout the eastern Caribbean, and therefore should be encouraged (Chakalall et al. 1998).

This paper looks at how the fisheries management planning process began for the formulation of the 2001 - 2003 FMP, with emphasis on the process used to involve fisherfolk, especially those associated with fishing industry organisations. It looks at the initial inputs and outputs related to this participatory event as a result of fieldwork. It is a work in progress that is being reported upon here as part of a graduate student research project. Early in 2001, the new plan is expected to be approved by the fisheries Minister prior to implementation, as required by law, following several other steps in the process.

PARTICIPATORY PLANNING PROCESS

The Barbados National Union of Fisherfolk Organisations (BARNUFO) is a secondary, or umbrella, fisherfolk organisation formed through the FODP. Its members are the primary fisherfolk organisations scattered around the coast. With the exception of a single fishing cooperative, these groups are associations bound by an internal constitution, but not any national legal framework. Their development process and structure is examined in McConney et al. (1998).

BARNUFO recognised the growing need for community based co-management approaches to fisheries governance in the Caribbean and its potential role in the formulation and implementation of the 2001 - 2003 FMP. Its constituent organisations and Board of Directors widely accepted that fisherfolk must play an integral role in the effective and efficient management of fisheries resources throughout the Caribbean. Consequently, they saw stakeholder participation as a prerequisite for providing an equitable mechanism for establishing strong fisheries management processes and plans throughout the region.

Consistent with this guiding philosophy, BARNUFO applied to the International Development Research Centre (IDRC) of Canada for research funding under its recently initiated Community Based Coastal Resources Management Project (Caribbean). The overall objective of the BARNUFO proposal was to undertake applied research and participatory activities to provide primary and secondary fisherfolk organisations in Barbados with the much needed capacity to meaningfully contribute towards the successful implementation of the 2001 - 2003 FMP, starting with formulation in a bottom-up planning process. BARNUFO's proposed project sought through its member organisations to formulate the fishing industry's perspective on issues for the formulation of the new FMP for 2001 - 2003, by funding research on fisheries issues to be conducted by and for the fisherfolk. The aim was also to facilitate capacity building in the fisherfolk organisations over an eighteen month period, set out in three phases: Pre-plan, Planning and Post plan, through the actual practice and experience of participatory planning. To achieve this the project was designed to comprise the following activities:

i) Community FMP consultations
ii) National FMP consultation
iii) Training in research methods
iv) Participatory research projects
v) Reports and recommendations
vi) Evaluation of the FMP process
vii) Fisheries study tour (optional)

This paper focuses only on the community FMP consultations, the first set of activities.

The project was approved by IDRC and launched on 12 January 2000 at a BARNUFO Board of Directors' meeting by Ms Angela Watson, President. The BARNUFO project and the parallel year long Fisheries Division review of the existing 1997 - 2000 FMP with formulation of the 2001 - 2003 FMP, termed "FMP 2000" by the government of Barbados, were strategically scheduled to coincide.

This was to allow greater interaction between the two management-planning processes. The fisheries Minister launched FMP 2000 at the same BARNUFO meeting in a show of support for the simultaneous grassroots process. Figure 1 compares the processes for the two management plans, noting the intention for the present process to be driven by the fishing industry through the BARNUFO intervention. A fuller analysis of the 1997-2000 FMP process is in McConney and Mahon (1998).

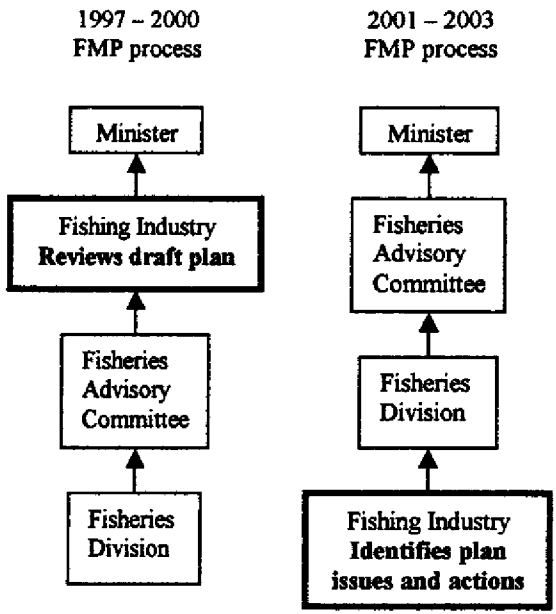


Figure 1. Comparison of past and present FMP processes

After launching the project, BARNUFO formed a sub-committee of three fisherfolk (a young fisherman, a boat owner/former fish processor and a boat owner/part-time fisherman) to work with a technical coordinator/advisor (the Chief Fisheries Officer) on project implementation. This sub-committee was intended to oversee all aspects of the project and to report to the monthly meeting of the BARNUFO Board of Directors. However, due mainly to logistic and communication problems this group did not function as intended. The President subsequently took on its role partly by co-opting available members of constituent fisherfolk organisations for various tasks, but primarily by doing most of the work herself. Although the Board of Directors, comprising primary organisation representatives, was kept informed, the President exercised considerable freedom in

making decisions in consultation with the adviser. The organisations participated little in decision-making although requested to do so by the President on occasion.

The FMP "community consultations", as they were called, began on 23 July 2000 at Oistins, home of one of the more active and proactive fisherfolk associations. The community consultations were held at primary, secondary, and tertiary fish landing sites in Barbados, bringing the meetings to the fisherfolk on their turf and under their terms. Preparation for the twice-weekly consultations consisted of preparing promotional flyers for the particular location, and then distributing them to fisherfolk at the location and surrounding landing sites.

The one-page meeting flyers were designed to attract the attention and participation of fisherfolk at each site by highlighting important issues specific to fisheries management and development at each location. For example, some flyers focussed on the inshore fisheries where these were most important, and others on the offshore fisheries, links with tourism, physical infrastructure, or other matters as necessary. Attempts were made to have fisherfolk organisations host or promote the consultations when held in their locations, but only a few responded with action. In several cases fisheries officers distributed the meeting flyers on behalf of BARNUFO in the absence of fisherfolk organisation members identified for the task. BARNUFO's President also communicated with key community contacts to spread the word about the consultations prior to each event.

A similar sequence of steps was followed at each consultation as shown in Figure 2. On arrival at the consultation location, often a fish market, shady tree or neighbourhood shop, a flipchart was set up after encouraging people to gather closely around the preferred spot. The Chief Fisheries Officer and President of BARNUFO gave an overview of the past and present FMP processes, highlighting the role of BARNUFO and the fisherfolk generally in this bottom-up exercise. BARNUFO's President then usually chaired the community consultation, with help if necessary from the technical coordinator/advisor. Refreshments were served halfway or later during the process to keep the discussion going and extend the informality.

At each community consultation participants were encouraged to share any pressing issues that they had pertaining to the fishing industry in general, a specific fishery, or a particular fish landing site. A graduate student recorded on the flipchart each issue as it was presented, and participants were then encouraged to analyse how these issues of concern could be reasonably addressed and by whom. The responses were recorded next to the issues as the recommended actions in an adjacent column. Sometimes there was more than one action per issue, and sometimes there were several alternative actions if the participants did not reach consensus on their preferred response. Late arriving participants checked the flipchart to see what had gone before, and sometimes the recorded issues or actions were returned to for further elaboration or clarification.

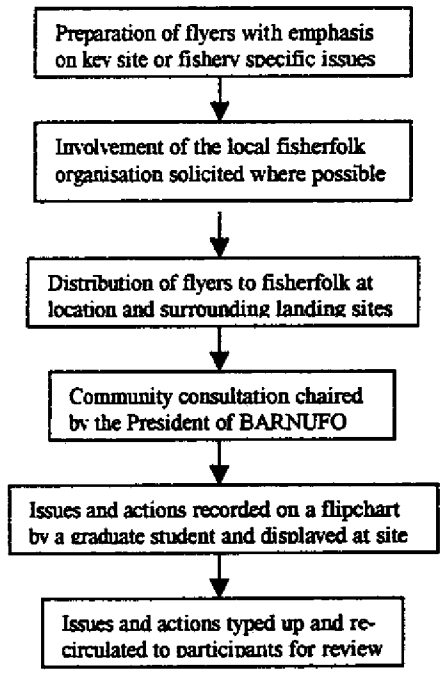


Figure 2. Typical community consultation activity sequence

Consultations lasted from one to nearly three hours in the afternoon going on to evening. They were informal with on-site media coverage only on one occasion. The majority of those who attended the community consultations were older males who had participated in the fishing industry for many years. There was also fairly good representation of younger male fishermen or boat owners, and some older women fisherfolk who were mainly fish vendors. Young women were generally scarce, except at Bridgetown where they comprised a substantial portion of the postharvest workers (e.g. fish cleaners and vendors). Although fisherfolk were notified well in advance of community consultations, there were still some who chose not to participate even when on site and encouraged to do so by the organisers or their peers. In most cases, however, consultations were greeted with enthusiasm from the fisherfolk and there were usually more than ten active participants at each location. Fifteen community consultations of this type were undertaken, with even geographical distribution around the coast.

In conclusion, the fisherfolk participants were notified that their contributions would be circulated back to them for review and further community discussion. They were also told that what was recorded should find its way into the 2001 - 2003 FMP if even as an appendix of public participation. Finally, they were reminded that not all matters could be dealt with in the FMP, but that BARNUFO would assist in ensuring that those of major importance to the fishing industry would receive priority attention.

ISSUES AND ACTIONS IDENTIFIED

The following tables present examples of the array of issues and actions that were frequently mentioned at the community consultations. They reflect only the views of those who participated in this stage of the 2001 - 2003 FMP planning process undertaken through the BARNUFO project. The issues and actions varied slightly at each community consultation due to differences in the location, history, and character of each fish landing site, and as a result of the different occupations of the fisherfolk who participated in the planning process. However, some points were raised at almost every session. Most issues tended to be immediate rather than future-oriented, and actions usually entailed government intervention. Quantitative analyses of the issues and actions by site, subject and other criteria are yet to be done.

Table 1 lists a few of the issues and actions that concern mainly the harvest sector. As much attention was paid to development and profitability issues as to matters of fisheries resource management. The latter mainly concerned inshore fisheries already known to be under threat due to habitat degradation, overfishing, or combinations of these and other factors. There was relatively little concern over the status of shared stocks of migratory pelagics.

Table 1. Some harvest sector issues and actions

Harvest sector issues	Harvest sector actions
Small mesh in traps	Increase for deep traps
Small seine net mesh	Regulate minimum size
Sea urchin overharvest	Extend closed season
Inadequate boatyards	Allocate coastal areas
Too few boatbuilders	Youth training needed
Inadequate ice supply	More, bigger ice machines
Government too slow	Simplify paperwork
Fishery inputs costly	Increase subsidies

The situation with postharvest sector issues and actions reflected a narrower range of topics, emphasising quality-related matters and physical infrastructure for fish processing, storage and sale (Table 2). While workers in postharvest occupations seldom raised harvest sector issues, fishermen and boat owners had much to say about postharvest.

Table 2. Some postharvest sector issues and actions

Postharvest sector issues	Postharvest sector actions
Need quality assurance	Put HACCP in new law
Improve public markets	User group committees
Ex-vessel prices too low	Guaranteed min. price
Fish prices too variable	Increase storage space
Imports too competitive	Restrict fish importation
Fishers are price-takers	Government protection
Poor fish handling	Code of practice, train
Consumers not buying	Customer relations

In general, participants did not demonstrate familiarity with regional and international fisheries problems. Also, participants made points that reflected poor awareness of the Barbados government's policies on international and regional trade, subsidies, and price control, among others. Information that was available from the Fisheries Division was not reaching these clients, even in cases where that information had been provided to representatives of the fisherfolk organisation serving the area. An overarching issue raised was that there should be better interaction and feedback between the Fisheries Division staff and fisherfolk as follow-up after important meetings have been held.

The final 2001 - 2003 FMP BARNUFO consultation will be a national event opened up to a wider selection of fishing industry stakeholders such as tourism and watersport interests, government agencies, environmental non-governmental agencies and others. This will be a one-day event where the diverse stakeholders will discuss issues and actions from the community consultations amongst their peers and other interested parties. Co-management approaches is the theme of the consultation. It will provide an opportunity for all of the stakeholders to share their concerns and recommendations with each other and the relevant authorities. This will further encourage bottom-up, as opposed to top-down, approaches to fisheries management planning in Barbados. The other project activities are still to be undertaken.

DISCUSSION

During the previous FMP planning process for formulating the 1997 - 2000 Fisheries Management Plan, the Barbados Fisheries Division and the Fisheries Advisory Committee determined the plan addresses more than just the fishing industry. The Fisheries Advisory Committee was relegated to the role of reviewing a prepared document that would integrate the industry's concerns regarding the agenda and prioritization of issues.

This differs from the current FMP planning process whereby all members of the fishing community were given an opportunity to attend and participate in the scheduled events designed to make their input, through oral communication, the point of departure for the 2001 - 2003 FMP. Community consultations in the present FMP planning process emphasize fisherfolk as vital in developing the new

plan. Paying greater attention to the opinions' of fisherfolk may further encourage their integration into fisheries management decision-making.

The simple methodology of the BARNUFO "community consultations" successfully brought the planning process to fisherfolk on their own terms and in their own territory. Logistics were simple, and fisherfolk did not have to make much effort to attend. Visibly recording each issue and action raised was well received by consultation participants who were reassured that their concerns would not be overlooked during this exercise, but would provide inputs towards developing the new Fisheries Management Plan. Circulating the issues and actions back to them reinforced the concept. However, perhaps the Fisheries Division became too associated with the project by being very visible and perhaps making it difficult for participants to distinguish between a government process and the fisherfolk organisations' initiative.

However, few fisherfolk organisations were effective in promoting the participation of their members. The project has confirmed that effective participation in fisheries management and planning demands additional capacity building in fisherfolk organisations. Fishing industry organisations' role in the 2001 - 2003 FMP planning process was largely confined to BARNUFO, as many organisations still remain ineffectual, mainly because of weak leadership, poor communication, internal disputes, or inactive members. The fact that BARNUFO's President chaired the community consultations may help to encourage fisherfolk leaders to either re-activate their organisations or to develop new effective fisherfolk organisations through liaising with BARNUFO. The involvement of more active fisherfolk organisations in future FMP planning processes might inevitably become a key element of fisheries management planning in Barbados. However, some informational issues have to be addressed first.

Although fisherfolk welcomed consultation they lacked basic information, especially on policy-related matters. Yet fisherfolk are aware of problems facing their industry and have thought about solutions, even though most participants saw solutions by government rather than through their own collective action and organisational initiative. Many of the proposed protective government interventions were contrary to national policy on trade, subsidies, price control, etc.. This tends to confirm the observations by fisherfolk that communication problems exist among themselves, and between them and government. Information inadequacies constrain bottom-up approaches, but top-down approaches are not likely to be considered legitimate planning processes given the interest of fisherfolk in actively participating in decision-making.

The issues and actions raised during the community consultations are an important part of developing fisheries' human resources. They help to generate discussion between stakeholders that should strengthen the industry's role in management and facilitate sustainable fisheries in Barbados and throughout the Caribbean. They also help to bring the concerns of fisherfolk to the attention of the public and so uplift the image of fisherfolk by eradicating the stereotype of them as uninterested in managing their own affairs. The consultation outputs show that

fisherfolk have good interpretative and analytical skills, and they are capable of coherently discussing the problems facing the fishing industry and the management of fisheries resources, despite their lack of some information. In many instances, their wealth of first-hand practical ecological knowledge compensates for second-hand scientific knowledge, and it is only in the realm of policy that the information deficiency is particularly evident.

Furthermore, some of the issues raised by fisherfolk were controversial. Had recommendations such as mandatory national insurance contributions for fishermen, fish vendors having to pay their own light and water bills at public markets, and blood tests for fish handlers as a health requirement, been raised by non-fisherfolk the objections would have been severe. Fisherfolk also have many concerns which pertain more to management of fish landing sites than fisheries. These are relevant in the context of improving working conditions. They remind us that the fish resource is only one aspect of fisheries operations and that other factors may be equally relevant to quality of life. Addressing the problems at fish landing sites may encourage fisherfolk to take an active interest in other aspects of the management and development of the fishing industry and fisherfolk organisations. There was talk of fish market user group committees being formed and affiliated with fisherfolk organisations.

The new Fisheries Management Plan, if it is a true reflection of fisherfolk participation and input during this round of community consultations, should give fisherfolk a greater sense of achievement and satisfaction than the 1997 - 2000 FMP process. The process of bottom-up participation of fisherfolk in formulating the 2001 - 2003 FMP can, however, only be considered successful at a later stage when the plan is complete and being implemented. Getting the input of fisherfolk during planning may, or may not, encourage their integration into later fisheries management plan decision-making. While improved participation in planning and management may be feasible, most fisherfolk organisations are far from becoming partners with government in co-management at this time. Further developmental work is clearly warranted, particularly in capacity-building.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Brown, D.N. and R.S. Pomeroy. 1999. Co-management of Caribbean Community (CARICOM) Fisheries. *Marine Policy* **23**:549-590.

Chakalall, B., R. Mahon, and P. McConney. 1998. Current issues in fisheries governance in the Caribbean Community (CARICOM). *Marine Policy* **22**:29-44.

Fisheries Division. 1997. *Barbados Fisheries Management Plan*. Ministry of Agriculture and Rural Development, Government of Barbados. 68 pp.

Jentoft, S., B.J. McCay and D.C. Wilson. 1998. Social Theories and Co-management. *Marine Policy* **22** (4-5):423-436.

McConney, P.A. 1997. Social strategies for coping with uncertainty in the Barbados small-scale pelagic fishery. *Proceedings of the Gulf and Caribbean Fisheries Institute* **49**:99-113.

McConney, P.A. 2001. Organising fisherfolk in Barbados without completing a clean round. *Proceedings of the Gulf and Caribbean Fisheries Institute* **52**:290-299.

McConney, P.A., A. Atapattu and D. Leslie. 1998. Organising fisherfolk in Barbados. *Proceedings of the Gulf and Caribbean Fisheries Institute* **51**:299-308.

McConney, P.A. and R. Mahon. 1998. Introducing fishery management planning to Barbados. *Ocean and Coastal Management* **39**:189-195

Pomeroy, R. S. and F. Berkes. 1997. Two to tango: the role of government in fisheries co-management. *Marine Policy* **21**:465-480.

Understanding the Impacts of the Florida Net Ban (Article X, Section 16 of the State Constitution)

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ABSTRACT

This research examines the effects of Article X, Section 16 of the Florida State Constitution, which restricted the types and sizes of fishing nets that can be used in state waters. The methodology for the analysis relies on social impact assessment (SIA) and analytic inductive logic (Taylor et al. 1995).

The effects of the net ban amendment are assessed in terms of stakeholder groups. Groups are identified through a comprehensive review of the literature pertaining to fisheries management in Florida in the context of the events leading to the net ban amendment being voted upon in a general election in November 1994. Stakeholder groups include the biophysical environment (fish populations) and the commercial and recreational fishing industries.

Fishery resources are examined through data available from the National Marine Fisheries Service (NMFS). When coupled with anecdotal evidence, and the use of inductive logic, conclusions are reached about the effects of the net ban on the restoration of selected fish species.

The net ban amendment affected certain commercial fishers who depended on nets for their livelihood. Because small-scale commercial fishers are involved, the effect on commercial fishing families is assessed and reported. The dissatisfaction of these commercial fishers, manifested in protests and illegal activities, are also examined.

Recreational anglers view the net ban as a change in fisheries management practices in the state of Florida. The recreational angling literature regards the net ban as a success for conservation practices in the state. To examine the effects on recreational anglers, the conclusions reached about fishery resources are related to angling satisfaction, a necessary component of the recreational angling experience.

KEY WORDS: Recreational fisheries, commercial fisheries, net ban, Florida

INTRODUCTION

In 1994 the voters of Florida made one of the most controversial fisheries management decisions in state history. After much debate between commercial and recreational fishing interests over reasons and remedies for declining fish populations, a constitutional referendum, Article X, Section 16 of the State Constitution, was passed and implemented, placing new restrictions on the types of

nets that can be used in state waters. The rationale was that fish stocks would be significantly improved by this action.

The purpose of this research is to determine the impacts of the net ban policy. The methodology will rely on social impact assessment (SIA). SIA is defined as "a method of projecting social consequences of human actions that alter the environment" (Bryan 1996, p. 145). It is a tool for decision makers, not only to understand the social environment in which they make decisions, but also to use the information gathered in the SIA process "to optimize decisions having environmental consequences" (Bryan 1996, p. 145). Using the methodology established by Wolf (1983), and further revised by Taylor, Bryan and Goodrich (1995), the research identified the major stakeholders in the Florida fishing industry and examined the ways in which these stakeholders were involved in the net ban issue and affected by subsequent policy.

A description of the types of nets the amendment restricted is useful at this point. According to the amendment, a " 'gill net' means one or more walls of netting which captures saltwater finfish by ensnaring or entangling them in the meshes of the net by the gills," and an " 'entangling net' means a drift net, trammel net, stab net, or any other net which captures saltwater finfish, shellfish, or other marine animals by causing all or part of heads, fins, legs, or other body parts to become entangled or ensnared in the meshes of the net . . ." (Florida State Constitution, Article X, Sect. 16). The nets mentioned in the amendment are unselective in the types of fish that they catch: this was a major argument of the net ban proponents. The bycatch associated with these nets can be large and often dies in the net before it can be released alive.

A historical look at fisheries management in Florida is useful for understanding the issues that led to the net ban amendment. Prior to what can be called the modern era (post-1983) in fisheries management, authority resided first with state tax assessors who also served as fish commissioners. In 1980, a Saltwater Fisheries Study and Advisory Council was established which recommended that the legislature create the Marine Fisheries Commission (MFC). The MFC began operations in 1983. As Marston and Nelson (1994) point out, "the creation of the MFC was driven largely by vocal criticism from Florida's recreational fishing community over the lack of adequate management action on the part of the former Department of Natural Resources . . ." (p. 8). Another important aspect about the history of management in Florida, noted by Grimes (1996), is that, "Each time the Florida Legislature has created or reorganized the administrative structure, ultimate authority and accountability has resided with the Governor and Cabinet. Thus, the ultimate decision is made by a political office, rather than independent rulemaking [sic] within the administrative structure" (p. 32). The highly effective lobbying by the commercial fishing industry ultimately led to the net ban.

Beginning in the late 1980s, the MFC began to try to implement new management regimes for striped mullet (*Mugil cephalus*). Mullet, which is the major component of the inshore netting industry, is also important to anglers because of its importance as a food source to more sought after game fish. In June

1990, the MFC reviewed the effects of the new regulations. They had not achieved their goal of a twenty-percent reduction in effort or mortality. According to Marston and Nelson (1994), the following roe season actually saw a twelve percent increase in effort and a nine percent increase in mortality. The rules were "tweaked", but still remained ineffective.

In January 1991, the Florida Marine Research Institute (FMRI) delivered the first preliminary stock assessment of mullet populations. They indicated mullet stocks were in worse condition than previously thought. Several management alternatives were proposed, each dealing with extending the closure of the fishery for a number of days during the annual roe harvest. All efforts met with significant opposition by the commercial fishing industry and were successfully stalled in the legislature.

In October 1992, the official drive to implement the net ban began. Because of the apparent ineffectiveness of the MFC, the recreational industry began a petition drive that, with enough signatures, would allow the voters in Florida to decide if they wanted to restrict commercial netting practices within state waters. Launching a statewide media campaign, the Florida Conservation Association (FCA) and the *Florida Sportsman* magazine were successful in getting enough signatures to put the net ban initiative on the ballot in November 1994.

Ultimately the amendment passed by an overwhelming majority, 2,876,091 to 1,135,110, and went into effect on July 1, 1995. During 1995, after passing of the amendment but prior to its implementation, a number of questions were raised pertaining to how the affected fishers would cope with the loss of their livelihood.

METHODS

The following section includes discussion of the major components of SIA as they pertain to the current research. Taylor et al. (1995) recognize the following steps in the assessment process: scoping and profiling; formulation of alternatives; projection and estimation of effects; monitoring, mitigation, management and evaluation. Scoping and profiling will be the only two components detailed here, as they were an integral part of this research. For a detailed description of the methodology, see Anderson (1999).

In the origins of the SIA process, the scoping component is when stakeholders and their relative positions are recognized. Closely linked to scoping is profiling, which consists of creating the database of the key social variables found in the scoping exercise so that a social description of the community can be created. At this stage it is important to recognize all key stakeholders and their positions with regard to issues (Taylor et al. 1995). Scoping and profiling were performed by reviewing various forms of data concerning the state of Florida and particularly the state's fishing industry. The review of the scientific and popular literature provided coverage of the historical description of fishery management practices in Florida. It also provided an adequate social profile of both the commercial and recreational fishing industries and the people associated with these industries.

Analytic induction was used to formulate a consistent interpretation from a wide variety of data sources. Though these data sources are both qualitative and quantitative in nature, the inductive process allows for the interpretation of the data in a way that other methods could not. Thus, conclusions reached were consistent with all of the data used, and are considered reliable because of the power of the analytic inductive methodology.

This research is based largely on secondary sources, due to the constraints of time and money. However, this is not unusual for assessment research — for the same reasons, but also because the analytic inductive approach allows for the accommodation of a variety of data. For this research, magazine articles, newspaper clippings, scientific reports and other media were used as effective qualitative data. Also included are survey results from the National Marine Fisheries Service (NMFS), and the Florida Sea Grant College Program. These provide useful quantitative data that assist in the interpretation of qualitative data.

RESULTS

Stakeholder Identification

The biophysical environment is a particularly critical dimension in the analysis. It obviously cannot "speak for itself," yet it is the yardstick with which the success or failure of the net ban is judged. The net ban variable, its effects, and the perception of its effects are obviously linked to stakeholder outcomes.

Only those species that were popular targets for netters are identified. As previously mentioned, mullet is the most important species they targeted. Mullet is usually considered a low-end seafood product. However, with the opening up of the Asian roe market, the price of mullet skyrocketed, providing the incentive for a greater harvest.

Spanish mackerel (*Scomberomorus maculatus*), spotted seatrout (*Cynoscion nebulosus*) and king mackerel (*Scomberomorus cavalla*) are species that were targeted by commercial netting operations and also have a recreational fishing value. Red drum (*Sciaenops ocellatus*) were not directly affected by the net ban since this fishery was closed to commercial harvest in the 1980s. However, a historical look at the fishery can be useful for understanding the probable track of other fisheries affected by the ban.

Before the passage of the net ban amendment, approximately 7,500 people held commercial fishing licenses in Florida. The entire industry generated $1.2 billion, and employed between 12,000 and 15,000 people. Of these, around 1,000 people depended on gill nets for most of their income (Long 1994). Taking into account the number of commercial boat licenses (33,783) and the estimated number of boats affected by the amendment (2,225), it is possible to speculate on where these boats fished in relation to state waters. The gill net boats were not equipped to fish in deep water, so these boats probably concentrated their fishing effort within three miles of the Florida coast. The remaining boats, approximately 1,225, probably

fished anywhere from one to three miles on the Atlantic coast, and one to nine miles on the Gulf coast, depending on the type of nets they used.

Smith (1994) provides an effective typology of nearshore commercial fishers. The average fisher in the study had been involved with commercial fishing for twenty-two years, and the income derived from fishing operations accounted for seventy three percent of household income. The average fisher "derived great satisfaction from being on the water, doing physical work, being independent, and providing food for consumers" (Smith 1994). It is also important to realize that netting operations are often not an individual activity. The family is involved in the operation, with the husband and older sons being responsible for the "on the water" activities and the wives and daughters responsible for the bookkeeping and support activities (supplying ice and meals, repairing nets). The wives also provide emotional support to the family in this work intensive enterprise (Smith 1994).

The absence of gill nets also affects other industries related to commercial fishing, aside from individual family fishing operations. These include: gasoline, diesel and oil suppliers, ice, bait, and fishing gear suppliers (such as nets, rain coats, boots, gloves, groceries, boats, engines and electronic equipment), and services associated with docking, registration, and licenses. Also included in this category are the fish processing plants, warehouses, and distributors associated with the commercial fishing industry. These "flow-on" effects, when looked at cumulatively, are likely to be substantial. However, this analysis focuses only on first-order effects (e.g., those who are most directly affected by the net ban).

Recreational anglers are broken into two categories: residents and tourists. Resident anglers are mostly male, white, and married and prefer to spend their leisure time outdoors. About half of the resident anglers have lived in Florida for twenty years or more and most have children in the household. The majority had a higher than average education, with most having household incomes above $25,000. Benefits that recreational anglers expect from their time fishing include enjoying nature, relaxing, and the enjoyment of a challenge (Milon and Thunberg 1993). There are an estimated 2.3 million resident anglers in the state and they account for 20 million angler days. There are around three million tourist anglers per year, which account for 11.9 million angler days. In 1991, tourists were estimated to have spent $1.3 billion and supported 23,518 jobs in the retail and service sectors. Resident anglers were also estimated as having a total economic output in the state of $949.1 million in the same year (Florida Sea Grant 1993).

Trends in Catch Statistics

The net ban amendment directed the removal of all entanglement nets and other nets greater than five hundred square feet in state waters. The purpose of removing these nets was to protect the nearshore fisheries found in Florida state waters. Thus, an indicator of the biological success of the net ban for the years following the net ban can be determined by examining fishery resources data. Although the lack of baseline fisheries independent data was particularly troublesome, the SIA

methodology allows for other types of data to be used to gauge the reaction of fishery resources.

All catch data were obtained from the NMFS website. For the recreational data, the option "Florida" was used, the species was selected, and the option "All Modes Combined" and "State Waters" were chosen. Finally, the numbers represent total catch, which includes fish that were brought to the dock in a recognizable form (identification by scientists), fish that were filleted or released dead (identification by individual anglers), and fish that were released alive (identification by individual anglers). For the commercial statistics, "annual landings" was chosen, the species was selected and the option "Florida, State Total" was used.

Spotted seatrout are considered to be one of the more sought after gamefish found in Florida's state waters. The effect of the net ban amendment on seatrout is touted as a success in the recreational angling literature. *Florida Sportsman* ran articles in which they report that trout populations are on the increase, all due to the net ban (Farren 1998, *Florida Sportsman* 1998). The recreational catch of the species is presented in Figure1A (NMFS, pers. comm.).

An analysis of this data reveals that the recreational catch is somewhat static in nature. Excluding peaks in 1984, 1986, 1989 and 1991, and troughs in 1981, 1982 and 1985, the total catch has been hovering just under 10,000,000 fish. For the year of 1997, there is a preliminary trend of an increase in the recreational catch above the mean for the years 1981 - 1997.

A word of caution is necessary when interpreting the data. The total recreational catch for all species depends on much more than the presence of more fish in the water. Recreational catch rules and regulations (bag limits, size limits), as well as fishing effort in any given year will influence the number of fish in total catch statistics. Participation can be influenced by a variety of factors, including tourist visitation. Tourist visitation can be influenced by adverse weather in any given year (hurricanes), bad publicity for the state (murders at rest areas), and the price of traveling to the state. Nevertheless, the data are the best available to gauge the reaction of fish populations to the net ban policy. Data also exist for the commercial catch of spotted seatrout, also presented in Figure 1A. These data reveal a peak in 1982 followed by a downward trend throughout the late 1980s and early 1990s. As expected, when any cause of fish mortality is removed or restricted, the two years following the net ban show a sharp drop in commercial catch. Again, caution is advised when interpreting the data since commercial catch is influenced by the same factors that affect the recreational catch (rules and regulations, effort).

The recreational catch data for spanish mackerel are presented in Figure 1B. The data for 1986, although high, were double-checked by the scientists at NMFS, and are an accurate estimate. Reasons given for the peak in the data are that the spanish mackerel fishery is considered a "pulse" fishery, which means that peaks in the data are considered normal (NMFS personal comm.). The commercial catch data follows (See Figure 1B). There are two years in which the recreational catch slumped (1984 and 1985), and two peaks in 1986 and 1992. From the peak in 1992, recreational catch exhibits a declining trend until 1995 (the year of net ban

implementation). The following two years (1996 and 1997) reveal a slight positive trend over 1995, but remain below 1990 - 1994 levels.

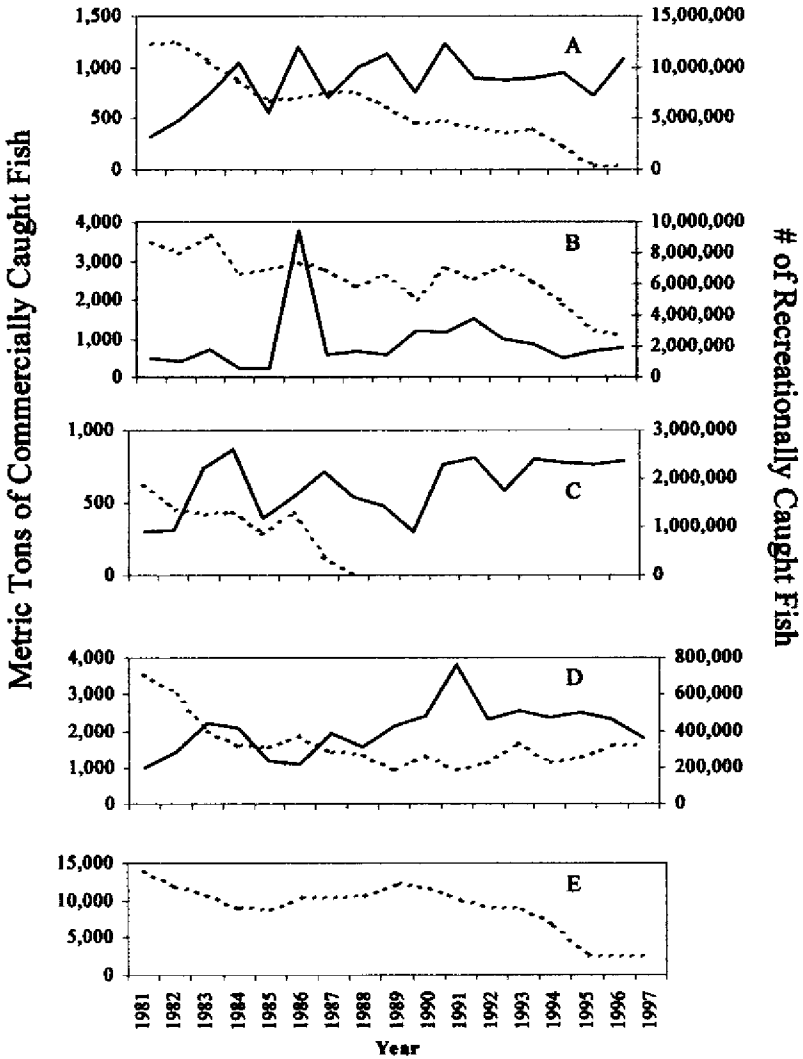


Figure 1 Trends in Catch Statistics for Selected Species—A) Spotted Seatrout, B) Spanish Mackerel, C) Red Drum, D) King Mackerel, E) Striped Mullet. The solid line represents recreational catch and the dashed line commercial catch.

Like the commercial catch of spotted seatrout, the commercial catch of spanish mackerel peaked in the early 1980s. From this point onward, the fishery exhibits a downward trend, excluding small increases in 1985, 1986, 1989, 1991 and 1993. However, these increases never reached the historical highs exhibited in the early 1980s. The years following the net ban show a substantial drop in catch from 1995 to 1996, with the trend continuing into 1997.

Red drum was not directly affected by the net ban since the fishery was closed to commercial harvest in the 1980s. The data for the recreational catch of this species are presented in Figure 1C. There is a peak in recreational catch in 1984 and several troughs (1981, 1982, and 1990) in the data. Other years they have been maintaining themselves just above the 2,000,000 level. There is a slight increase in recreational catch for the years following the net ban implementation; however, it is not as pronounced as the trend in the recreational catch of spotted seatrout. The commercial catch for the species exist for the same years until 1988, when the commercial catch was closed. The commercial catch was declining in the years leading up to the closure of the commercial fishery in 1988. There is one upward trend from 1985 to 1986, possibly a result of the expected closure of the fishery or a result of 1995 being an "off" year for this particular fishery.

Recreational and commercial catch rates for king mackerel are shown in Figure 1D. An analysis of these data reveals that, excluding one peak in 1991, the recreational catch has been static. There are downward trends from 1984 to 1987, followed by a positive trend leading to the peak in 1991. From 1991 on, the trend is negative, culminating in a trough for the last year (1997). Figure 1D also reveals two definitive dips in the commercial catch in 1989 and 1991. The trough in 1989 was preceded by a downward trend in catch, and the dip in 1991 is followed by an increase through 1997, excluding one minor dip in 1994. The two years shown for after the net ban maintain this increase in commercial catch. Reasons for this may be that this is the only species of fish where fishery resources are outside of the demarcation line established by the net ban. This is supported in the popular literature. The April 1999 issue of *Florida Sportsman* has an article in which they highlight this in the area around Key West (Conner 1999).

Recreational catch rates for mullet do not exist since this fishery is not a recreational fishery. Only commercial catch statistics exist for this fishery (See Figure 1E). The commercial catch of striped mullet has been declining in the years shown in Figure 1E. There is one positive trend from 1986 to 1989, possibly relating to the demand in the roe market. From 1989 onward, the trend is negative, culminating in a sharp decrease in 1995. This decrease in 1995 can be related to the net ban in that the roe season occurs in the fall, which is after the date of net ban implementation (July 1, 1995). The following two years do show a slight increase; however, the commercial catch in 1997 does not come close to the numbers for the years prior to net ban implementation.

Impacts to Commercial Fishing

As one would expect, the inshore gill netting industry was severely affected by the net ban amendment. Since this industry is considered to be a family enterprise, we must examine the effects the net ban had on fishing families involved with the industry. Smith et al. (1999) conducted an investigation to examine these effects and how the net ban has affected family life for this stakeholder group. Their research concentrated on a sample of fishing families identified prior to the net ban; they were studied to examine the ways fishing families were preparing to cope with the net ban. They concluded fishing families were coping with the net ban in several different ways. Women, who are primarily responsible for the day-to-day activities of the household, were still working outside of the home to supplement household income. Men were also looking outside of the fishing industry to maintain their status as "breadwinners." Men were also spending less time with on-the-water activities, as well as changing their perceptions about the future of commercial fishing. The research shows that men would be less likely to choose fishing as an occupation if they had to do it again, considered changing occupations more often than prior to the net ban, and expressed a decrease in their desire to stay in fishing as an occupation. Stress indicators taken before and after the net ban went into effect show that married couples had a higher incidence of emotional problems, used drugs or alcohol more frequently, and had increased sexual problems after the net ban went into effect. One of the most noteworthy results of the research is that divorce rates for this stakeholder group were four times higher than the state average.

Dissatisfaction among inshore gill-netters manifested itself in different ways. After the net ban amendment passed, a number of challenges were brought before the courts to question the legality of the constitutional amendment. One court case, ruled upon in May of 1995, questioned the wording of the amendment and the definitions found therein. Specifically, the plaintiffs wanted a ruling on the definition of trawl nets and how the square footage of a trawl net is interpreted. The stimulus for this case was the construction of a trawl net, termed the "Golden Crum" net, which according to the plaintiffs was constructed to meet the new regulations of the net ban amendment. The defendants in the case argued that the area of the trawl should be measured by using the formula to calculate the area of a cone with the mesh of net in the closed, or stretched, position. The plaintiffs argued that the amendment is not clear on the requirement of the mesh being in the closed position, which greatly increases the mesh area of any net. The judge in the case ruled in favor of the plaintiffs, and deemed the "Golden Crum" net to be legal under the net ban amendment (Millender, Crum & McClain v. State of Florida 1995).

In a separate case, the commercial fishing industry questioned the interpretation of the three-mile demarcation line used in the net ban amendment. The MFC maintained that three miles referred to three nautical miles, however a judge in Wakulla County ruled that the wording of the amendment was vague and that three miles refers to three statute miles, thus shortening the extent of waters affected by the net ban (Cotterell 1996). The ruling only affected the waters of Wakulla County. It was also in 1996 that several commercial fishers started experimenting with other

types of material to replace the nets outlawed by the net ban. The most controversial of these new nets is one fashioned out of tarpaulins that replaces the monofilament line used to make entanglement nets. The battle over the legality of this type of net lasted several months and resulted in seven companies being given permission to use the tarp nets as an experiment to continue harvesting baitfish off of the Panhandle.

Not only did the commercial fishing industry challenge the net ban amendment through legal means, illegal activities were also used to protest the amendment. As early as July 2, 1995, one day after the net ban amendment went into effect, a recreational fishing tournament was targeted in Fort Pierce. Hundreds of two-inch roofing nails were placed on the boat ramp at the marina where the tournament was being held. Other protests on this first day of the net ban implementation included another boat ramp being littered with nails, illegal nets being found strung between two channel markers, several pleasure boats being spray painted, and dead fish being left at the entrance to a tackle shop (Cocking 1995). Two incidents in 1998 are similar to these early protests. The Coastal Conservation Association of Florida (CCAF, formerly the FCA) reported that poachers left the filleted remains of snook carcasses in the road on Pine Island on two separate occasions within a period of two weeks (CCAF 1998). Ted Forsgren, Executive Director of CCAF, commented that the Pine Island area continues to be a center for illegal netting activities (CCAF 1998).

Illegal netting practices have continued to be a problem since the implementation of the net ban amendment. *Saltwater Sportsman*, a national recreational angling publication, ran an article to highlight this in June 1996. In the article, the magazine reports that in the second half of 1995 the Florida Marine Patrol (FMP) had given 135 citations for illegal netting. Most of the illegal netting was in response to the roe season for mullet, when prices for mullet reached three dollars a pound (Brownlee 1996). He also commented on how commercial netters were using discrepancies in the net ban amendment to illegally harvest fish in state waters. It is still legal for netters to traverse state waters to reach federal waters where the use of nets is legal. These net boats also carry cast nets, still legal in state waters. Illegal activity occurs when illegal nets are used in state waters, and fishers claim the catch was made with the cast net. Through the years these illegal activities have become even more creative. Reports in *Florida Sportsman* identify the use of night vision equipment, stowing illegal nets on barrier islands or underwater where they may be retrieved after leaving the dock, and the use of two boats to deceive authorities. This operation consists of a boat equipped with the illegal nets, which are legal to own (but not use in state waters), and the other boat equipped with a cast net. The boat with the illegal net transfers the catch to the boat with the cast net so as to appear legal. If the boat with the illegal net is stopped, they can claim that they were going to fish in federal waters.

The FMP provides a net ban arrest database at their website (Table 1). However, this table only reports those activities where someone was apprehended, so the total number of illegal net operations in Florida state waters is unknown. The

total numbers of arrests for net ban violations peaked in 1996 and have decreased in 1997 and 1998. It is also interesting to examine the totals given month by month. This reveals an increase in total arrests made in the months September through December, corresponding to the annual mullet roe harvest. Again, the numbers for these particular months peaked in 1996 and have decreased in 1997 and 1998.

Table 1. Arrests Due to Illegal Netting Activities

	1995	1996	1997	1998	1999	TOTAL
January	N/A	12	31	29	18	90
February	N/A	20	25	22	15	82
March	N/A	17	32	9	15	73
April	N/A	24	21	11	N/A	56
May	N/A	27	23	18	N/A	68
June	N/A	11	4	24	N/A	39
July	12	52	17	28	N/A	109
August	9	36	17	16	N/A	78
September	17	65	21	29	N/A	132
October	12	76	45	39	N/A	172
November	31	111	45	48	N/A	235
December	48	92	51	27	N/A	218
TOTAL	129	543	332	300	48	1352

Source: Florida Marine Patrol

Impacts to Recreational Fishing

Recreational fishing in Florida exhibits the same characteristics as angling elsewhere. The economic impact of recreational angling far outweighs that of commercial fishing. However, rather than elaborate on the economic indicators that obviously show that recreational fishing has a larger economic impact than commercial fishing within Florida, this research concentrates on the social components of the recreational angling experience and how those components may have changed as result of the net ban amendment.

An important social component of the recreational angling experience is angling satisfaction. Put simply, anglers who catch more fish are more satisfied with their experience. This is particularly true when anglers are asked about trip satisfaction on the same day the fishing trip occurred (Matlock et al. 1991). In the research described herein, the presence of more fish, as captured by the examination of popular literature, equates to increased satisfaction.

The anecdotal evidence from popular fishing literature was examined to gauge the perception of recreational anglers of what has happened to fish populations as a result of the net ban. In the April 1999 edition of *Sport Fishing*, a local captain makes the comment about recreational angling in Tampa Bay, "Three or four years ago, there were virtually no mullet, and now we see them everywhere" (Hahn 1999). *Florida Sportsman* has also reported on the resurgence of mullet populations. In an article devoted to the three-year anniversary of the net ban, the comment is made that, "Mullet populations also are surging to numbers not seen in a generation . . ."

(*Florida Sportsman*, 1998). The article goes on to report that mullet populations may not be recovering as quickly as expected due to illegal netting.

Anecdotal evidence also supports the resurgence of trout populations. *Florida Sportsman* reports, "Already, anglers are shaking their heads in amazement at the number of big seatrout being caught in areas that for several decades served as little more than nurseries for commercial netting" (*Florida Sportsman* 1998). Also, the magazine reports in the September 1998 issue, "Mainly because of the net ban, seatrout stocks have been growing in most areas" (Farren 1998).

DISCUSSION

Some preliminary conclusions can be reached. First, there has been a drastic reduction in the commercial catch of the individual species since the net ban policy went into effect. This represents more fish not being harvested for commercial use. Secondly, fish not being harvested by commercial fishers do not show up as recreational catch. This is important in that the net ban did not simply reallocate the harvest of these species to the recreational sector. Lastly, the anecdotal evidence strongly supports an increase in availability in species sought after by recreational anglers.

The Florida net ban policy is still a work in progress. Although five years have passed since the implementation of the policy, it is still a topic that will spark debate. Much of the opposition and associated protests from the commercial fishing industry will probably decline in the future as the policy ages, but opposition should not be dismissed lightly. The policy has forever closed one segment of the Florida commercial fishing industry, but it has not destroyed the industry outright. Some commercial fishers have moved to other forms of commercial fishing, i.e. cast nets, aquaculture, in order to remain within the industry. The commercial fishing industry has simply had to adjust to what the recreational fishing industry views as a victory for the recreational pursuit of the fishery resources in the state.

The net ban policy should not be viewed as a complete solution to the problem of dwindling fishery resources in the state; it is merely one step in protecting these valuable resources. Without continued effective management strategies, the people of Florida may find themselves in a similar situation in the future.

One problem concerning the net ban policy is the lack of adequate fisheries population data for the state of Florida. The data presented in this paper are estimates of catch made by NMFS and do not necessarily reflect the changing status of particular fish populations. However, this is the best available technical data currently available and, when coupled with anecdotal evidence in the literature, they provide the best insights to the status of these fish populations. In the future, better fishery-independent data are needed at the state and regional level.

There is no definitive answer to the question "Has the net ban been effective?" It has certainly been effective in reducing the commercial catch of selected species. However, recreational catch data are inconclusive at this time. One would certainly expect to see some sort of increase in recreational catch if selected fish populations

are on the rebound. This is simply not the case. Anecdotal evidence supports the resurgence of selected species, so perhaps an increase in catch rates will show up in the future. It is simply too early to tell if the net ban is responsible for any resurgence in Florida's fisheries. If anecdotal evidence is correct, Florida may be experiencing an increase in fish populations for reasons other than the net ban amendment, such as better habitat, a natural fluctuation in fish population cycles, or effective management strategies implemented prior to the net ban. In the future, if it is determined that the net ban is not responsible for an increase in fish populations, commercial fishers affected by the net ban policy would likely advocate a limited-entry return to inshore fishery resources. If it can be proven at a later date that the net ban is primarily responsible for increases in fish populations, then perhaps agencies need to focus on similar types of restrictions for other types of commercial fishing (such as longline fisheries) to help rebuild ocean fishery resources.

The state of the world's fisheries populations is not good (McGinn 1998). Throughout the world's oceans, there is evidence of overfishing for most resources. We can expect to see continued battles between recreational and commercial fishers in the future years, and continued problems for the fisheries managers who must both seek to protect and allocate the harvest of economically and socially valuable fishery resources.

LITERATURE CITED

Anderson, D.K. 1999. Environmental/social impacts of the Florida net ban (Article x, Section 16 of the State Constitution). M.S. Thesis. The University of Alabama, Tuscaloosa, Alabama USA. 90 pp.

Browning, M. 1994, November 10. Net ban leaves towns in search of new soul. *The Miami Herald*:1A, 22A. Miami, Florida USA.

Brownlee, J. 1996, June. Illegal netting in Florida. *Saltwater Sportsman* **57**:40.

Bryan, H. 1996. The assessment of social impacts. Pages 145-166 in: A.W. Ewert (ed.) *Natural Resource Management: The Human Dimension*. Westview Press, Boulder, Colorado USA.

Coastal Conservation Association Florida. 1998. Pine Island poachers dump 45 more snook carcasses on roadside. <http://www.cca-florida.com/press_releases/1998/08-18-98_pr.htm>.

Cocking, S. 1995, July 2. Protests greet new fishing rules. *Miami Herald*:6B. Miami, Florida USA.

Conner, M. 1999, April. Gill netters in federal waters far exceed kingfish quota. *Florida Sportsman* **31**:135.

Cotterell, B. 1996, September 11. Judge rules against net ban. *Tallahassee Democrat*:1C. Tallahassee, Florida USA.

Ditton, R.B. [1994] A social and economic assessment of major restrictions on marine net fishing in Florida. Florida Conservation Association, Tallahassee, Florida USA. 32 pp. Unpubl. MS.

Farren, R. 1998, September. Are we doing all we can. *Florida Sportsman* **30**:70-71.

Florida Marine Patrol. 1999. Net ban arrest database. <http://www.dep.state.fl.us/law/fisheries/netban/arrests/NETBAN1.htm>.

Florida Sea Grant Program. 1993. Saltwater recreational fishing in Florida: The economics of resident and tourist participation (SGEB-24)Gainesville, Florida USA. [Brochure].

Florida Sportsman. 1998, July. Rambunctious three-year old causes astounding comeback of fish stocks. **30**:64-65.

Grimes, S.R. 1996. The 1994 net ban constitutional amendment: A case study of marine fisheries management in Florida. M.S. Thesis. Texas A&M University, College Station, Texas USA. 122pp.

Hahn, A. 1999, April. Too many fish, too little time. *Sport Fishing* **14**:78-82.

Long, P. 1994, November 6. 2 Sides angling for votes. *The Miami Herald*:5B. Miami, Florida USA.

Marston, R.Q. and R.S. Nelson. 1994. *New directions in the management of Florida's marine fisheries: A report to the Florida Marine Fisheries Commission following passage of article X, section 16 of the constitution of the state of Florida*. <http://www.dep.state.fl.us/mfc/NEWDIR.htm>.

Matlock, G.C., H.R. Osburn, R.K. Riechers, and R.B. Ditton. 1991. Comparison of response scales for measuring angling satisfaction. Pages 413-422 in: D. Guthrie, J.M. Hoenig, M. Holliday, C.M. Jones, M.J. Mills, S.A. Moberly, K.H. Pollock, D.R. Talhelm (eds.) *Creel and Angler Surveys in Fisheries Management*. American Fisheries Society, Bethesda, Maryland USA.

McGinn, A.P. 1998. Promoting sustainable fisheries. Pages 59-78 in: L.R. Brown, C. Flavin, and H. French (eds.) *State of the World 1998*. W.W. Norton & Co., New York, New York USA.

Millender, Crum & McClain v. State of Florida, Department of Environmental Protection, No. 94-450-CA (2d Cir. Ct., Franklin County, Florida 1995).

Milon, J.W. and E.M. Thunberg 1993. *A Regional analysis of current and future Florida resident participation in marine recreational fishing* (SGR-112). Florida Sea Grant College Program, Gainesville, Florida USA.

National Marine Fisheries Service. 1999. Personal communication from National Marine Fisheries Service, Fisheries Statistics and Economics Division.

Smith, S. [1994] The hidden costs of changes in fisheries regulations for commercial fishing families. Paper presented at the Mid-Year Technical Meeting of the American Fisheries Society Southern Division, Little Rock, Arkansas, USA. February 1994. 18 pp. Unpubl. MS.

Smith, S., S. Jacob, C. Adams, J. Gates, and M. Jepson. [1999] Social impacts of the Florida net ban. Paper presented at the Elise B. Newell Seminar, Transformations in the Lives of Commercial Fishing Families and Communities: Reports from the Late Twentieth Century, Gainesville, FL. February 26. 4 pp. Unpubl. MS.

Taylor, C.N., C.H. Bryan, and C.G. Goodrich. 1995. *Social Assessment: Theory, Process and Techniques*. Taylor Baines and Associates, New Zealand. 228 pp.

Wolf, C.P. 1983. Social impact assessment: A methodological overview. Pages 15-33 in: K. Finterbusch, L.G. Llewellyn and C.P. Wolf (eds.) *Social Impact Assessment Methods*. Sage Publishing, Beverly Hills, California USA.

Economic Assessment of Limited Entry Strategies in Multi-Species Fisheries in South Florida

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ABSTRACT

The commercial fishery that primarily targets king mackerel, stone crab, snappers, groupers, and spiny lobster in Monroe and Collier counties is one of the most important commercial fisheries in Florida. These species currently face problems of overfishing and/or overcapitalization. A dual-based restricted profit function is used to estimate the economic and technical interactions that exist in this multi-species fishery, primarily using own-price and cross-price elasticities of supply. It is found that the production technology does not exhibit input-output separability and nonjointness-in-inputs, over all species groups. This result suggests that these key species may be more efficiently managed as a group, rather than with the use of existing single species regulations. Spiny lobster and stone crab, the dominant value species in the fishery, are shown to have very elastic substitution relationships with king mackerel.

KEY WORDS: Multi-species fisheries, duality theory, joint products

INTRODUCTION

Today, "...most U.S. fish stocks are in a state of full exploitation or overutilization," furthermore, the recent depletion of some dominant species has led to the collapse of a few major fisheries (National Research Council 1999). In Florida, the commercial fishing industry is a very important one. Statewide, among the most predominant species in terms of value are shrimp (primarily *Penaeus duorarum*), spiny lobster (*Panulirus argus*), and king mackerel (*Scomberomorus cavalla*). In terms of landings, stone crab (*Menippe mercenaria*) in Florida's Southwest region (i.e., Charlotte to Monroe counties) accounted for approximately 73% of total landings in Florida during the 1995-1996 fishing season. Also in 1996, Monroe and Collier counties accounted for approximately 90% of Florida's spiny lobster landings, 40% of snapper/grouper landings, and 40% of king mackerel landings (Milon et. al. 1998).

There has been rapid growth in many primary South Florida fisheries in the past two decades. For some species, such as king mackerel, this growth has occurred for both the commercial and recreational fisheries (although most of the growth has occurred in the recreational sector). For example, by 1985, the Total Allowable Catch (TAC) for the Gulf migratory group of king mackerel was allocated 9.673

million pounds to the recreational catch and 4.552 million pounds to the commercial catch (GMFMC 1985). This ratio continues today. Traditionally, for each managed species, the stock size that allows for the attainment of the Maximum Sustainable Yield (MSY) is calculated and efforts are made to keep the harvest levels at or below MSY. Today, the stock of king mackerel in the Gulf migratory group is below the level of producing MSY. Furthermore, the stock has been reduced to the point where recruitment has been affected, and uncontrolled fishing would further reduce the biomass. In addition to this problem, there are intense conflicts between recreational and commercial fishermen, and between commercial fishermen who use different gear. Part-time commercial fishermen compete with full-time commercial fishermen for the quota. Further, large catches of mackerel over a short period often causes the quota to be exceeded before closures can be implemented (GMFMC 1999). Snappers and groupers, which are considered in this paper as a single "species" group, have suffered a similar fate. There are no closed seasons in either the king mackerel or snapper/grouper fisheries.

There has been an increasing amount of effort (which is typically represented by the total number of traps available) in the spiny lobster fishery. For example, between 1951 to 1999 the number of traps increased from approximately 12,000 to 540,000 (declining from a high of over 900,000 in the early 1990s before the certificate program was implemented). This increase in effort was accompanied by a rapid decline in Catch per Unit Effort (CPUE), which fell from levels of approximately 150 pounds per trap to less than 10 pounds per trap over the same period. Despite this, total commercial landings have remained relatively stable since 1976 (Milon et al. 1998). The closed season is April 1st to August 5th.

For stone crab harvests, excessive growth of the trap fishery has reduced the efficiency of the industry such that the likelihood of increased landings with additional effort are minimal. This excessive growth has also caused increased conflicts with the shrimp trawl fishery and there has been an increase in destruction of live bottom species such as soft coral as well as a rise in shore debris from displaced buoys and traps. While the biological viability of this species has not been affected (since the recruits into the fishery are mature and have had an opportunity to spawn), crabs harvested are becoming increasingly smaller, leading to a loss in commercial value. The closed season for this species is May 16th to October 14th.

Many fishermen in South Florida catch king mackerel, snapper/groupers, spiny lobster, and stone crab depending largely on the availability and profitability of each species at a given time. However, each of these species is currently managed by separate management plans and, in some fisheries, moratoriums exist on increases in effort. It is likely that inputs used in the harvest of one species can result in the harvest of, or use in the harvest of, another species; this type of production process is known as jointness-in-inputs. It is also possible that a particular input does not directly affect the harvest of a given species, however, it may be possible to use a representative input, combine inputs, or create a composite input that is known to affect the harvest levels of each species; a representation of the production process that follows this approach is known as input-output separability.

In South Florida (i.e., Monroe and Collier counties) there are four primary fisheries: king mackerel, spiny lobster, snapper/grouper, and stone crab. Each of these fisheries face problems of overfishing and/or overcapitalization. To date, efforts to address these issues have been on a single-species basis. The main deficiency of this approach is that the production linkages that may exist between fisheries are essentially ignored. As a result, there is a great propensity for effort redirection by fishery participants to other species where similar gear or vessels are utilized. The main objectives of this paper are, therefore, to: (1) assess the temporal fleet components in the fishery; (2) identify resource linkages; and (3) determine if a multi-species management approach would be appropriate for some or all of the primary species in the South Florida.

EMPIRICAL FRAMEWORK

Models that have been used to describe multi-species fisheries have made assumptions about the underlying decision-making process of the fisherman/fishing firm. These models assume that a firm wishes to maximize profit, but in achieving this objective, many decisions have to be made. These include decisions about fishing locations, target species, gear and homeport, number of crew, length of trip, landing port, and duration at a fishing location. The exact nature of the decision-making framework is not certain, but given a selected fishing location and inputs, such as vessel size and gear type (which are fixed in the short run), profit maximization becomes equivalent to revenue maximization. However, if information on variable inputs is available, a profit function can be defined and both output supply (i.e. production) and input demand functions can be obtained using a duality approach. Several types of revenue/profit functions have been utilized by previous researchers. Recent research of multiproduct firms has described the profit function using a translog form (Thunberg et al. 1995), a quadratic form (Dupont 1990), and a generalized Leontief function (Kirkley and Strand 1988, Squires and Kirkley 1995). These functions are "flexible" in that they are a second-order differentiable approximation to an unknown, twice continuously-differentiable function (Blackorby and Diewert 1979). Therefore, this allows the mimicking of a great deal of curvature when it is used to approximate another function, and it does not restrict the values of the elasticities of substitution, which are second derivatives of the output supply or input demand functions (Greene 1997).

These restricted profit functions can then be transformed via Hotelling's Lemma (Diewert 1971), to obtain a system of (i) input-compensated output supply functions and (ii) input demand functions. The major drawback of the translog functional form is that the derivatives of the profit function yield input and output share equations (i.e. input and output values are in terms of its share of total revenue), which are not easily interpreted. In addition, the translog functional form requires restrictions for linear homogeneity in addition to symmetry restrictions on the parameters.

This paper utilizes a nonhomothetic Leontief functional form, which has an advantage of automatically imposing linear homogeneity in prices (Squires and Kirkley 1995). The basic functional form is represented as:

$$R(E, P) = \Sigma_i\Sigma_j\beta_{ij} (P_i P_j)^{1/2} E + \Sigma_i \beta_i P_i E^2$$

where R represents net revenue per unit time as a function of fishing effort (E), such as the number of trips, and the output and input prices (P_i where i = 1,...,M). This basic function can be extended to include a dummy variable, D_y that reflects (for example) the year in which a trip was taken:

$$R(E, P) = \Sigma_i\Sigma_j \beta_{ij} (P_i P_j)^{1/2} E + \Sigma_i \beta_i P_i E^2 + \Sigma_i\Sigma_y \alpha_{iy} D_y P_i E.$$

Output supply and input demand functions are obtained using Hotelling's Lemma:

$$\delta R(E, P)/\delta P_i = Q_i (E, P) = \beta_{ii} E + \Sigma_j \beta_{ij} (P_j /P_i)^{1/2} E + \beta_i E^2 + \Sigma_y \alpha_{iy} D_y E \; \forall \; i^1j.$$

The dependent variables in these equations represent outputs and inputs in quantities (Q_i). In this paper, the output supply and input demand equations are defined as follows:

$$\delta R(E, P)/\delta P_i = Q_i = \beta_{ii} E + \Sigma_j \beta_{ij} (P_j /P_i)^{1/2} E + \beta_i E^2 + \Sigma_y \alpha_{iy} D_y E$$

for all i^1j, i=1, 2, ...5, which includes four outputs (i.e., the primary species groups) and one input, labor. D_y (y=1, 2, ...4) =1 for observations in 1995 to 1998 respectively, zero otherwise. The imposition of symmetry requires that:

$$\beta_{ij} = \beta_{ji} \quad \forall \; i^1j.$$

DATA

In Florida, all commercial fishermen are required to fill out a Trip Ticket, which contains various trip data, upon completion of each fishing trip. This information is collected and maintained in a database by the Florida Marine Research Institute (FMRI). Trip level data on the type and quantity of landings of all species for fishermen in Monroe and Collier counties were obtained from FMRI. FMRI also provided the associated landing date and ex-vessel price received (dollars per pound) for each species at landing. This trip level data was obtained for each fishing firm (i.e., Saltwater Products License number and vessel) via coded identification numbers to maintain confidentiality.

The data set included information from trips taken January 1994 through December 1998 and was aggregated on an annual basis for each firm. The minimum wage was used to represent the cost of labor (dollars per hour) for each trip. Information on the average number of crew, trip days, and hours spent per trip for

fishermen that target each species was obtained from a recent survey of Monroe County fishermen (Milon et al. 1999). These data were used to calculate the number of man-hours employed by each firm in each year and represents the annual quantity of labor used.

ESTIMATION

Four outputs and one input were specified: king mackerel; stone crab; snapper/grouper (all snapper and grouper species were placed into one group to facilitate the use of cost information from secondary sources); spiny lobster; and labor. The associated output supply and input demand functions were estimated as a system using iterated Seemingly Unrelated Regression (SUR) estimation with SAS®. Since the output supply and input demand equations are all derived from one profit function, this implies that we cannot rule out the possibility that the error terms in different equations are mutually correlated. In this case, we have:

$$E(\varepsilon_i \varepsilon'_j) = \sigma_{ij} I_T.$$

where σ_{ij} is the covariance of the disturbances of the *ith* and *jth* equation, which is assumed to be constant over all observations. This covariance represents the only link between the *ith* and *jth* equation. Because this link is subtle, the system of M equations is called a system of SUR equations (Kmenta 1997). The SUR method therefore uses the correlations among the errors in different equations to improve the regression estimates.

Only firms that had a minimum $5,000 average annual income (the minimum required to obtain a Saltwater Products Licence) from the landings of at least one of the target species were included in the estimation. For the years 1994 to 1998, 1550, 1591, 1574, 1563, and 1473 firms, respectively, met this criteria.

Even after aggregating the data, it was found that not all firms landed all species in a particular year. This created a limited-dependent variable problem. According to Maddala (1977), this may lead to biasedness, non-normality in the results, and incorrect rejection of tested hypotheses. To alleviate this problem, zero values for the dependent variable were replaced by a small positive value of 0.01 (similar values were used by Squires and Kirkley (1995) and Larkin and Adams (1999)). Also, for observations in which a specific species was not landed, the prices used for that observation was the mean of all non-missing observations for that year. The total number of trips taken (in order to capture all species) in a specific year was used to represent the effort variable.

The type and strengths of the technical and economic interaction of the fishery was determined using the own and cross-price elasticites. The elasticities were derived from the estimated output supply and input demand equations and are used, specifically, to indicate substitute and complementary relationships among the inputs and outputs. Also, since firms in a multi-species fishery may seek to maximize revenue by directing their effort to the highest valued species, the calculation of the cross-price elasticites can be used to determine the level of redirection of effort that

may take place in the fishery when the relative prices of species change (Roderick, Adams and Taylor 1995). The parameters of the supply and input demand functions were used to calculate own and cross-price elasticities of supply and demand using the following formulas:

Own-price Elasticity

$$\frac{\partial Q_i}{\partial P_i}\frac{P_i}{Q_i}=\left[\Sigma_j\left(\frac{-\beta_{ij}E}{2P_i}\right)\left(\frac{Q_j}{P_i}\right)^{1/2}\right]\frac{P_i}{Q_i}$$

Cross-price Elasticity

$$\frac{\partial Q_i}{\partial P_j}\frac{P_j}{Q_i}=\left[\left(\frac{\beta_{ij}E}{2}\right)\left(\frac{1}{P_iP_j}\right)^{1/2}\right]\frac{P_j}{Q_i}$$

where the respective variable means are used.

Nonjointness-in-inputs and input-output separability have often been assumed in the management of fisheries. Separability implies that there is no interaction between the harvest of any one species and any one input so that composite input and output bundles can be specified to represent the harvesting function. This suggests that the marginal rates of substitution between pairs of inputs do not rely on the makeup of the catch while the marginal rates of transformation between pairs of species do not rely on the mix of inputs. Therefore, only the level of catch and effort need to be regulated and this does not affect the optimal input combinations (Squires 1987). If the harvest of one species is independent of the inputs used to harvest another, then this suggests that there exists non-jointness in inputs so that each species has an independent harvest function. If nonjointness-in-inputs exists over all species, then:

$$R(E,P) = \Sigma_j R_i(P_i, E).$$

The test for nonjointness-in-inputs was carried out by testing the following restriction:

$$\frac{\partial^2 R(E,P)}{\partial P_i \partial P_j}=\frac{Q_i}{P_j}=0\text{, that is, } \beta_{ij}=0,\ \forall\ i^1j.$$

If separability exists, then the profit function is separable in output prices and the composite input, that is:

$$R(E,P) = R(p)E.$$

The test for input-output separability was carried out by testing the following restriction:

$$H_0: \beta_i = 0 \quad \forall i$$

This paper therefore presents the following hypotheses:

i) There exists jointness-in-inputs for the harvest of all four species,
ii) If jointness-in-inputs exist for stone crab and spiny lobster, then these species are strong substitutes,
iii) Snappers and groupers are weak substitutes with either stone crab or spiny lobster; and
iv) Input-output separability does not exist in the harvest of all species. A priori, it is also expected that own-price elasticities are positive.
v)

RESULTS

Table 1 reports a summary of sample statistics for the fishery. The target species have, on average, a large difference in their ex-vessel price per pound. For 1994 to 1998, the mean price for king mackerel was $1.25. At the other end of the range, stone crab had an average price of $6.89. In addition, there were considerable differences in the variances of prices received, with spiny lobster (one of the species with the most price variability) having a range from $0.50 to $14.00 per pound. The mean number of trips was similar for 1994 and 1995, then there was an approximate 10 percent increase in the mean number of trips for 1996 and 1997; however, by 1998, the mean number of trips fell to levels approaching 1994 levels. Therefore, no clear trend was evident in the number of trips taken by each firm. A comparison of annual landings for all years shows substantial variation for the target species. Spiny lobster was the dominant species in terms of landings, with a mean of approximately 4,114 pounds per year over the study period. In order of magnitude, spiny lobster landings were followed by snapper/grouper, stone crab, and king mackerel.

For 1994 to 1998, total landings of the target species for the sample are shown in Figure 1. King Mackerel landings showed the largest increase over the period, from approximately 547,900 pounds in 1994 to 1.3 million pounds by 1998. Landings for stone crab were fairly steady over time, unlike that for snapper/grouper where landings exhibited a declining trend. Spiny lobster landings exhibited no clear trend.

The estimated coefficients of the output supply and input demand equations are reported in Table 2 with standard errors in parentheses. The parameter β_{ii} is reported as the coefficient for the effort variable. The generalized R^2 for the system

of equations was 0.33, which indicated only a moderate fit. Most of the coefficients are significant at the 0.05 percent level. The statistical results suggest that there are annual differences in landings for the target species and in the demand for labor.

Table 1: Sample descriptive statistics

Variable	Mean	Standard Deviation	Minimum Value	Maximum Value
Annual Prices				
King Mackerel	1.25	0.17	0.41	3.00
Stone Crab	6.89	0.81	0.33	10.85
Snapper/Grouper	2.13	0.36	0.33	10.00
Spiny Lobster	4.31	0.80	0.50	14.00
Annual Trips				
1994	71.8	74.1	1.0	537.0
1995	71.4	72.4	1.0	500.0
1996	77.9	75.6	1.0	505.0
1997	78.7	79.5	1.0	538.0
1998	72.9	76.3	1.0	551.0
Annual Landings				
King Mackerel	698.3	4252.7	0	147930.0
Stone Crab	1371.4	3719.9	0	52652.0
Snapper/Grouper	2769.2	8017.0	0	107695.0
Spiny Lobster	4114.1	8056.7	0	73106.0

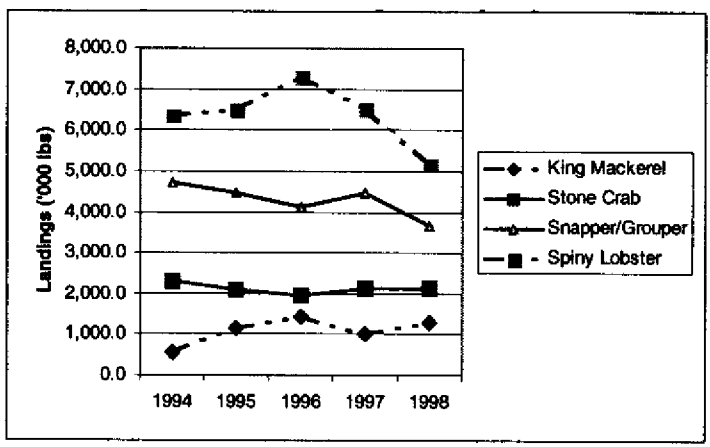


Figure 1. Total landings of target species

Table 2. Parameter Estimates - Output Supply and Input Demand Functions

	Output/Input (Dependent Variables)				
Independent Variables	King Mackerel	Stone Crab	Snapper Groupers	Spiny Lobster	Labor
Fishing Effort	-24.898*	-111.199*	50.781*	-119.529*	-50.451*
	(4.930)[a]	(5.042)	(6.058)	(8.028)	(2.864)
Effort squared	-0.02*	0.039*	-0.094*	-0.016*	0.001
	(0.003)	(0.003)	(0.005)	(0.005)	(0.0006)
Output Prices:					
King Mackerel					
Stone Crab	-7.202*		SYMMETRIC		
	(2.422)				
Snapper Groupers	1.487	2.194			
	(2.922)	(4.189)			
Spiny Lobster	-28.956*	166.249*	-26.200*		
	(3.658)	(5.302)	(5.382)		
Input Price:					
Labor	55.891*	-9.206*	16.062*	14.430*	
	(2.716)	(1.172)	(1.373)	(1.913)	
Dummy Variables:					
1995	1.320	0.206	-2.327	-16.967*	2.486*
	(1.038)	(1.038)	(1.842)	(1.911)	(0.242)
1996	-4.018*	8.545*	-7.399*	-34.198*	6.668*
	(1.270)	(1.182)	(2.031)	(2.091)	(0.312)
1997	-12.695*	7.872*	-4.904*	-36.096*	9.803*
	(1.369)	(1.117)	(1.945)	(1.963)	(0.419)
1998	-14.530*	15.050*	-9.783*	-48.804*	9.553*
	(1.382)	(1.183)	(2.040)	(2.130)	(0.441)

[a] Standard errors in parentheses.
* Denotes statistically significant at the 0.05 percent level.

The coefficients of the effort variable were all significant at the 0.05 percent level. However, except for snapper/grouper, all the parameters are negative. For this group, an additional trip per year is anticipated to increase landings by 50.8 pounds. These results suggest that additional effort may be directed toward snapper/grouper. However, the rate of change in harvest levels as effort increased for all target species, while significant, were negligible. The model suggests that an additional trip will lead to an increase in the quantity of labor utilized by approximately 50 man-hours.

The results of the tests for nonjointness-in-inputs and input-output separability are presented in Table 3. As shown in Table 3, nonjoint production of all species and input-output separability are rejected.

The rejection of nonjointness implies that the quantity of landings of a particular species is dependent on the inputs used in harvesting other species. This affirms the existence of economic interactions in the production of the four key species groups of Monroe and Collier counties. Therefore, single species management would affect

the harvest of the other species. The rejection of separability suggests that the species could be better managed with the regulation of the composite input, rather than with individual variable inputs. It should be noted, though, that while nonjointness-in-inputs and separability were rejected for all species, these results do not preclude possible interactions between subsets of the species.

Table 3. Statistical Results of tests - Jointness and Separability in Outputs

F-Statistics[b]	
Nonjointness (R, MT-K)[c]	Separability (R, MT-K)
157.62 (10, 38,715)	129.03 (5, 38715)

[b] The critical F-value, $F^{10}_{38,715} = 2.32$, and for $F^{5}_{38,715} = 3.02$.
[c] R is the number of restrictions and MT-K is the degrees of freele

The technical and economic interactions of the fishery are also shown by the calculated own and cross-price elasticities of supply and demand, which are shown in Table 4.

Table 4. Estimated own-price and cross-price elasticities (1994 - 1998)

Ith species	King Mackerel	Stone Crab	Snapper Grouper	Spiny Lobster	Labor
King Mackerel	-3.722	-11.240	0.400	-22.408	47.690
Stone Crab	-0.189	-6.017	-0.189	0.128	27.942
Snapper Grouper	0.035	0.662	0.209	-1.705	0.035
Spiny Lobster	-0.320	23.719	-0.644	-3.135	0.662
Labor	19.819	-42.154	12.669	32.921	-23.314

The own-price elasticity of snapper/grouper is positive (0.209), but is very inelastic, which indicates that as the price rises by 1 percent, the quantity harvested will increase, but by only 0.2 percent. All other own-price elasticities were negative. The positive cross-price elasticities between king mackerel and snapper/grouper indicate that these outputs are complementary (i.e., joint) in production. However, this effect is inelastic so that a 1 percent increase in the price of snapper/grouper would lead to only a 0.4 percent rise in the harvest of king mackerel. The cross-price elasticity between king mackerel and both stone crab and spiny lobster are negative, which indicates that these species are substitutes. In fact, these relationships were extremely elastic so that, for example, a 1 percent increase in the price of spiny lobster will cause a 22.4 percent fall in the quantity harvested of king

mackerel. These results are consistent with the descriptive statistics, which show that stone crab and spiny lobster are the two highest priced species. The bigger cross-price effect for spiny lobster may be due to the fact that although spiny lobster has the highest price, it had more than twice the volume of landings, on average, than stone crab and is therefore the higher valued species. The nature of these relationships (complements and substitutes) between king mackerel and the other species are consistent for all reported cross-price elasticities. However, the strength of these relationships is much smaller for the mirror cross-price calculations. For example, a 1 percent increase in the price of king mackerel will only lead to a 0.3 percent fall in the landings of spiny lobster. This reinforces the suggestion of the results that indeed stone crab and spiny lobster are the dominant species in the fishery. The relationship between stone crab and snapper/grouper is not consistent. The positive cross-price elasticity between stone crab and spiny lobster indicates that these species are complements. As expected, higher prices for king mackerel, snapper/grouper and spiny lobster increased the demand for labor.

CONCLUSION

The four primary fish species in the Monroe/Collier County fishery (i.e., king mackerel, spiny lobster, snapper/groupers and stone crab) all face the problems of overfishing and/or overcapitalization. To date, efforts to address these issues have been on a single-species basis. These target species have, on average, a large difference in their ex-vessel price per pound. Spiny lobster was the dominant species in terms of landings, with a mean of 4,114.1 pounds per year per firm, over the study period. In order of magnitude, spiny lobster landings were followed by snapper/grouper, stone crab and king mackerel. In this preliminary study, total number of trips taken annually was used as the effort variable and labor was the only variable input included.

Nonjoint production of all species and input-output separability were rejected. This implies that the quantity of landings of a particular species was dependent on the inputs used in harvesting other species. This affirms the existence of economic interactions in the production of the four key fisheries in South Florida, therefore, single species management would affect the harvest of the other species.

The own-price elasticity of snapper/grouper was positive but very inelastic (0.209). All other own-price elasticities were negative. The positive cross-price elasticities between king mackerel and snapper/grouper indicate that these outputs are complementary (joint) in production, however, this effect is inelastic. The cross-price elasticity between king mackerel and both stone crab and spiny lobster were negative, which indicates that these species are substitutes. These relationships, however, were extremely elastic. For example, a 1 percent increase in the price of spiny lobster would cause a 22.4 percent fall in the quantity harvested of king mackerel. These results are consistent with the descriptive statistics, which showed that stone crab and spiny lobster are the two highest priced species. The bigger cross-price effect for spiny lobster may be due to the fact that although spiny lobster

has the highest price, it has more than twice the volume of landings (on average) than stone crab and is, therefore, the higher-valued species. The relationship between stone crab and snapper/grouper is not consistent. The positive cross-price elasticity between stone crab and spiny lobster indicates that these species are complements. As expected, higher prices for king mackerel, snapper/grouper and spiny lobster increased the demand for labor.

REFERENCES

Blackorby, C. and W.E. Diewert. 1979. Expenditure functions, local duality, and second order approximations. *Econometrica.* **47**(3):579-602.

Diewert, W.E. 1971. An Application of the shephard duality theorem: a generalized leontief production function. *The Journal of Political Economy.* **79**(3):481-507.

Dupont, D. P. 1990. Rent dissipation in restricted access fisheries. *Journal of Environmental Economics and Management.* **19**:26-44.

Greene, William H. 1997. *Econometric Analysis*. 3rd Ed. Prentice-Hall. Princeton, New Jersey, USA.

Gulf of Mexico Fishery Management Council (GMFMC). 1985. *Amendment 1 Fishery Management Plan: Environmental Impact Statement for the Coastal Migratory Pelagic Resources (Mackerels).* GMFMC: Tampa, Florida.

Gulf of Mexico Fishery Management Council (GMFMC). 1999. *Amendment 12 to the Fishery Management Plan for Coastal Migratory Pelagic Resources (Mackerels) in the Gulf of Mexico and South Atlantic including Environmental Assessment and Regulatory Impact Review.* GMFMC: Tampa, Florida.

Kirkley. J.E. and I.E. Strand. 1988. The Technology and management of multi-species fisheries. *Applied Economics.* **20**:1279-1292.

Kmenta, J. 1997. *Elements of Econometrics*. 2nd Ed. The University of Michigan Press. Ann Arbor, Michigan USA.

Maddala, G.S. 1977. *Econometrics*. McGraw-Hill. New York, New York USA.

Larkin, S.L and C. Adams. 1999. Economic Evaluation of the U.S: Atlantic Pelagic Longline Fleet. *Journal of Agricultural & Applied Economics.* **32**(2):420.

Milon, J.W., S.L. Larkin, D.J. Lee, K.J. Quigley, and C.M. Adams. December 1998. *The Performance of Florida's Spiny Lobster Trap Certificate Program.* Sea Grant Report Number 116. Florida Sea Grant College Program. Gainesville, Florida USA.

Milon, J.W., S.L. Larkin, and N.M. Ehrhardt. August 1999. *Bioeconomic Models of the Florida Commercial Spiny Lobster Fishery.* Sea Grant Report Number 117. Florida Sea Grant College Program. Gainesville, Florida USA.

National Research Council (NRC). 1999. *Sharing the Fish: Toward a National Policy on Individual Fishing Quotas.* National Academy Press. Washington, D.C. USA.

Roderick, J., C. Adams, and T. Taylor. 1995. An Economic Analysis of Effort Supply Relationships Between the Swordfish and Tuna Longline Fisheries in the

South Atlantic and Gulf of Mexico. Staff Paper Series. Food and Resource Economics Department, University of Florida. Gainesville, Florida USA.

Squires, D. 1987. Public Regulation and the Structure of Production in Multiproduct Industries: An Application to the New England Otter Trawl Industry. *Rand Journal of Economics* **18**:232-247.

Squires, D. and J. Kirkley. 1995. Resource Rents from Single and Multi-species Individual Transferable Quota Programs. *Journal of Marine Science* **52**:153-164.

Thunberg, E.M.., E.W. Bresnyan, and C.M. Adams. 1995. Economic Analysis of Technical Interdependencies and the Value of Effort in a Multi-Species Fishery. *Marine Resource Economics* **10**:59-76.

Actividad Pesquera en las Comunidades de Mano Juan, Catuano y Bayahibe, Parque Nacional del Este, República Dominicana: Recomendaciones para su Manejo Compartido

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RESUMEN

Un censo de la actividad pesquera fue realizado en el Parque Nacional del Este, República Dominicana, de enero-marzo del 2000, como parte de las actividades de monitoreo que desarrolla en la zona la Fundación MAMMA bajo los auspicios de The Nature Conservancy. El censo se efectuó mediante entrevistas directas y manipulación de las capturas desembarcadas. Los pescadores entrevistados provienen de Saona, La Romana Higuey y Bayahibe. Operan embarcaciones impulsadas por motores fuera borda o por velas. El cuarenta porciento trabaja para dueños de pescaderias y el pago por gasolina y equipos se realiza mediante descuento de una parte de la captura total. Los pescadores pescan langosta, lambí y peces demersales y pelagicos. Aseguran que las capturas han disminuido con respecto a épocas anteriores debido al aumento en el número de artes y pescadores y a las actividades turísticas sin control en la zona. Recomendaron prohibir el uso de compresores y trasmayos y favorecen la construcción de balsas (FADs), entre otras medidas. Se plantea la necesidad de diseñar e implementar una estrategia de comanejo de las pesquerías en el lugar con el involucramiento de los usuarios directos, representantes del gobierno y entidades sociales y de investigación con presencia en la zona, tomando en cuenta las necesidades educativas, económicas y sociales de los usuarios y al mismo tiempo proveyendo opciones que permitan la explotación de los recursos marinos en dicho lugar de una manera sostenible.

PALABRAS CLAVE: co-manejo pesquero, usuarios directos, manejo pesquero sostenible

Fishing Activity in the Communities of Mano Mano Juan, Catuano & Bayahibe, Parque Nacional del Este, Dominican Republic: Recommendations for its Co-management

ABSTRACT

A census of the fishing activity was conducted in Parque Nacional del Este, República Dominicana, from January to March 2000 as part of the monitoring activities executed in the area by MAMMA Foundation, with the support of The Nature Conservancy. The census was undertaken through direct interviews and analysis of landings. The fishers interviewed come from Saona, La Romana, Higuey & Bayahibe. They fish from small to medium-size boats powered from outboard engines or sails. Forty percent work for fish micro-enterprises, and the payment for fuel and equipment is deducted from the total catch. They fish for lobster, conch and demersal and pelagic fishes. The fishers feel that the total catch has decreased in comparison with the past years mainly due to the high number of fishers and fishing gears and the uncontrolled tourism activities in the zone. Fishers recommended to prohibit the use of hookah and trammel net, but they favored the construction of Fish Aggregation Devices (FADs), among other measures. In this document we raised the need for designing and implementing a fisheries co-management strategy involving the direct users, representatives of the government and social and research entities that are present in the area. That strategy should take into account also, the educational, economical and social needs of the users and provide options for the sustainable management of the marine resources in the area.

KEY WORDS: Fisheries co-management; direct users, sustainable fisheries management.

INTRODUCCIÓN

El Parque Nacional del Este (PNE) en el sudeste de República Dominicana, ocupa el 2do lugar en tamaño de las áreas protegidas del país con 143,000 hectáreas en hábitats de tierra firme, 11,000 hectáreas en Isla Saona y 12,000 hectáreas de hábitats marinos). Estos últimos no forman parte del área protegida (Chiappone 1999, Torres et al. 1998).

El PNE alberga varias comunidades las cuales combinan la pesca con otras actividades de subsistencia. La pesca es una actividad tradicional en la zona y se considera como una fuente importante de ingresos. Este trabajo forma parte de las actividades de monitoreo que desarrolla en la zona la Fundación MAMMA con el auspicio de The Nature Conservancy (TNC).

Desde 1993 varias actividades han sido conducidas en PNE teniendo como propósitos los siguientes:

i) Lograr la integración del parque a las actividades económicas de apoyo a las comunidades locales,
ii) Proveer una infraestructura conservacionista,
iii) Usar la conservación como instrumento de enseñanza, y
iv) Crear mecanismos tendentes a lograr el manejo sustentable del área.

En 1994 se realizó en el parque una evaluación ecológica integral la cual permitió caracterizar y evaluar el ecosistema marino de la zona.

Dicha evaluación fue la base para el establecimiento de un programa de monitoreo (calidad de agua, estado de los arrecifes de coral y sus especies y manejo de las pesquerías) por un período de cinco años.

El objetivo principal de este trabajo fue realizar un censo pesquero en las comunidades de Mano Juan y Catuano, en Isla Saona y en la comunidad pesquera de Bayahíbe como parte del programa de monitoreo de la pesca en PNE.

MÉTODOS

Con el propósito de continuar el monitoreo de los desembarcos y la actividad pesquera en las comunidades aledañas al Parque Nacional del Este, se hicieron visitas a la zona y entrevistas a los pescadores de las comunidades de Mano Juan y Catuano (Isla Saona) y en Bayahibe, durante el período de enero a marzo del 2000, como parte de las actividades dentro del proyecto Parques en Peligro en Parque del Este el cual se ejecuta con el apoyo económico de The Nature Conservancy.

El censo se llevó a cabo mediante entrevistas a los pescadores individuales de cada una de las comunidades antes mencionadas. El formulario usado en las entrevistas fue diseñado en conjunto por técnicos de TNC, la Fundación MAMMA y el Acuario Nacional e incluyó información referente a aspectos sociales y económicos de los pescadores, además de información de las capturas en los desembarcos y datos de longitud y peso de las especies (anexo 1). Los pesos de los individuos de las especies se determinaron usando pesolas, la longitud total se determinó usando una regla. Los pesos se expresaron en gramos y las longitudes en centímetros.

Para facilitar el registro de la actividad pesquera, al inicio del monitoreo se entrenaron siete voluntarios en el llenado de los formularios y en la identificación, pesaje y medición de la captura de los pescadores. Tres de los voluntarios pertenecen a las comunidades locales y quatro estudiantes universitarios de Santo Domingo. Los datos recopilados en los formularios fueron analizados y luego se procedió a preparar un informe. Los resultados encontrados se muestran a continuación.

RESULTADOS

Sobre el Pescador

No de Entrevistados — Durante el período comprendido entre enero y marzo del 200 se entrevistaron 47 pescadores (3 en Catuano, 27 en Mano Juan y 13 en Bayahibe), quienes faenan en las aguas circundantes al PNE, alrededor de las Islas Saona y Catalinita y en las cercanías del Río Chavón. La pesca es realizada solo por hombres a diferencia de otros lugares del país en donde también la mujer y los niños se integran a la misma (Mateo et al. 1998).

Edad y Procedencia — La edad de los pescadores oscila entre 20 y 70 años (mayormente entre 20 y 30 años). La mayor parte de los pescadores entrevistados provienen de Saona (40%), La Romana (30%) y Bayahibe (16%). En menor proporción se hallaron pescadores de Higuey, Cabrera, Puerto Plata y Hato Mayor. El tiempo de dedicación a la pesca (en años) se visualiza en la Figura 1.

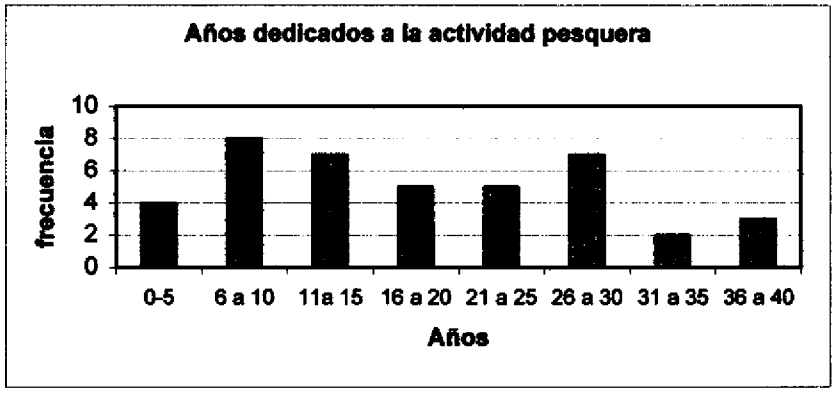


Figura 1. Tiempo de dedicación (en años) a la actividad pesquera.

Estado Civil y Número ye Dependientes— El 58% de los pescadores vive bajo unión libre con sus compañeras con las cuales han procreado entre 1-9 niños.

Nivel Educativo — El 60% de los entrevistados llegó a realizar estudios primarios; 26% alcanzó la intermedia (26%) y en menor grado, algunos iniciaron estudios universitarios, mientras otros no recibieron ninguna instrucción escolar

Sobre la Embarcación — Las embarcaciones de la zona poseen tallas entre 13 y 24 pies de largo, impulsadas por motores fuera de borda (entre 8 y 40Hp), velas o remos. Las más populares son las yolas (70%), hechas de madera o fibra de Vidrio. También se hayan en la zona botes, pivotes y veleros (especialmente en Bayahibe) y pivotes.

Sobre la Actividad Pesquera

Años en la Actividad — La mayor parte de los pescadores tiene entre 6-10 años pescando (8, 19%); 7 de ellos (15%) entre 11-15 años y entre 26-30 (17%) años.

Frecuencia de la actividad —
La faena pesquera se lleva a cabo principalmente de lunes a viernes, de lunes a sábado o todos los días; aunque algunos solo faenan 2 o 3 veces durante la semana, principalmente aquellos que realizan otros oficios alternativos a la pesca. Sólo 2 (4%) de los pescadores entrevistados faenan durante algunos meses mientras que 45 (96 %) lo hacen a través de todo el año.

Lugares de Pesca — La mayoría de los pescadores faena en El Bajo (20, 44 %) y en los arrecifes (11, 33%); algunos combinan las capturas en El Bajo y los arrecifes (6, 14 %) y unos pocos pescan en las praderas de hierbas marinas y fondos arenosos

Artes de Pesca — El buceo a compresor orientado a la captura de langostas, langostinos y lambí es el arte de mayor uso en la zona (22%), seguido por el uso de cordel y de arpón/buceo a compresor. éste último dedicado a la captura de peces de mediano tamaño a grande como sonlos pargos, meros y capitanes. Otras artes usadas en menor proporción son las nasas chilleras, el chinchorro, la pesca con luz, el palangre y el buceo a pulmón

Ingresos, Gastos Y Propiedad De Equipos

Ganancia — La ganancia por día fue de 1200-1500 (23%), el 18% gana entre 900-1000 pesos y los demás entre 30 y 3000 pesos. El 90% de los pescadores conoce las balsas; de estos, el 40% las ha usado.

Gastos — Los pescadores gastan entre 100 y 600 pesos por salida. Éste dinero incluye los gastos en gasolina y almuerzo de los pescadores.

Propiedad de Equipos — El 46% de los pescadores son dueños de sus equipos, mientras que el 40% trabaja para las pescaderías establecidas en Bayahibe, Mano Juan y Catuano, y para dueños de pescaderías de La Romana los cuales setrasladan a la playa arecoger el pescado diariamente. El 14% pide el equipo prestado.

Especies Capturadas — Las especies registradas en la captura durante el censo se muestran en la tabla 1

Actividades Alternativas — El 65% (28) de los pescadores se dedica de manera exclusiva a la actividad pesquera, mientras que los demás se dedican a actividades de venta de comida 8%),albañilería (5%) y en menor porcentaje: construcción, artesanía, pastor evangélico, milicia, agricultura, pintura de brocha gorda, traducción de italiano, ebanistería, corte y confección, músico y comercio.

El 44% de los pescadores no está interesado en cambiar de oficio pero les gustaría aprender otras técnicas de pesca ; los demás mostraron interés en los siguientes oficios: mecánica; artesania, electricidad, ebanistería, Ingles, computadora, carpintería, pintura artística, guías de la naturaleza y transporte turístico. Los pescadores que no han recibido educación primaria expresaron interés en ser alfabetizados

Disminución de los Stocks de Peces
Causas (respuesta de los pescadores):

i) Menos peces y demasiados pescadores,
ii) Muy difícil conseguir carnada,
iii) Es algo bíblico,
iv) Empeoramiento en la condición de los recursos,
v) Paso de las lanchas con turistas ahuyentan los peces,
vi) Uso indiscriminado de artes de pesca nocivas como son la atarraya, el chinchorro y el buceo a compresores, y
vii) Incremento sostenido del número de pescadores explotando un mismo recurso. .

Recomendaciones de Manejo (Respuesta de los Pescadores)
i) Cambiar el uso de las artes y prohibir algunas como los compresores,
ii) Pescar con balsas,
iii) Buscar otro trabajo,
iv) Cambiar el uso de las artes.

Tabla 1. Especies registradas en las capturas en Parque ncional del Este de enera a marzo del 2000

Familia	Nombre común	Nombre científico	# Individuos
Balistidae	Semina, Puerco Negro	*Melichthys niger*	2
	Puerco anaranjado/chuflay	*Aluterus schoepfli*	2
	Chupetin/Lija/chivo	*Aluterus scriptus*	2
	Chincha	*Cantherines pullus*	1
	Peje puerco	*Balistes vetula*	11
Carangidae	Chicharro	*Selar crumenophtalmus*	9
	Cojinua amarilla	*Caranx bartholomaei*	1
	Cojinua	*Caranx ruber*	2
Coryphaenidae	Dorado	*Coryphaena hippurus*	2
Chaetodontidae	Mariposa	*Chaetodon capistratus*	1
	Jurel	*Caranx hippos*	1
Holocentridae	Candil	*Holocentrus adscensionis*	1
	Candil ojo negro	*Holocentrus rufus*	1
Labridae	Capitán	*Lachnolaimus maximus*	1
Lutjanidae	Sama	*Lutjanus analis*	7
	Pargo aleta amarilla	*Lutjanus apodus*	14
	Chillo	*Lutjanus vivanus*	12
	Colirrubia	*Ocyurus chrysurus*	10
Mullidae	Salmonete	*Mulloidichthys martinicus*	2
	Salmonete	*Pseudopeneus maculatus*	2
Ostraciidae	Chapin	*Lactophrys triqueter*	3
Palinuridae	Langosta	*Panulirus argus*	8
	Langosta pinto	*Panulirus guttatus*	14

Tabla 1 cont.

Familia	Nombre común	Nombre científico	# Individuo
Pomacanthidae	Guinea	*Pomacanthus paru*	1
	Guinea prieta	*Pomacanthus arcuatus*	3
	Guinea pinta	*Holacanthus ciliaris*	35
	Banderita, Angel	*Holocanthus tricolor*	1
Pomadasyidae	Bocayate	*Haemulon plumieri*	22
	Bocayate amarillo	*Haemulon flavolineatum*	1
	Bocayate raya azul	*Haemulon sciurus*	1
	Bocayate negro Chopa prieta	*Anisotremus surinamensis*	5
Priacanthidae	Zapatero	*Priacanthus cruentatus*	1
Scaridae	Loro none	*Sparisoma viride*	21
	Loro princesa/ cotorro	*Sparisoma taeniopterus*	2
	Loro	*Sparisomo chrysopterum*	1
Scombridae	Albecora aleta amarilla	*Thunnus albacares*	1
	Atun	*Thunnus albacares*	1
	Carite	*Scomberomorus regalis*	2
	Gustapaná	*Acanthocybium solandri*	1
Serranidae	Cabrilla	*Epinephelus adscensionis*	5
	Mero	*Epinephelus fulvus*	3
		Epinephelus morio	1
Sparidae	Pluma	*Calamus pennatula*	2
Sphyraenidae	Picus	*Sphyraena barracuda*	8
Strombidae	Lambi	*Strombus gigas*	29

CONSIDERACIONES FINALES

Los datos registrados en el presente censo evidencian una intensa explotación de los recursos pesqueros en las aguas que rodean el PNE. A dicha explotación se ven agregados especímenes de *Strombus gigas* de hasta cinco centímetros los cuales se pescan y venden como souvenirs en los pequeños negocios de artesanías de Isla Saona.

El uso de ciertas artes de pesca aparenta haber cambiado con el paso de los años constituyéndose el buceo a compresor el método de pesca mas empleado por los pescadores de la zona en general, con la respectiva disminución del empleo de nasas.

En PNE las pesquerías continúan efectuándose de manera artesanal o de subsistencia al igual que en años anteriores (Alarcón 1996) pero el número de pescadores y en general la presión de pesca y el esfuerzo pesquero ha ido en aumento, aunque en Bayahibe se nota un incremento en la actividad turística y en la integración de algunos pescadores a dicha actividad en donde fungen como guías o boteros que transportan a los turistas desde tierra firme hasta Saona. De igual manera como ha sido indicado en trabajos anteriores (Gálvez et. al. 2000) los pescadores del Parque del Este continúan explotando un recurso marginal y obteniendo de esa explotación el mínimo beneficio. Este podría ser un indicador de la falta de mecanismos de regulación pesquera realistas o de escasez de otras opciones económicas en la región.

Aunque no se vieron o registraron capturas de especies protegidas bajo el convenio CITES algunos lugareños de Mano Juan comentaron que aún se practica en la zona la captura de tortugas de manera ilegal. Asimismo, la captura de lambí en el área correspondiente al canal de Catuano y la pesca con trasmayo continúan siendo una práctica común por parte de los pescadores del lugar ante la ausencia de autoridades correspondientes que hagan cumplir las regulaciones existentes.

Los pescadores de Catuano mostraron su inconformidad con la práctica de buceo a compresor por parte de los pescadores de Mano Juan. Ellos están al tanto de las leyes y prohibiciones pero argumentan que las mismas no se cumplen. En realidad, dadas las condiciones de dependencia del recurso pesca por parte de los comunitarios de Mano Juan, Catuano y Bayahibe y de la vigilancia inefectiva por parte del personal encargado del cumplimiento de las regulaciones, especialmente las que involucren periodos de veda de lambí, meros y langostas, convierten esas mismas regulaciones en medidas de control y/o manejo no realistas.

En cuanto a los buzos a compresor, aun concientes del peligro que encierra esta practica, la mayoría de los pescadores dicen sentirse obligados a practicarlo pues se lo requiere la compañía que los contrata.

Al comparar las informaciones obtenidas durante el presente trabajo con estudios anteriores (Chiappone 1999) se evidencian algunos cambios en la composición por edades de pescadores, número de pescadores faenando en la zona y tiempo (años) de dedicación a la actividad pesquera en la zona. Por ejemplo, para el 1996 y 1997 la edad de los pescadores oscilaba entre 20 - 40 años, mientras que en el presente censo se entrevistaron pescadores de hasta 70 años. De igual manera

se nota la integración de nuevas personas a la actividad pesquera pues se registraron pescadores con menos de 10 años de faena pesquera.

Es evidente que la abundancia de ciertas especies pesqueras es cambiante en diferentes épocas, siendo la captura de especies pelágicas como atún, carite y agujones comunes en los primeros meses del año. El tipo de pesquería pelágica además de reportar buenas ganancias a los pescadores también quita presión a los Recursos mas frecuentemente explotados en las partes someras de la costa.

La variable gama de artes de pesca usadas actualmente en la zona y la combinación de dos o más de ellas hace la evaluación de las pesquerías por arte difíciles de llevar a cabo y la interpretación de los resultados puede ser ambigua.

RECOMENDACIONES

i) Facilitar la realización de pruebas con nuevas tecnologías de pesca, menos nocivas al ambiente como son las balsas (FADs).
ii) Regular la entrada de nuevos pescadores y embarcaciones al parque.
iii) Iniciar un proceso de concienciación de los encargados y dueños de las compañías pesqueras que funcionan en la zona y que controlan en gran parte la actividad pesquera a fin de que colaboren en el respeto a las regulaciones pesqueras vigentes.
iv) Realizar monitoreos de la actividad pesquera en una base anual para determinar la estacionalidad de las pesquerías en los alrededores del PNE para diferentes épocas del año.

LITERATURA CITADA

Alarcón, J. 1996. Monitoring and assesment of the artisanal fisheries operating at Parque Nacional del Este, Dominican Republic. Pags. 1-28. En : Marine Conservation Science MSC 411, Spring 1996. University of Miami Undergraduate Marine Science Program and The Nature Conservancy- Florida and Caribbean Marine Conservation Science Center.

Bustamante, G., M. Chiappone, K. M. Sullivan, R. Torres, Fx. Geraldes and Y. Rodriguez. 1998. Fisheries sampling and reconnaissance in Parque Nacional del Éste, Dominican Republic. Methods manual. 77 pp.

Colom, R., Z. Reyes y Y. Gil. 1991. Censo comprensivo de la pesca costera de la República Dominicana. Paginas 3, 1-34 en: Secretaría de Estado de Agricultura. Sub-secretaría de Recursos Naturales. Proyecto de Promoción de la Pesca Costera Artesanal del litoral sur. Reportes del PROPESCAR-SUR: Contribuciones al conocimiento de las pesquerías en la República Dominicana. / PROPESCAR-SUR.- Barahona, R. D. 1994. 264 pp.

Chiappone, M. (ed.) 1999. Investigaciones pesqueras y su aplicación al manejo de áreas marinas protegidas del Caribe. Estudio del Parque Nacional del Éste, República Dominicana. Parte 1. 20 pp.

Gálvez, J. E., R.E. TORRES and K. M. Sullivan [In press]. Fisherman Surveys as a Management Tool: Case Study of Nearby Communities of Parque Nacional del Este, Dominican Republic. *Proceedings of the Gulf and Caribbean Fisheries Institute*.

Mateo, J., I. Arias, B. Hierro y E. Garrido. 1998 Diseño del programa de pesca de la Laguna de Oviedo, Parque Nacional Jaragua. Paginas 6 en: L. Creswell (ed.) Resúmenes de ponencias de la reunión de pesquerías del Caribe y El Golfo, Saint Croix, 1998.

Torres, R. E., G. Bustamante, M Chiappone, F. X. Geraldes, E. Pugibet, Y. Rodriguez, K. M. Sullivan, and M. Vega. 1998. Fisheries Zoning and Resource Conservation in Parque Nacional del Este, Dominican Republic. *Proceedings of the Gulf and Caribbean Fisheries Institute* **51**:475-491.

The 1998 Florida Special Two-day Sport Spiny Lobster Season: Results of a Mail Survey

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ABSTRACT

A special two-day spiny lobster season for recreational fishers only is held in Florida before the start of the regular commercial and recreational season. This special season has generated much discussion and controversy, as well as many defenders and opponents, especially in the Florida Keys. A mail survey was conducted after the 1998 special sport two-day sport season so that we could determine the level of the spiny lobster harvest, level of participation by fishers, the patterns of travel of the fishers, and any patterns in the survey answers as they relate to the fisher's home residence. The two-day statewide harvest totaled more than 314,000 lobsters. Approximately 39,000 fishers were on the water each day. Two-thirds of the harvest and fishing effort occurred in the Florida Keys. We estimate that those who traveled to the Keys spent approximately $2.3 million during their travels and stay in the Keys and trailered in 2,500 boats. Regarding fishery issues, those living in Monroe, Dade, and Broward counties where most of the fishing occurs, strongly oppose a weekend two-day sport season, whereas those who travel to these areas favor a weekend two-day sport season. Those who hold the opinion that lobster abundance is declining and that bag limits are too high, think that the two-day sport season should be abolished.

KEY WORDS: Florida, spiny lobster, recreational fishery

INTRODUCTION

Recreational fishing for the Florida spiny lobster (*Panulirus argus)* is a popular sport, attracting approximately 120,000 fishers annually. Although lobsters are harvested by recreational fishers throughout Florida's coastal waters, approximately two-thirds of the lobster fishers fish in the Florida Keys (Monroe County).

Since 1975, the State of Florida has administered a special two-day recreational spiny lobster season prior to the beginning of the regular commercial and recreational-fishing season. This special two-day sport season was originally designed to remove some of the pressure from the opening day (August 6) of the regular season, when many recreational and commercial boats traveled to (and sometimes fought over) the same fishing grounds. The special two-day sport season is conducted on the last Wednesday (midnight) through Thursday (midnight) in July. The bag limit is 12 lobsters per person per day, except in Monroe County, where the limit is six lobsters per person per day. Diving at night is banned in Monroe County

but permitted elsewhere. These different regulations were established in response to requests, mainly by Monroe County residents, to attempt to reduce the influx of people into the Keys. Prior to 1993, the statewide bag limit was six lobsters per person per day, and the special two-day sport season occurred on the last Saturday and Sunday of July.

The Florida Marine Research Institute has conducted a mail survey about the special two-day sport season since 1991. We found that the harvest remained steady at approximately 300,000 lobsters statewide with 60% harvested in the Keys. One poor harvest (200,000 lobsters in 1995) was attributable to bad weather (storms and 20+ knot winds) on the second day of the season.

We recently revised our annual special two-day sport season questionnaire so that we could determine how various user groups (principally those who travel to fish for lobsters and those who fish local waters) perceive the special two-day sport season and lobster fishing in general. The survey now contains several fishery-issue questions concerning bag limits and the continuation of the special two-day sport season. We also ask for the respondent's perceptions concerning the abundance of lobsters and the number of commercial traps.

METHODS

Survey methods followed procedures defined by Dillman (1979). Within a week of the conclusion of the special two-day sport season, we mailed 2000 questionnaires with cover letters to current lobster permit holders within the United States. Lobster permit holders were randomly picked from ten geographic strata (Figure 1). Each questionnaire recipient received a follow-up postcard one week later, and seven weeks after the initial mailing, nonrespondents received a reminder letter and another questionnaire. This technique consistently resulted in a 60% response rate.

Harvest estimates were calculated using the means of the catch rate, size, and the number of unlicenced fishers within each group of fishers. Details of each step of the calculations can be found in Sharp et al. (in press). A computer program performing 1000 Monte Carlo randomizations of the survey provided a sampling error term for each harvest estimate. Analytical and descriptive computations were performed by using SPSS.

Five new questions about the special two-day sport season and the lobster fishery in general were added to this survey:

i) Should the special two-day sport end be ended, restricted, continued without change, or broadened?
ii) Should the season be moved to the weekend?
iii) Are bag limits too high or low?
iv) Are spiny lobsters more or less abundant than five years ago?
v) Have the number of traps in the water increased, stayed the same, or declined over the past five years?

The responses to these questions along with the respondent's resident region

were analyzed using nonlinear canonical correlation to determine patterns in the respondents' answers and to associate patterns of responses to resident regions. The responses to these five questions, the corresponding resident region, and whether or not the respondent fished were entered as single nominal sets.

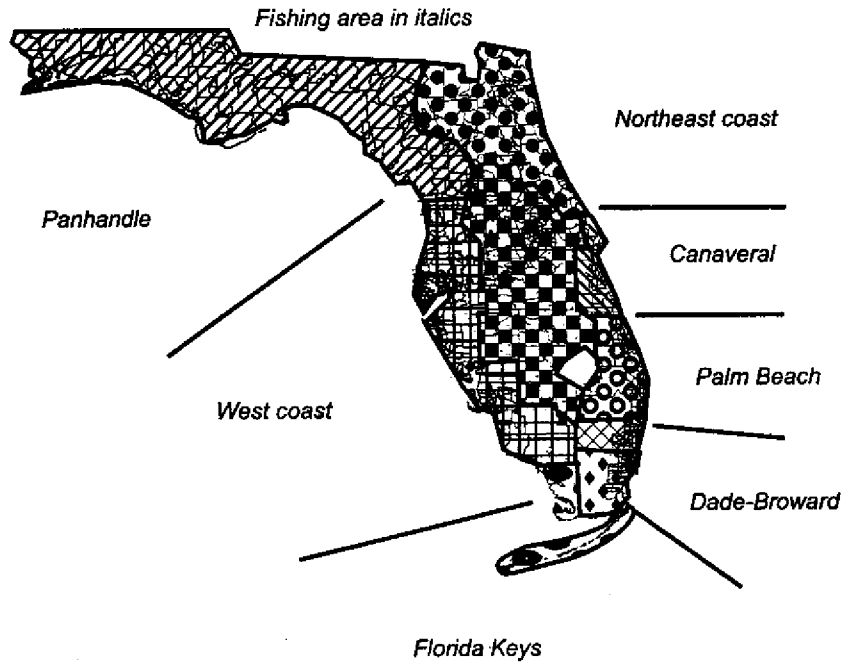


Figure 1. Residence regions used in surveys (based on zip codes - one additional residence region encompasses all zips codes outside Florida).

RESULTS

The largest per-capita concentration of lobster permit holders resided in Monroe county where 196 of 1,000 persons purchased the permit (Table 1). This was an order of magnitude greater than anywhere else in the state, but in spite of the high popularity of the permit in Monroe County, represented only 13% of total sales. Total per-capita sales of the permit were generally above average (more than 10 per 1,000 persons) on the east coast of Florida, from Miami to Cape Canaveral. For the remainder of Florida, sales were greatest along the west coast of Florida. On a per-capita basis, sales of the lobster permit to non-Floridians were less than one sale per 1,000 but the total number of permits sold to non-Floridians were of the same order of magnitude as the total number of permits sold to Monroe County residents (13 to 16 thousand, respectively).

The overall participation rate for the 1998 special two-day sport season was 31% (Table 1). Participation rates generally followed the pattern of stamp sales. Monroe, Dade, Broward, and Palm Beach counties had the highest (approximately 40%) participation rates and the other areas had participation rates of 10 to 30%.

The estimated harvest statewide was more than 314,000 lobsters (Table 2). The bulk of the harvest (60%) came from the Florida Keys (more than 189,000 lobsters). An average of nearly 39,000 fishers were on the water each of the two days with 69% of them fishing in the Keys (Table 3). In most areas, the local residents harvested the majority of the lobsters (>90%) (Figure 2), but in the Keys, travelers as a whole harvested the majority of the lobsters even though the group comprising local residents (23%) was larger than any other single regional group of fishers. Travelers from the west coast (22%) and Palm Beach (18%) account for the majority of the Keys harvest by non-locals.

We estimate that those who traveled to the Keys to participate in the special two-day sport season spent approximately 2.3 million dollars over the course of their trip (Table 4). The bulk of the money was spent by those from the west coast of Florida (0.8 million). The length of stay of a nonresident was typically between four and seven days. The length of stay was longest for those traveling from outside Florida (10 days) and shortest for those from neighboring Dade County (2 days). More than 2,500 boats were trailered into the Keys for the special two-day sport season, with the majority coming in from the west coast (880 boats). Those traveling from out of state and those traveling from Dade and Palm Beach Counties were the most likely to have a second home there or be staying at a friend's house. Motels and vacation rentals made up the bulk of accommodations for those from the central and west coast portions of the state. Those who traveled the greatest distances to get to the Keys tended to travel farther into the Keys than did those who came in from a short distance (Figure 3).

Table 1. Demographics of lobster permit sales and participation in the 1998 special two-day sport season.

Residence Region	Population* (x1000)	Lobster** permits	Permits per 1000 persons	Percent*** participation
Outside Florida		12,924		7
Panhandle	1,357	4,350	3	18
N.E. coast	1,811	4,913	3	27
West coast	3,666	22,092	6	27
Central inland	2,404	8,355	3	30
Centr. E. coast	612	10,451	17	29
Palm Beach	1,328	12,986	10	45
Broward	1,503	10,545	7	36
Dade	2,152	24,314	11	36
Monroe	81	15,896	196	43

*Estimated 1998 population obtained from U.S. Census Bureau (http://www.census.gov/index.html)

**Numbers represent our estimated partitioning of valid permits during the 1998 special two-day sport season; total number of permits was 126,826

***Overall estimated percentage of participation of lobster permit holders was 31%.

Table 2. Estimated number of lobsters harvested by recreational fishers during the 1998 special two-day sport season, by residence region of the fisher and by fishing area. Cells marked "nd" indicate that questionnaire responses were not received for that residence region and fishing area.

	Fishing area					
Resident Region	**Keys**	**Dade-Broward**	**Palm Beach**	**Canaveral**	**Elsewhere**	**Totals**
Outside Florida	2,997	nd	nd	nd	nd	2,997
Panhandle	5,963	nd	nd	nd	80	6,043
N.E. coast	4,520	61	nd	nd	703	5,284
West coast	41,250	nd	243	nd	862	42,355
Central inland	19,235	nd	nd	2,875	1,494	23,604
Central coast	11,071	nd	3,379	10,252	nd	24,702
Palm Beach	33,433	2,821	14,712	nd	nd	50,966
Broward	7,720	22,886	nd	nd	nd	29,606
Dade	20,536	46,470	nd	nd	nd	67,006
Monroe	42,542	204	nd	nd	nd	42,746
Totals	189,267	72,381	18,334	13,127	3,139	314,582

Table 3. Estimated number of fishers by residence region and fishing areas during the 1998 special two-day sport season. Cells marked "nd" indicate that questionnaire responses were not received for that residence region and fishing area. Because not everyone fished both days, the number indicates the average number of fishers on the water for both days.

	Fishing areas					
Residence Region	**Keys**	**Dade-Broward**	**Palm Beach**	**Canaveral**	**Elsewhere**	**Totals**
Outside Florida	952	nd	nd	nd	nd	952
Panhandle	812	nd	nd	nd	40	850
N.E. coast	1,021	41	61	nd	202	1,325
West coast	5,639	nd	nd	58	359	6,056
Central inland	2,362	nd	nd	210	188	2,760
Central coast	1,178	nd	630	1,112	nd	2,910
Palm Beach	4,182	191	2,110	nd	nd	6,483
Broward	1,018	2,167	nd	nd	nd	3,185
Dade	3,066	4,637	nd	nd	nd	7,703
Monroe	6,466	90	nd	nd	nd	6,556
Totals	26,696	7,126	2,801	1,380	977	38,980

Table 4. Estimated economic impacts of those who traveled to the Florida Keys to fish during the special two-day sport season.

Residence Region	Money spent (dollars)	Length* of stay (days)	Boats trailered	Accommodations (percent)			
				Motel	Vacation Rental	Camp/ other	2nd/friend home
Outside Florida	120,000	10	28	29			71
Panhandle	91,650	4	44	29	14	43	14
N. E. coast	132,160	7	123	25	50	13	12
West coast	821,700	5	880	32	29	30	10
Central inland	330,720	5	403	37	37	15	11
Central coast	108,400	7	134		43	29	29
Palm Beach	434,520	4	551	17		33	40
Broward	89,400	4	86	17		33	17
Dade	209,400	2	300	33		20	47
Totals	2,337,950		2,549				

*Median length of stay

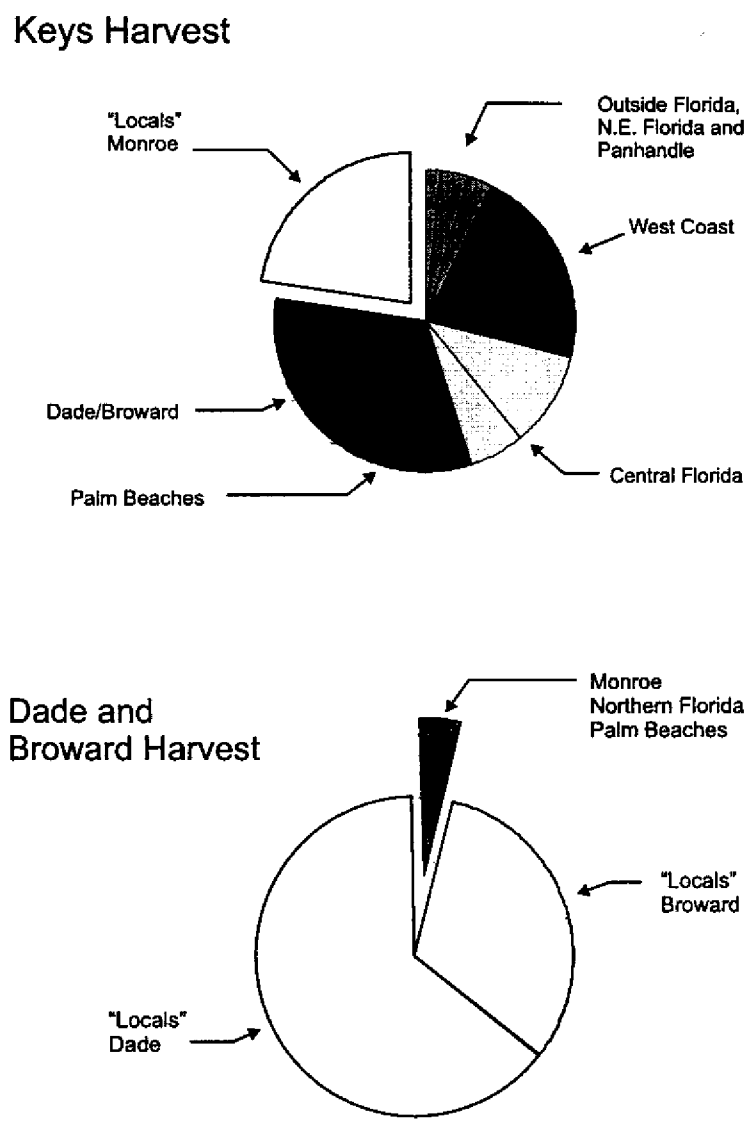


Figure 2. Pie charts representing proportions of the total lobster harvest in the Keys and Dade-Broward fishing areas harvested by fishers from the various residence zones. Portions of the harvest taken by residents from outside the fishing area are shaded, and harvest by "Locals," those residing in the fishing area, are shown in white.

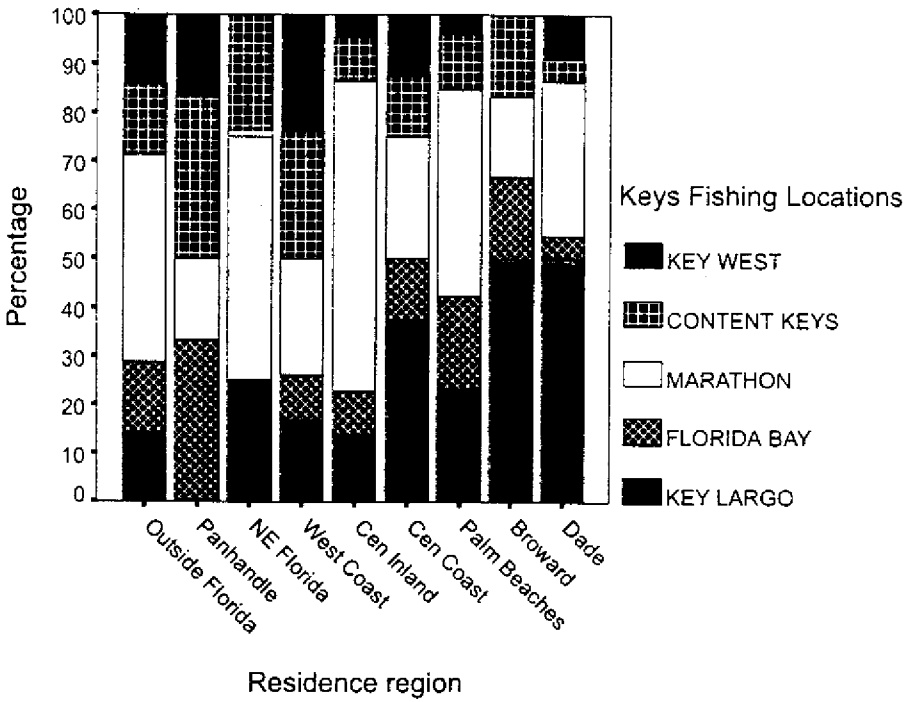


Figure 3. The percentage of fishers by residence region fishing in different locations within the Keys. Residence regions are arranged so that distance traveled to the Keys decreases from left to right (i.e. residents of regions Outside Florida and the Panhandle traveled the longest distances and those from Dade traveled the shortest distance). Destinations within the Keys are arranged so that distance traveled within the Keys increases from bottom to top (i.e., Key Largo is the shortest distance into the Keys and Key West is the farthest).

The nonlinear canonical correlation analysis used to determine the relationships between these variables revealed three basic groups as shown by the component loadings of the variables (Figure 4). Group 1 was based on respondents' answers to whether or not they fished and to their perception concerning whether the number of traps has increased of decreased over the past five years. Those who fished generally expressed the opinion that the number of traps had decreased whereas

those who did not fish were more likely to express an opinion that the number of traps had increased (Figure 5A). Group 2 was based on the respondents' area of residence and opinions concerning whether the special two-day sport season should be moved to the weekend. Those living in the Keys and south Florida were generally against moving the sport season back to the weekend, whereas those from near the middle of the state were neutral and those living along the west coast, north Florida, and outside Florida were more likely to express the opinion that the sport season should be moved to the weekend (Figure 5B). Group 3 was based on responses to the bag-limit question, perceptions of lobster abundance, and responses concerning the future of the special two-day sport season. Opinions about the future of the special two-day sport season range from "end it now" to "keep it forever". Although the opinion that the special two-day sport season be ended was strongest in the Keys (50% held that view), residency was not the strongest factor associated with this opinion. Regardless of where those in group 3 live, the respondents who believed that the abundance of lobster is declining and that bag-limits are too high are the most likely to express the opinion that the special two-day sport season be ended (Figure 5C).

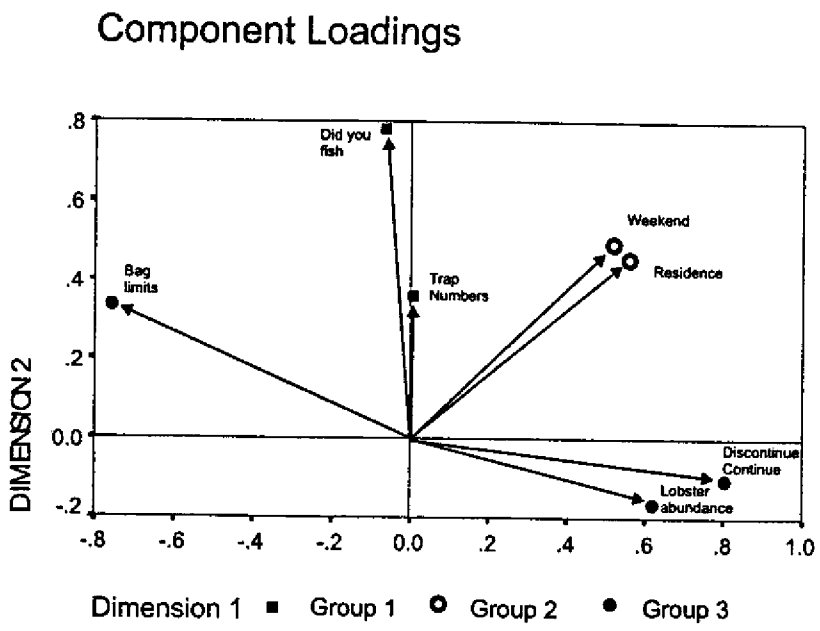


Figure 4. Component loadings results of the nonlinear canonical correlation analysis of fishery issue questions and residence regions. Each mark on the chart represents the component loadings for one of six fishery-related questions (see text) and the residence region. Groupings were determined by inspection and were comprised of component loadings that have nearly the same angle or are nearly 180° away from the origin.

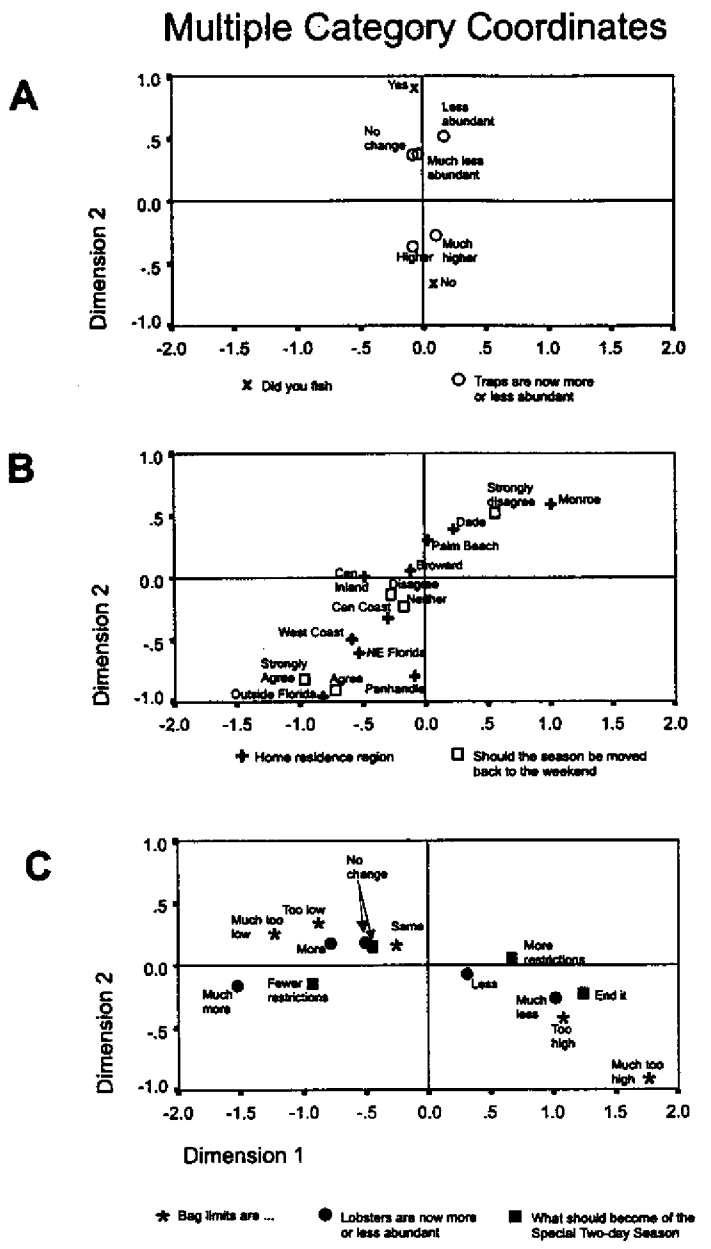


Figure 5. Multiple Category Coordinates for Group 1 (A), Group 2 (B), and Group 3 (C). Each mark on these charts represents the coordinates for each possible response to the six fishery questions. See text for an explanation of the relationship of the responses.

DISCUSSION

Since its inception in 1975, the special two-day sport season has attracted many lobster fishers to the Keys. The Florida Keys remain a popular destination because they contain a large population of spiny lobsters, large areas of shallow water with lobsters, and a long reef tract that attracts both divers and snorkelers. In addition, the Florida Keys Tourism Board advertises the event to attract visitors. In spite of the divided opinions about the season, especially among Monroe County residents, satisfaction about the fishing experience remains high among those who fish (Bertelsen and Hunt 1991, FMRI, unpub. data).

The special two-day sport season was created to alleviate problems, primarily in the Keys, caused by the large number of both recreational and commercial fishers who harvest lobsters on the opening day of the regular season. An assumption was that a miniature recreational-only season held on a weekend prior before the opening of the regular season should mitigate some of the recreational "opening day fever" that overwhelmed the fishery on the opening day. Subsequent modifications (moving the special season to midweek and increasing bag limits outside the Keys) were instituted to reduce the overall level of participation in the Keys. Unfortunately, there were no surveys made prior to the modifications that could be used to assess these modifications. However, previous surveys have shown that approximately one third of those who fish the special two-day season do not fish during the regular season (FMRI unpub. data). This suggests that many recreational fishers do satisfy their "opening day fever" during the special two-day sport season. However, a popular perception expressed on our surveys and at public hearings concerning lobster fishing is that the special two-day sport season and opening day are as crowded as ever. If this is true, perhaps the reason is that recreational lobster fishing has grown enough to populate both events. Answers to trends in popularity of the two events are beyond the scope of this paper, but future analyses that integrate patterns of movements by fishers since 1992 may be able to determine if perception and our mail surveys agree or disagree.

ACKNOWLEDGMENTS

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LITERATURE CITED

Bertelsen, R.D. and J.H. Hunt. [1991]. Results of the 1991 mail surveys of rescreation lobster fishermen (Special Sport Season and Regular Season Surveys). Florida Marine Fisheries Commission Report. 27 pp. Unpub. Ms.

Dillman, D.A. 1979. *Mail and Telephone Surveys: the Total Design Method.* John Wiley and Sons, New York, New York USA. 325 pp.

Sharp, W.C., R.D. Bertelsen, and J.H. Hunt. [In Press]. The 1994 Florida recreational spiny lobster fishing season: results of a mail survey. *Proceedings of the 48th Gulf and Caribbean Fisheries Institute.*

Observaciones Preliminares sobre la Pesquería de Meros (Serranidae: Epinephelinae) en el Parque Marino Nacional "Arrecife Alacranes", Yucatán, México

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RESUMEN

En el sur del Golfo de México, el Arrecife Alacranes constituye la formación arrecifal más importante de la plataforma continental de la Península de Yucatán. Debido a su gran potencial científico y económico, este arrecife fue declarado por el Gobierno mexicano como Parque Marino Nacional en junio de 1994. Cada año, de julio a febrero, cuatro cooperativas pesqueras explotan en esta área la langosta y el mero. En el presente estudio se analizó las capturas realizadas entre enero de 1997 y febrero del 2000 por los barcos pesqueros de la cooperativa SCPP "Pescadores de Sisal." Diez especies de meros: *Epinephelus guttatus, E. itajara, E. morio , E. striatus, Mycteroperca bonaci, M. interstitialis, M. microlepis, M. phenax, M. tigris* y *M. venenosa* son explotados por esta pesquería. *M. bonaci* constituyó el serránido más abundante (en peso vivo) en las capturas, seguido por *E. morio* y *E. guttatus*. El análisis de las gónadas de los especímenes capturados entre noviembre de 1999 y febrero del 2000, permitió determinar que individuos machos y hembras de *M. bonaci*, *E. guttatus*, *M. venenosa* y *M. tigris* estaban sexualmente activos durante este periodo. Los resultados de este estudio hacen suponer que el Arrecife Alacranes puede constituir un área de reproducción para varias especies de meros consideradas de mayor importancia comercial en el Golfo de México.

PALABRAS CLAVES: Arrecife alacranes, meros, pesquería

Preliminary Observations on the Grouper Fishery (Serranidae: Epinephelinae) in Nacional Marine Park "Alacranes Reef", Yucatan, Mexico

ABSTRACT

Alacranes Reef is the most important coraline formation on the Yucatan continental shelf, in the southern Gulf of Mexico. Due to its high scientific and economic potential, the mexican governement declared it a Nacional Marine Park in June 1994. Every year from July to February, four fishing cooperatives are allowed to exploit spiny lobsters and serranid fishes in the area. The present study includes the analysis of the catches provided by the cooperative *SCPP "Pescadores de Sisal"*, between January 1997 and February 2000. The target species of this

fishery are 10 groupers: *Epinephelus guttatus, E. itajara, E. morio, E. striatus, Mycteroperca bonaci, M. interstitialis, M. microlepis, M. phenax, M. tigris* y *M. venenosa*. *M bonaci* was the most important (by weight) in the catches, followed by *E. morio* and *E. guttatus*. The analysis of gonads from specimens caught between November 1999 and February 2000 showed that male and female individuals of *M. bonaci, E. guttatus, M. venenosa* y *M. tigris* were sexually active during this period. The results of this study suggest that Alacranes Reef may represent a reproductive area for various grouper species which are of considerable commercial interest in the Gulf of Mexico.

KEY WORDS: Alacranes Reef, Fishery, Groupers

INTRODUCCIÓN

Por su extensión, el Arrecife Alacranes constituye la más importante de las formaciones coralinas presentes en la parte noroeste de la plataforma continental de la Península de Yucatán (Banco de Campeche). Este complejo arrecifal se caracteriza también por presentar una elevada biodiversidad en algas y pastos marinos, moluscos, crustáceos, corales, reptiles, peces, aves y mamíferos marinos (Kornicker et al. 1959, Kornicker y Boyd 1962, Garduño 1988, Canela-Rojo 1992, Aldana-Aranda 1993, Carricart-Gavinet y Horta-Puga 1993, Martínez-Guzmán y Hernández-Aguilera 1993, Huerta-Múzquiz et al. 1994). Debido a su gran potencial científico, económico y cultural, este sistema arrecifal único fue decretado Area Natural Protegida con el carácter de Parque Marino Nacional (PMN) el 6 de junio de 1994. En el Parque Marino Nacional Arrecife Alacranes (PMNAA) únicamente se autorizan las actividades relacionadas con la preservación de los ecosistemas acuáticos y sus elementos; la investigación, recreación y educación ecológica, y el aprovechamiento de recursos naturales. Se permite la pesca deportiva y comercial de las especies ícticas, malacológicas y carcinológicas, en las áreas, épocas y con los limites, artes, equipos y métodos que se establezcan en el programa de manejo de esta zona (Diario Oficial de la Federación 1994). Cuatro Sociedades Cooperativas de Producción Pesquera (SCPP) del puerto de Progreso gozan de permiso para capturar las langostas (*Panulirus argus* y *P. guttatus.*) y los peces de escamas (Serranidae, Lutjanidae, Gerridae, Sphyraenidae, Labridae) en este PMN: SCPP "Pescadores de Sisal", "Pescadores del Golfo de México", "Alacran Reef" y "Pescadores de la Jurisdicción Marítima de las Costas del Estado de Yucatán" (Canela-Rojo 1992, Aldana-Aranda y Domínguez-Tec 1994, Ardisson y Durán-Nájera 1997). Actualmente, estas cooperativas desempeñan sus actividades en el arrecife únicamente durante la temporada autorizada para la captura de la langosta la cual inicia el 1 de julio y termina el 29 de febrero de cada año (SEMARNAP 2000a).

El Arrecife Alacranes parece constituir una importante zona para la reproducción, refugio y alimentación de diversas especies marinas, muchas de ellas de gran valor económico para la región como lo son el caracol rosado (*Strombus*

gigas), el pulpo (*Octopus* spp.), la langosta, el mero (*Epinephelus* spp. , Mycteroperca spp.) y el tiburón (*Carcharhinus* spp.). Estudios preliminares permitieron identificar en esta zona a 142 especies de peces teleósteos agrupadas en 82 géneros y 41 familias. Una de las familias mejor representada en cuanto a diversidad especifica corresponde a la de los serránidos con al menos 12 especies que pertenecen a los géneros: *Cephalopholis*, *Epinephelus*, *Mycteroperca*, *Hypoplectrus* y *Serranus* (Hildebrand et al. 1964, Garduño 1988). Los recursos pesqueros del PMNAA han sido aprovechados desde el siglo XIX. Durante el último tercio del siglo pasado, la presión de pesca sobre el caracol, la langosta, el mero y el tiburón, se ha incrementado a grado tal que se estima que algunas de estas pesquerías ya muestran síntomas de sobreexplotación (Ardisson y Durán-Nájera 1997). Desafortunadamente, no existen estadísticas oficiales sobre el sector productivo que ejerce la pesca en el arrecife ni tampoco sobre las características cuali y cuantitativa de sus capturas en esta zona (Aldana-Aranda y Domínguez-Tec 1994). Hoy en día, los serránidos constituyen todavía uno de los recursos marinos más importantes del arrecife, tanto desde el punto de vista ecológico como económico. En efecto, este recurso esta representado por unas de las mayores especies depredadoras del ecosistema arrecifal, las cuales constituyen, después de la langosta, el segundo producto de más alto valor comercial que se pesca en Alacranes. En el marco de la actualización del programa de manejo del PMNAA, elaborado entre 1995 y 1997 (Ardisson y Durán-Nájera 1997), el presente estudio tiene como propósito proporcionar información preliminar sobre la explotación por pesca de los serránidos en esta área.

MATERIAL Y MÉTODOS

Area de Estudio

El PMNAA esta localizado en la parte central del Banco de Campeche (22° 21' - 22° 35' N y 89° 37' - 89° 49' O), a 132 km al norte del puerto de Progreso en el estado de Yucatán (Figura 1). Es un complejo arrecifal emergente de forma oval que cubre una área total de 293 km^2, con una longitud y anchura máximas de 26.5 km y 14.8 km. Es el único de todos los arrecifes de la plataforma continental de Yucatán que presenta una laguna central (Kornicker et al. 1959, Kornicker y Boyd 1962, De la Cruz-Agüero et al. 1993, Bello-Pineda 1998). Tres zonas pueden ser distinguidas en esta formación coralina: la zona de barlovento al noreste, con una barrera arrecifal semicircular de unos 34 km de largo que alcanza el nivel del mar; la zona de sotavento al suroeste, totalmente submergida entre 1 m y 10 m de profundidad; la zona de laguna central con 23 m de profundidad máxima, numerosos bajos arrecifales y arenales, pequeños atolones e islas. Las cinco islas del arrecife ubicadas en la laguna central cerca de la orilla interna de la zona de sotavento, son en dirección norte-sur: Isla Desterrada, Isla Muertos o Desertora, Isla Pérez, Isla Pájaros e Isla Chica o Blanca (Figura 2). Estas islas están constituidas de arena y grava no consolidadas y presentan una vegetación de tipo duna costera formada por

plantas pioneras (Kornicker et al. 195, Kornicker y Boyd 1962, Flores-Guido 1983, 1992). El clima en esta área es de tipo seco-cálido, con lluvias escasas y temperatura media anual de 26.7°C (rango entre 10°C y 40°C). Las corrientes marinas se dirigen al oeste y los vientos dominantes, más intensos entre octubre y marzo, provienen del este y noreste a los cuales se suman los efectos de tormentas tropicales, huracanes y nortes (Logan et al., 1969).

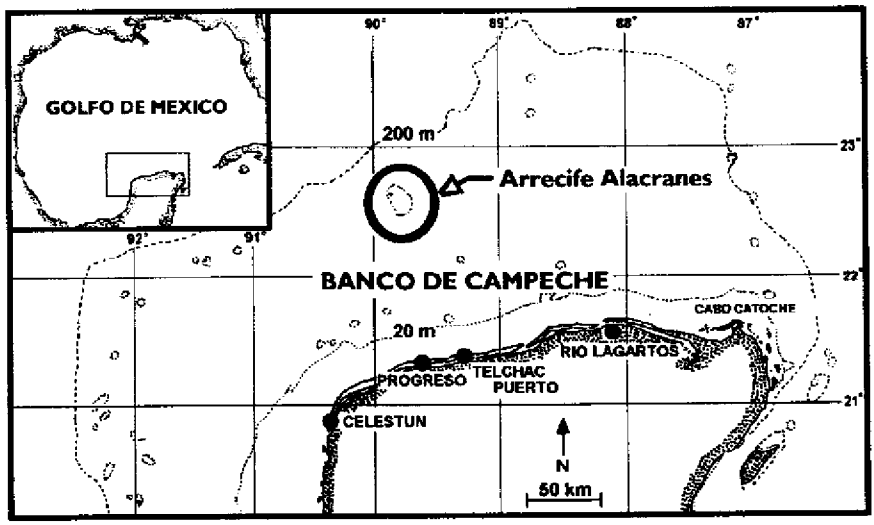


Figura 1. Ubicación geográfica del Parque Marino Nacional Arrecife Alacranes en la plataforma continental de la Península de Yucatán (Banco de Campeche).

Análisis de Desembarques en el Puerto

La producción pesquera de meros del Arrecife Alacranes, expresada en peso desembarcado (organismos eviscerados), fue analizada tomando en cuenta la información disponible contenida en los registros de captura mensual de la SCPP "Pescadores de Sisal" para el periodo enero de 1997 - febrero de 2000. Las otras sociedades no tenían la costumbre de llevar un registro de sus volúmenes de producción pesquera o expresarón el deseo de no colaborar con el estudio propuesto. Además, en noviembre de 1999 los autores analizarón directamente un desembarque de la SCPP "Pescadores de Sisal" con el afán de identificar personalmente a las especies explotadas, estimar el número de individuos desembarcado por cada especie y definir los intervalos de tallas a las cuales fueron capturadas.

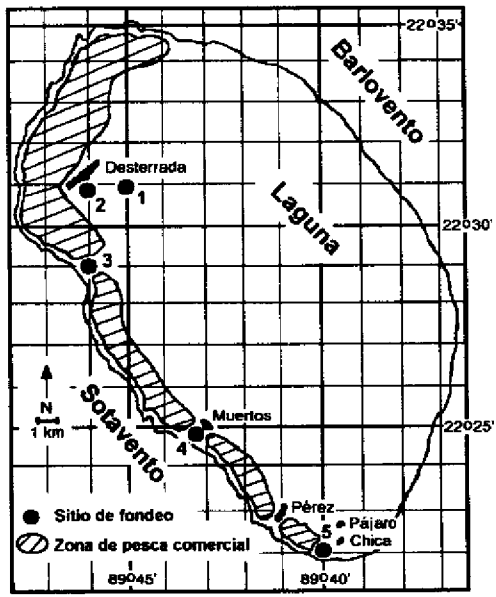


Figura 2. Sitios de fondeo y zonas de pesca de meros del buque pesquero "Propemex 41" de la SCPP "Pescadores de Sisal" en el PMN "Arrecife Alacranes" de noviembre de 1999 a febrero de 2000. 1 - 31/01/00; 3-10/02/00; 18-20/02/00. 2 - 20-26/11/99; 9-20/12/99; 3- 21 y 22 /02/00; 4 - 28-29/11/99; 5 - 30/01/00.

Análisis de Capturas a Bordo

De noviembre de 1999 a febrero de 2000 se analizarón las capturas de meros realizadas por dos de los tripulantes del barco pesquero "Propemex 41" de la SCPP "Pescadores de Sisal". Los organismos fueron capturados con arpón en la parte de sotavento del arrecife, entre 7 y 13 m de profundidad (Figura 2). Todos los especímenes capturados fueron identificados, medidos (longitudes total: Lt y furcal: Lf), pesados (pesos total: Pt y del pez eviscerado: Pe) y sus gónadas fueron extraídas y pesadas (Pg). El sexo y estadio de desarrollo sexual de los organismos fueron determinados utilizando criterios microscópico (histología) y ponderal (índice gonadosomático). Para el estudio histológico de las glándulas sexuales, una muestra de gónada de cada organismo capturado fue fijada en líquido de Bouin, deshidratada, incluida en Paraplast, cortada a un espesor de 6 µm, teñida por el Tricromo en un tiempo de Gabe y Martoja y montada en resina sintética (Gabe 1968). El examen microscópico de los cortes histológicos fue realizado tomando en cuenta los criterios propuestos por Moe (1968) y Brulé et al. (1999) para el estudio de la gametogénesis y la definición de las clases sexuales en *E. morio*. El índice gonadosomático (IGS) se calculó según la fórmula: IGS = 100 x Pg/Pev.

RESULTADOS

Características Generales de la Pesquería

Un total de 5 embarcaciones escameras nodrizas (SCPP "Juridiscción" con dos; SCPP "Sisal", "Golfo de México" y "Alacran Reef" con una cada una) explotan los recursos marinos en el PMNAA durante ocho meses al año (julio-febrero). La langosta se captura con mayor esfuerzo entre julio y octubre, en la zona de barlovento y en diversas partes de la laguna. Durante este periodo, los meros se capturan junto con la langosta pero como un recurso adicional. Estos representan el principal recurso explotado durante la segunda mitad de la temporada de pesca (noviembre a febrero) cuando son capturados en la zona de sotavento del arrecife. Cada embarcación nodriza transporta varios alijos equipados con motor fuera de borda. Una vez que ésta fondea en una zona del arrecife, los alijos, cada uno con dos pescadores a bordo, se dispersan en el área de pesca para realizar sus capturas desde las 8:00am hasta las 4:00pm. Los meros son capturados con arpón durante la realización de inmersiones a pulmón o eventualmente con la ayuda de un compresor de aire. En condiciones óptimas (clima favorable, pesca abundante) las embarcaciones realizan dos salidas de pesca al mes con una duración de hasta 15 días máximo. Las características técnicas de la embarcación de la SCPP "Pescadores de Sisal" utilizada para este estudio se presentan en la Tabla 1.

Tabla 1. Características técnicas del buque escamero "Propemex 41" de la SCPP "Pescadores de Sisal" de Progreso utilizado en la pesca de langosta y peces de escama en el PMN Arrecife Alacranes.

Eslora	14.6 m
Tonelaje neto	24.59 toneladas
bruto	40.99 toneladas
Casco	Fibra de vidrio
Potencia	166 H.P.
Velocidad	10-12 nudos[1]
Autonomía	15-18 días
Capacidad bodega	15 toneladas
Tripulacion	14 personas
Alijos : material	Madera
eslora	2 m
propulsión	Motor fuera de borda 15 H.P.
número	8 máximo
Artes de pesca	Arpón (escama); gancho (langosta)
Técnica de pesca	Inmersiones a pulmón y con compresor de aire

[1] 6-8 horas de viaje entre el puerto de Progreso y el PMN Arrecife Alacranes.

Volumen de Producción

De enero de 1997 hasta marzo de 2000 el volumen de producción de serránidos alcanzado por la SCPP "Pescadores de Sisal" fue, en promedio, de 990 kg por viaje. Las capturas fluctuaron entre 846 kg y 1,119 kg de producto obtenido por viaje en

el periodo 1997-1999. Durante el primer trimestre de 2000 el volumen de producción alcanzó solamente unos 430 kg por viaje (Tabla 2).

Tabla 2. Registro de capturas de meros realizadas en Arrecife Alacranes por la Cooperativa SCCP "Pescadores de Sisal", entre enero de 1997 y marzo de 2000. Los valores corresponden al peso desembarcado (producto eviscerado). *E g: Epinephelus guttatus; E i: E. itajara; E m: E. morio; E s: E. striatus; M b: Mycteroperca bonaci; M i: M. interstitialis; M m: M. microlepis; M p: M. phenax; M t: tigris; M v: M. venenose.*

Especies	Volumen de producción en kg y (%)				
	Año				
	1997[3]	1998[3]	1999[3]	2000[3]	1997-2000
Mero grande[1]	3,744 (40.2)	2,521 (15.1)	997 (10.7)	---	7,262 (19.8)
Mero mediano[2]	625 (6.7)	370 (2.2)	595 (6.4)	---	1,590 (4.3)
E g	1,451 (15.6)	883 (5.3)	9 (0.1)	432 (33.5)	2,775 (7.6)
E i	25 (0.3)	22 (0.1)	—	—	47 (0.1)
E m/E s	1,547 (16.6)	4,547 (27.2)	417 (4.5)	130 (10.1)	6,641 (18.1)
M b	1,902 (20.4)	7,046 (42.2)	7,042 (75.5)	681 (52.8)	16,671 (45.5)
M m	—	1,085 (6.5)	—	—	1,085 (3.0)
M p/M i	16 (0.2)	76 (0.5)	6 (0.1)	—	98 (0.3)
M v	—	152 (0.9)	262 (2.8)	47 (3.6)	461 (1.3)
Total	9,310	16,702	9,328	1,290	36,630

[1] Organismos cuyo Pev > 3 kg (principalmente M b)
[2] Organismos cuyo Pev = 1-3 kg (E m; E s; M t; M v)
[3] Los números de viajes de pesca fueron de 11 en 1997, 14 en 1998, 9 en 1999 y 3 entre enero y marzo de 2000. Hasta 1998 la vigilancia para el cumplimiento de los periodos de veda establecidos para la langosta y el caracol rosado en el PMN estuvo a cargo de las embarcaciones de las cooperativas, lo que les permitió realizar capturas de escamas todo el año en esta área.

Especies Explotadas

El análisis de los registros de captura así como las observaciones realizadas durante el desembarque del 28 de noviembre de 1999 y a bordo de la embarcación pesquera permitieron identificar 10 especies de mero en las capturas comerciales efectuadas en el arrecife: *Epinephelus guttatus*, *E. itajara*, *E. morio*, *E. striatus*, *Mycteroperca bonaci*, *M. microlepis*, *M. interstitialis*, *M. phenax*, *M. tigris* y *M. venenosa*.

Composición de las Capturas

De enero de 1997 hasta febrero de 2000, *M. bonaci* constituyó la especie más abundante en las capturas en cuanto al peso de producto desembarcado, seguida en importancia por *E. morio* y *E. guttatus*. Así mismo, los datos obtenidos durante el examen del desembarque de noviembre de 1999, expresados en número de organismos capturados, confirmaron la predominancia de estas tres especies en las capturas comerciales (Figura 3). En relación con su tamaño, los organismos se distribuyeron en los intervalos de tallas (Lt) siguientes: 46 - 64 cm para *E. morio* (N = 20); 45 - 51 cm para *E. striatus* (N = 4); 48-102 cm para *M. bonaci* (N = 77), 57 cm para *M. interstitialis* (N = 1); 58 - 63 cm para *M. microlepis* (N = 3); 51 y 52 cm para *M. phenax* (N =2); 53 - 57 cm para *M. tigris* (N = 3) y 56 - 71 cm para *M. venenosa* (N = 3). Las tallas de los ejemplares de *E. guttatus* (N = 5) y de *E. Itajara* (N = 1) no pudieron ser registradas.

De noviembre de 1999 a febrero de 2000 se analizaron un total de 287 meros capturados en la zona de sotavento del arrecife. Siete especies fueron encontradas durante estos muestreos: *E. guttatus*, *E. itajara*, *E. morio*, *E striatus*, *M. bonaci*, *M. tigris* y *M .venenosa*. Los ejemplares de *M. bonaci* (N = 206) y , en menor grado, los de *E. guttatus* (N = 40) y *M. venenosa* (N = 29) predominaron en las capturas. Los organismos machos se distribuyeron siempre en las clases de tallas superiores de cada distribución de frecuencias de longitudes (Figuras 4 y 5). El estudio histológico de las gónadas permitió observar que varios ejemplares hembras y/o machos de seis de las especies encontradas estaban sexualmente activos (maduros, en desove/emisión, en postdesove) en el arrecife, durante el periodo de estudio (Tabla 3). En particular, en febrero se observó 35 hembras de *E. guttatus* maduras con ovocitos en fin de vitelogenésis secundaria en sus ovarios (IGS = 14.1-33.4 %) y tres hembras de *M. bonaci* en desove (IGS = 1.7% y 3.0%) o postdesove (IGS = 0.8%) presentando, respectivamente, folículos postovulatorios u ovocitos vitelogénos en atresia en sus ovarios.

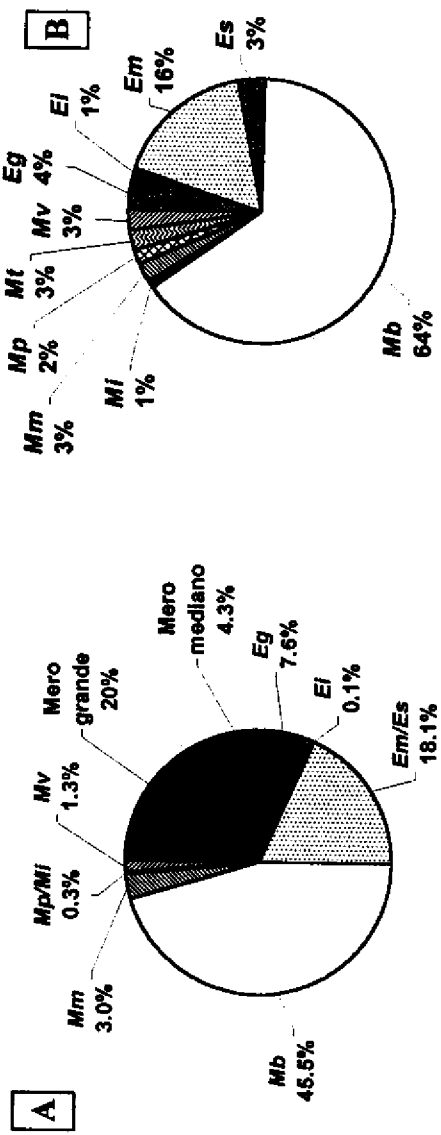


Figura 3. Composición relativa de las capturas de meros realizadas por la SCPP "Pescadores de Sisal" en el PMN Arrecife Alacranes. Peso desembarcado entre enero de 1997 y febrero de 2000 (A). Número de individuos observado en el desembarque del 12 de noviembre de 1999 (B). Eg: *Epinephelus guttatus*; Ei: *E. itajara*; Em: *E. morio*; Mb: *Mycteroperca bonaci*; Mi: *M. interstitialis*; Mm: *M. microlepis*; Mp: *M. phenax*; Mt: *M. tigris*; Mv: *M. venenosa*.

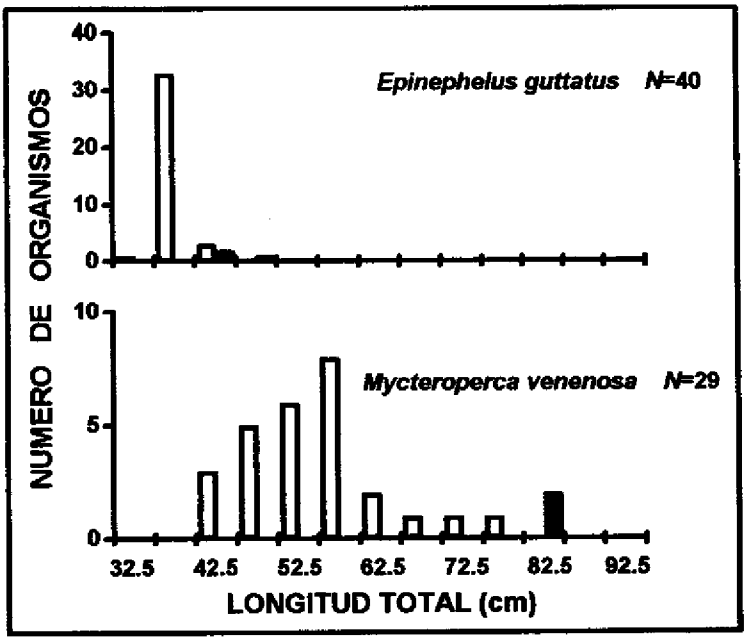


Figura 4. Distribuciones de frecuencias de tallas de hembras (blanco) y machos (negro) de *M. bonaci* capturados en el PMN Arrecife Alacranes, entre noviembre de 1999 y febrero de 2000.

DISCUSIÓN

Debido a la falta de estadísticas oficiales disponibles sobre la explotación de los serránidos en el PMNAA y las limitaciones logísticas encontradas durante la realización del estudio, no fue posible estimar la producción total obtenida por las cuatro cooperativas de pescadores que usufructúan los recursos marinos del arrecife. Manzanilla *et al.* (1988) reportaron que la pesquería de meros en Alacranes sufrió una caída de producción de 49,240 kg en 1985 a 31,000 kg en 1987. Sin embargo, se observó a través de este estudio que los volúmenes promedios de capturas de meros por viaje de la SCPP "Pescadores de Sisal", durante el periodo 1997-1999, fueron muy similares a los de captura de escama (más del 91% son meros) reportados por la SCPP "Pescadores del Golfo" para el año 1993: 800-1,000 kg/viaje (Aldana-Aranda y Domínguez-Tec, 1994). Si efectivamente la pesquería de mero en el Banco de Campeche, en particular la de *E. morio*, es considerada como en deterioro con necesidad de recuperación (SEMARNAP, 2000b), no se dispone de datos científicos para afirmar con certeza que este recurso esta actualmente sobreexplotado en el área del PMNAA.

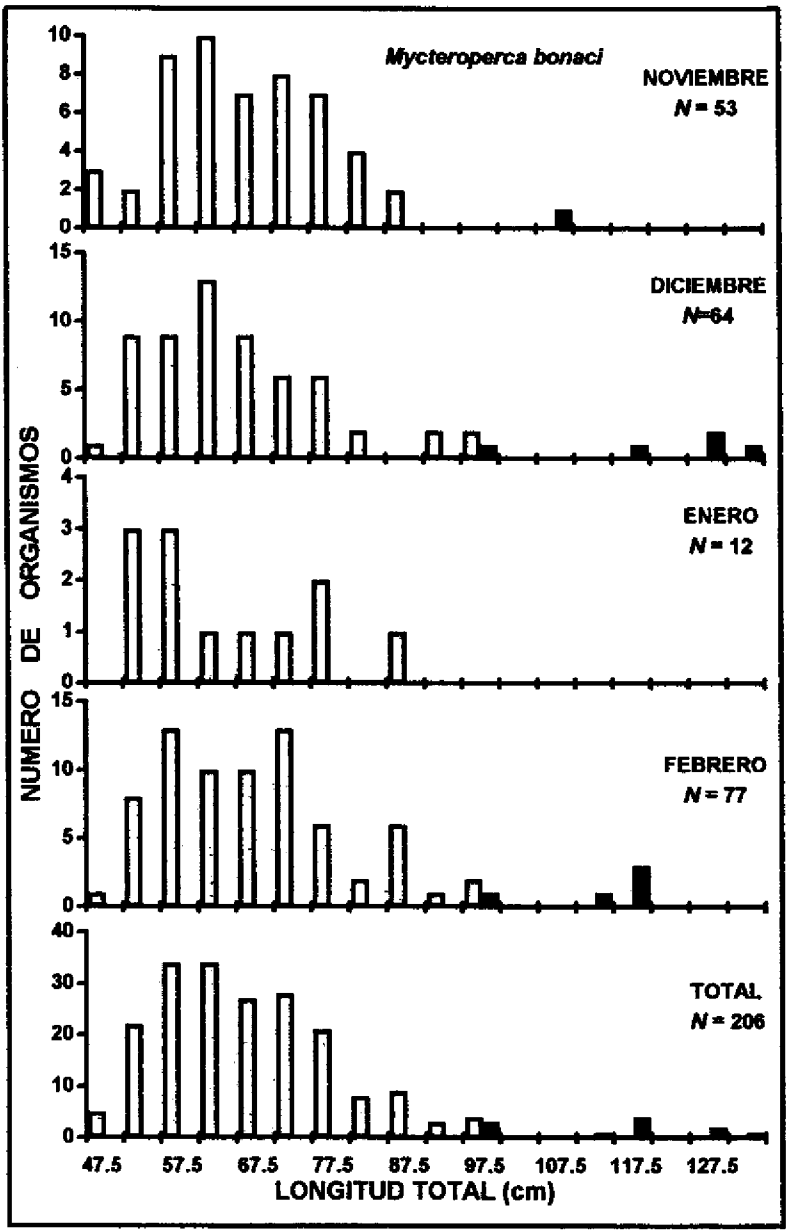


Figura 5. Distribuciones de frecuencias de tallas de hembras (blanco) y machos (negro) de *E. guttatus* y *M. venenosa* capturados en el PMN Arrecife Alacranes, entre noviembre de 1999 y febrero de 2000.

Tabla 3. Sexo, estado de madurez sexual e intervalos de IGS, tallas y pesos para los organismos analizados en las capturas comerciales realizadas en el Arrecife Alacranes, entre noviembre de 1999 y febrero de 2000. ○ - Especímenes inmaduros o en reposo sexual: hembras con ovocitos previtelogénos en los ovarios; machos con espermatogonias en los testículos;● - Especímenes en maduración sexual: hembras maduras cuyos ovarios presentan ovocitos en vitelogenésis primaria (a), en inicio (b) o fin (c) de vitelogénesis secundaria; hembras en desove con folículos post-ovulatorios (fpo); hembras en postdesove con ovocitos vitelogénos en atresia (at):Machos maduros con espermatocitos, espermatidas y espermatozoides (m) en los testículos; machos en emisión con preponderancia de espermatozoides (e).

Especie	Sexo	Noviembre 1999	Diciembre	Enero 2000	Febrero	IGS (%)	N	Tallas (cm Lt)	Pesos (kg Pt)
E.guttatus	Hembra	—	● c	—	● c	0.46-33.37	37	35-43	0.6-1.4
	Macho	● m	—	—	● m	1.69-3.78	3	41-47	0.9-1.7
E.morio	Hembra	○	—	—	○ / ● a	0.06-0.16	3	52-63	2.0-4.1
	Macho	—	—	—	—	—	0	—	—
E.striatus	Hembra	○	—	○	○ / ● a	0.13-0.17	4	47-54	2.0-2.3
	Macho	—	—	—	—	—	0	—	—
M.bonaci	Hembra	○ / ● a, b, c	○ / ● a, b, c	○	○ / ● a, b, c, fpo, at	0.02-7.17	195	46-100	1-16
	Macho	● e	● m	—	● m, e	0.03-0.44	11	97-135	3-25
M.tigris	Hembra	—	—	—	—	—	0	—	—
	Macho	● m	—	—	● m, e	0.18-2.31	4	59-68	2.9-3.4
M.venenosa	Hembra	○	○ / ● a	● a	○ / ● a	0.08-3.00	27	41-80	0.7-6.0
	Macho	○	—	—	● / m	0.08-6.49	2	81;85	5.0-7.5

E. itajara: un especímen (143 cm Lt; 45 kg Pt) capturado en enero, sin muestra de gónada.

Un total de 10 especies de Serranidae (subfamilia Epinephelinae; tribu Epinephelinii; géneros: *Epinephelus* y *Mycteroperca*) fueron identificadas en las capturas comerciales. Los datos disponibles en la literatura científica sobre los serránidos encontrados en el Arrecife Alacranes o a su proximidad inmediata señalan la presencia de 9 especies: *Cephalopholis cruentata, C. fulva, E. adscensionis, E guttatus, E morio, E. striatus, M. bonaci, M. tigris* y *M.venenosa* (Hildebrand et al. 1964, Garduño 1988, González-Salas 1999, Garduño y Chávez 2000). Durante el presente estudio se observó la presencia de otras cuatro especies más en este complejo arrecifal: *E. itajara, M. interstitialis, M. microlepis* y *M. phenax*. La ausencia de ejemplares de *C. cruentata, C. fulva* y *E. adscensionis* en las capturas comerciales se relaciona con el bajo atractivo económico que representan estas especies para el productor pesquero. Los ejemplares de *C. cruentata, C. fulva* alcanzan tallas máximas reducidas, generamente inferior a los 38 cm Lt (Bullock and Smith 1991, Heemstra y Randall, 1993) y los de *E. adscensionis* presentan tejidos musculares infestados por parásitos (Tuz-Sulub, com. pers.). La utilización del arpón a través del buceo submarino permite a los pescadores descartar sin equivocación posible estas especies de sus capturas. *M. bonaci* aparece como el principal mero capturado en el PMNAA por los pescadores profesionales. En las otras zonas de pesca del Banco de Campeche, esta especie ocupa, después de *E. morio*, el segundo lugar en la producción pesquera de serránidos (Colás-Marrufo et al. 1998, Tuz-Sulub 1999).

Varios ejemplares hembras y/o machos de *E. guttatus, E. morio, E. striatus, M. bonaci, M. tigris* y *M. venenosa,* capturados en la zona sotavento del arrecife entre noviembre de 1999 y febrero del 2000, fueron encontrados sexualmente activos. A pesar de que no se observarón agregaciones de reproducción de mero, tales como las definen Domeier y Colin (1997), la captura en febrero de las 35 hembras de *E. guttatus* en maduración avanzada y de las tres hembras de *M. bonaci* en desove y postdesove permite suponer que al menos estas dos especies podrían desovar dentro o en las cercanías del Arrecife Alacranes. Renán-Galindo (1999) observó que *M. bonaci* del Banco de Campeche presenta picos de desove máximos en enero y febrero, mientras que Domeier y Colin (1997) reportaron la formación de agregaciones de reproducción para *E. guttatus* en diciembre y enero (Belice y Puerto Rico) y en enero y febrero para *M. bonaci* (Belice y Honduras).

Como fue observado en otras zonas de pesca del Banco de Campeche (Colás-Marrufo et al. 1998), la pesquería de mero en Alacranes se caracteriza por ser multiespecífica. Con excepción de *E. itajara*, todas las especies identificadas son consideradas como de alto valor comercial en el Golfo de México y/o el Mar Caribe (Heemstra y Randall 1993). Todos los organismos analizados presentaron una longitud total igual o superior a los 35 cm, observación que permite confirmar el cumplimiento, por parte de los productores, de la recomendación sobre la talla mínima de captura de 30 cm Lt para estas especies. Es probable que la técnica de pesca utilizada en Alacranes para la captura de estos peces (buceo y arpón) sea la causante de este logro porque permite a los pescadores actuar de manera altamente selectiva en la explotación del recurso. Sin embargo, cabe señalar que esta talla

mínima de captura no fue establecida con base a las características biológicas de las especies (Brulé y Colás-Marrufo 1997). Por ejemplo, la talla de primera madurez sexual para las hembras de *E. morio* es de 51 cm Lf (Brulé et al. 1999) y entre 70 y 75 cm Lf para las de *M. bonaci* (Renán-Galindo 1999). Por consecuencia, la pesca comercial de mero en el PMNAA incide, en parte, en la fracción juvenil de las poblaciones, lo que podría implicar en caso de una pesca irresponsable, un cierto riesgo de sobreexplotación de crecimiento del recurso. Por otro lado, la temporada durante la cual se realiza la pesca en esta área corresponde generalmente a los meses de mayor actividad de reproducción para todas las especies encontradas con excepción de *M. phenax, M. tigris* y *M. venenosa* (Heemstra y Randall 1993). En caso de ocurrir agregaciones de reproducción en el arrecife, una explotación incontrolada de las mismas podría a futuro provocar su desaparición e inducir una sobreexplotación de reclutamiento del recurso. Finalmente es importante precisar que según la "1996 IUCN Red List categories" todas las especies, menos *M. interstitialis*, explotadas comercialmente en el PMNAA son clasificadas como especies amenazadas, con dos de ellas, *E. itajara* y *E. striatus*, consideradas como especies en peligro (Morris *et al.* 2000).

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LITERATURA CITADA

Aldana-Aranda, D. 1993. Arrecife Alacranes. *Avance y Perspectiva* **12**:141-145.

Aldana-Aranda, D. y J.O. Domínguez-Tec. 1994. Arrecife Alacranes II: sus pescadores. *Avance y Perspectiva* **13**:211-218.

Ardisson, P.L. y J.J. Durán-Nájera. [1997]. Programa de manejo del Parque Marino Nacional Arrecife Alacranes. Estudio presentado por la Unidad Mérida del CINVESTAV-INP ante el Instituto de Ecología y la Coordinación General del Programa Nacional de Apoyo para las Empresas en Solidaridad. Mérida, Yucatán. xi+114 p.+ VIII Anexos. Manuscrito no publicado.

Bello-Pineda, J. 1998. Sistema de clasificación para los tipos de fondo del Arrecife alacranes compatible con una imagen Landsat TM. Tesis de Maestría. CINVESTAV-IPN Unidad Mérida. 107 pp.

Brulé, T. y T. Colás-Marrufo. 1997. Explotación de los serránidos en el sureste del Golfo de México: evolución y situación actual. *Proc. of the Gulf and Caribbean Fisheries Institute* **49**:173-214.

Brulé, T., C. Déniel, T. Colás-Marrufo and M. Sánchez-Crespo. 1999. Red Grouper Reproduction in the Southern Gulf of Mexico. *Transactions of the American Fisheries Society* **128**:385-402.

Bullock L. H., and G. B. Smith. 1991. Seabasses (Pisces: Serranidae). Memoirs of the Hourglass Cruises, Volume 8, Part 2, Florida.

Canela-Rojo, J. 1992. Conocimiento y uso de los recursos del Arrecife Alacranes por pescadores de la zona maya de la Península de Yucatán. *Sostenibilidad Maya, Experiencias en Desarrollo Sostenible* **4**. 35 pp.

Carricart-Gavinet J.P. y G. Horta-Puga. 1993. Arrecifes de coral en México. Pages 80-90 in: S.I. Salazar-Vallejo Y N.E. González, (eds.) Biodiversidad marina y costera de México, CONABIO-CIQRO, Chetumal, Quintana Roo.

Colás-Marrufo, T., T. Brulé y C. Déniel. 1998. Análisis preliminar de las capturas de meros realizadas a través de unidades de la flota mayor en el sureste del Golfo de México. *Proceedings of the Gulf and Caribbean Fisheries Institute* **50**:780-803.

De la Cruz-Agüero, E. Martínez-Osegueda y R.F. Muñoz-Chagín. [1993]. Propuesta de zonificación del Arrecife Alacranes, Yucatán. CINVESTAV-IPN Unidad Mérida, 22 pp. Manuscrito no publicado.

Diario Oficial de la Federación. 1994. Tomo CDXXXIX, **4**:73-77.

Domeier, M.L. and P.L. Colin. 1997. Tropical reef fish spawning aggregations: defined and reviewed. *Bulletin of Marine Science* **60**:698-726.

Flores-Guido, J.S. 1983. Vegetación insular de la Península de Yucatán. *Boletín de la Sociedad Botánica de México* **45**:23-37.

Flores-Guido, J.S. 1992. Vegetación de las islas de la Península de Yucatán: florística y etnobotánica. Etnoflora Yucatanense, Universidad Autónoma de Yucatán, fascículo 4. 70 pp.

Gabe, M. 1968. *Techniques Histologiques*. Masson, Paris, France. 1113 pp.

Garduño, M. 1988. Distribución de la ictiofauna asociada a los arrecifes del Caribe mexicano. Tesis de Maestría. CINVESTAV-IPN Unidad Mérida. 57 pp.

Garduño, M. and E.A. Chávez. 2000. Fish resource allocation in coral reefs of Yucatan Peninsula. Pages 367-381 in: M. Munawar, S.G. Lawrence, I.F. Munawar and D.F. Malley (eds.) *Aquatic Ecosystems of Mexico: Status and Scope*. Ecovision World Monograph Series, Backhuys Publishers, Leiden.

González-Salas, C.F. 1999. Distribución y abundancia de los peces arrecifales asociada al sistema lagunar del Arrecife Alacranes, Yucatán, México. Tesis de Licenciatura. Universidad Autónoma de Yucatán, Mérida, Mexico. 72 pp.

Heemstra P. C., and J. E. Randall. 1993. FAO species catalogue. Vol. 16. Groupers of the world (Family Serranidae, Subfamily Epinephelinae). An annotated and

illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. Food and Agriculture Organization of the United Nations, Fisheries Synopsis 125, Rome, Italy.

Hildebrand, H., H. Chávez y H. Compton. 1964. Aporte al conocimiento de los peces del Arrecife Alacranes, Yucatán (México). *Ciencia* **23**:107-134.

Huerta-Músquiz, L., A.C. Mendoza-González y L.E. Mateo-Cid. 1994. Flora marina de los arrecifes coralinos del sureste de México. *Oceanología* **3**:55-68.

Kornicker, L.S., F. Bonet, R. Cann and C.M. Hoskin. 1959. Alacran Reef, Campeche Bank, Mexico. *Pub. Inst. of Marine Science*, University of Texas **6**:1-22.

Kornicker, L.S. and D.W. Boyd. 1962. Shallow-Water Geology and Environments of Alacran Reef Complex, Campeche Bank, Mexico. *American Assoociation. Petroleum Geologists Bulletin* **46**:640-673

Logan, B.W. 1969. Coral reef and banks: Yucatan shelf, Mexico. *American Assoociation. Petroleum Geologists Bulletin* 11:129-198.

Manzanilla S., W. Andrews, J. Clarck, M. Garduño, A. Mendoza, J. Correa, E. Boege, C. Barrera, E. Dunhe y G. I. Arcilla. [1988]. Propuesta preliminar de manejo de arrecife Alacranes como área estatal protegida. CINVESTAV-IPN Unidad Mérida, 30 pp. Manuscrito no publicado.

Martínez-Guzman L.A. y J.L. Hernández-Aguilera. 1993. Crustáceos estomatópodos y decápodos del Arrecife Alacranes, Yucatán. Pages 609-629 in: S.I. Salazar-Vallejo Y N.E. González, (eds.) *Biodiversidad marina y costera de México*, CONABIO-CIQRO, Chetumal, Quintana Roo, Mexico.

Moe, M.A. 1969. Biology of the red grouper *Epinephelus morio* (Valenciennes) from the eastern Gulf of Mexico. Florida Department of Natural Resources, Marine Research Laboratory, Professional Papers Series 10, Florida. 95 pp.

Morris, A.V., C.M. Roberts and J.P. Hawkins. 2000. The threatened status of groupers (Epinephelinae). *Biodiversity and Conservation* **9**:919-942.

Renán-Galindo, X. 1999. Aspectos de la reproducción de la cuna bonaci, *Mycteroperca bonaci* (Poey, 1860) del Banco de Campeche, Yucatán. Tesis de Maestría. CINVESTAV-IPN Unidad Mérida. 82 pp.

SEMARNAP (Secretaría de Medio Ambiente, Recursos Naturales y Pesca). 2000a. *Anuario estadístico de pesca 1999.* SEMARNAP, México D.F. 271 pp.

SEMARNAP. 2000b. *Sustentabilidad y pesca responsable en México: evaluación y manejo 1997-1998.* SEMARNAP, México D.F. 691 pp.

Tuz-Sulub, A.N. 1999. Composición, distribución e importancia pesquera de los serránidos (subfamilia: Epinephelinae) en el Banco de Campeche, Yucatán, México. Tesis de Licenciatura. Universidad Autónoma de Yucatán, Mérida, Mexico. 77 pp.

Portrait of the Commercial Fishery of the Red Hind, *Epinephelus guttatus*, in Puerto Rico During 1992 - 1999

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ABSTRACT

Puerto Rico' s fishery has shown symptoms of overfishing for the last fifteen years. Groupers (Serranidae) represented 4% of the total catch reported in Puerto Rico. The red hind, *Epinephelus guttatus*, is the grouper most reported in the landings of the commercial fishery and also is a very important component of the recreational fishery. *E. guttatus* is a protogynous hermaphrodite and forms spawning aggregations. This event occurs around the full moon of December, January and February. The spawning aggregation sites are well known by commercial fishermen, leading to a high exploitation rate of *E. guttatus*. This activity affects negatively the reproduction of this species.

Since 1995, three *E. guttatus* spawning aggregation sites off the west coast of Puerto Rico have been closed to all fishing activity. This paper analyzes the landings, catch per unit effort (CPUE), and length frequency distributions during 1992 - 1999 to evaluate the status of *E. guttatus*.

KEY WORDS: Commercial fisheries, *Epinephelus guttatus*, fishery management

INTRODUCTION

Puerto Rico's fishery has been monitored through the Fisheries Statistics Project (FSP) uninterrupted since 1967. The FSP is a program of the Puerto Rico's Department of Natural and Environmental Resources (DNER). FSP is located at the DNER's Fisheries Research Laboratory (FRL). The objective of the FSP is to provide data to know the conditions of the fishery resources found in the Territorial Sea of the Commonwealth of Puerto Rico and contiguous Federal Fishery Conservation Zone waters. The scientific data obtained by the FSP helps to implant management plans to protect the fishery resources.

Groupers (Serranidae) are an important resource in the Puerto Rico's commercial and recreational reef fishery. Grouper species share a number of life history characteristics believed to render them particularly vulnerable to human exploitation (Manooch 1987). Sadovy (1944) mentioned that groupers are carnivores, have a relatively long life span, attain a large size at sexual maturation, exhibit slow growth, and appear to be relatively easy to catch, being susceptible to a wide range of sizes and types of fishing gear. Many exhibit a sexual pattern incorporating adult sex change. Several western Atlantic grouper species are known to aggregate for spawning at specific times and locations. The exploitation of

grouper resources during spawning aggregations make them very vulnerable. In Puerto Rico, some grouper species spawn in large numbers at well-defined times and locations each year.

Nine species of the genus *Epinephelus* and two species of the genus *Mycteroperca* had been reported in Puerto Rico's commercial fishery. The Nassau grouper (*Epinephelus striatus*) was reported as one of the most common grouper caught in Puerto Rico since 1900 (Everman 1900). In 1970, *E. striatus* was reported as the fourth most commonly landed of all shallow water species in the Puerto Rico's commercial fishery (Suárez Caabro 1970). This species was heavily fished during the period of spawning aggregations. Now the species is considered to be extinct for commercial fishery purposes (Sadovy 1999). During 1992 - 1999, the FSP collected biostatatiscs data of approximately 75,000 fishes measured, less than 100 were *E. striatus* (Matos-Caraballo 2000).

The red hind, *Epinephelus guttatus*, has become the most important species of grouper taken commercially in Puerto Rico, following the decline of *E. striatus* (Matos-Caraballo and Sadovy 1990, Sadovy 1993, Matos-Caraballo 1997). Studies indicated that this species it is overfished (Appeldoorn, et. al. 1992, Sadovy and Figuerola 1992, Rosario, 1996). The red hind is the most reported grouper species in the landings of the commercial fishery and also is a very important component of the recreational fishery. The red hind is a protogynous hermaphrodite and forms spawning aggregations. This event occurs around the full moon of December, January and February. The spawning aggregation sites are well known by commercial fishermen, leading to a high exploitation rate of red hind. This activity affects negatively the reproduction of this species.

Since 1995, three red hind spawning aggregation sites off the west coast of Puerto Rico have been closed to all fishing activity (Tourmaline Bank, Abrir la Sierra Bank and Bajo de Sico Bank). The Caribbean Fishery Management Council and the DNER worked together to enforce this action. To evaluate the status of red hind this paper analyze the landings, catch per unit effort (CPUE), and length frequency distributions during 1992 - 1999. Also, data analysis to evaluate if the closed areas are improving this fishery resource in Puerto Rico.

METHODS

Commercial Landings

Commercial fishery landings data were collected weekly by four port agents and the principal investigator of the FSP. The data was collected voluntarily from fishermen, fish buyers, and fishing associations from 42 coastal municipalities of Puerto Rico. Landing trip tickets were provided by the fishermen. Through the landing trip tickets system, fishermen reported the following information:

i) Fishing date and municipality where catch was landed,
ii) Fishing center (municipality fishing area),
iii) Name of fishermen and name of helper (if any),

iv) Hours spent fishing,
v) Number of trips,
vi) Species caught,
vii) Weight in pounds of each species caught and price per pound (US $), and
viii) Gear type and number of gears used.

Confidentiality was maintained for individual fishermen or businesses that cooperated by providing data to the program. Fishes were usually landed in the round (not eviscerated).

Port agents delivered commercial landings data to the FRL. Data were then entered in MS-DOS PC using Microsoft FoxPro. Subsequently, data were revised, correcte,d and analyzed using Microsoft FoxPro and Microsoft Excel. Catch per unit effort of the red hind was calculated using the landings data.

Biostatatistical Data

Four port agents and the principal investigator of the FSP visited randomly the 42 coastal municipalities of Puerto Rico to collect biostatistical data. They visited different fishing centers three days per week, and randomly selected commercial landings. If the fishermen voluntarily cooperated, the port agent proceeded to identify at the species level every individual of fish and lobster caught. Fish were measured in fork length (FL) in millimeters, and weighed in grams. FSP's personnel collected information for each sample about fishing area, fishing depth (fathoms), fishing effort (gear type, number of gear, time spent fishing) and total catch in pounds. They delivered biostatistical data to the FRL. Data were entered in MS-DOS PC using "Trip Interview Program (TIP)", a National Marine Fisheries Service (NMFS) software. Data were then revised, corrected and analyzed using Microsoft Excel. The data was sorted by all Puerto Rico samples and west coast only. The last category is due to the fact of the closed areas to protect the red hind are on the west coast. This category includes the landings of the municipalities of Cabo Rojo, Mayagüez, Añasco, Rincón, Aguada and Aguadilla.

RESULTS

Commercial Landings

Due to market limitations, the red hind is reported by fishermen mostly in the red hind category and grouper category. Figure 1 shows the reported landings in pounds during 1992 - 1999 and the sum of red hind and grouper is the total landings reported for those categories. This Figure indicates a decrease in landings reported for the red hind from 1992 (42,015 pounds reported) to 1994 (28,738 pounds reported), but an increasing trend during 1995 (42,383 pounds) to 1999 (66,065 pounds).

To determine how the closed areas for the protection of the red hind have affected the resource, landings reported of the red hind for all of Puerto Rico were compared to the west coast only (Figure 2). In this figure it is observed that the

west coast shows a drastic decrease the landings from the year 1993 (21,620 pounds) to 1994 (11,312 pounds). The landings reported continued a similar for years 1995-97. An increase trend was observed for years 1998 (22,903 pounds) and 1999 (26,441 pounds). Another similar trend is observed for the all Puerto Rico sample of this species.

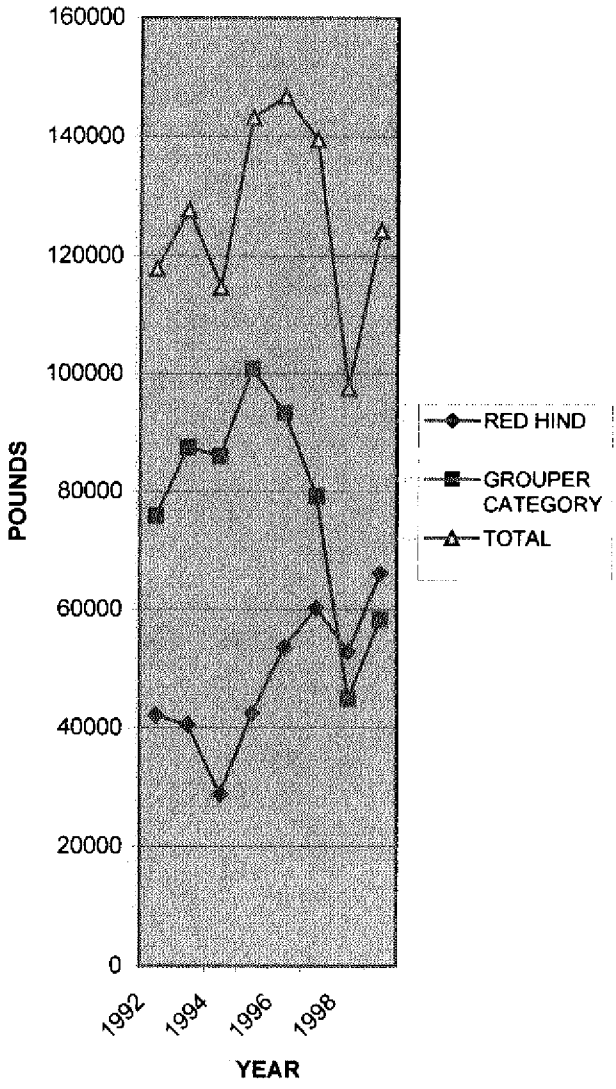


Figure 1. Landings reported (pounds) of red hind and grouper category in Puerto Rico during 1992 - 1999.

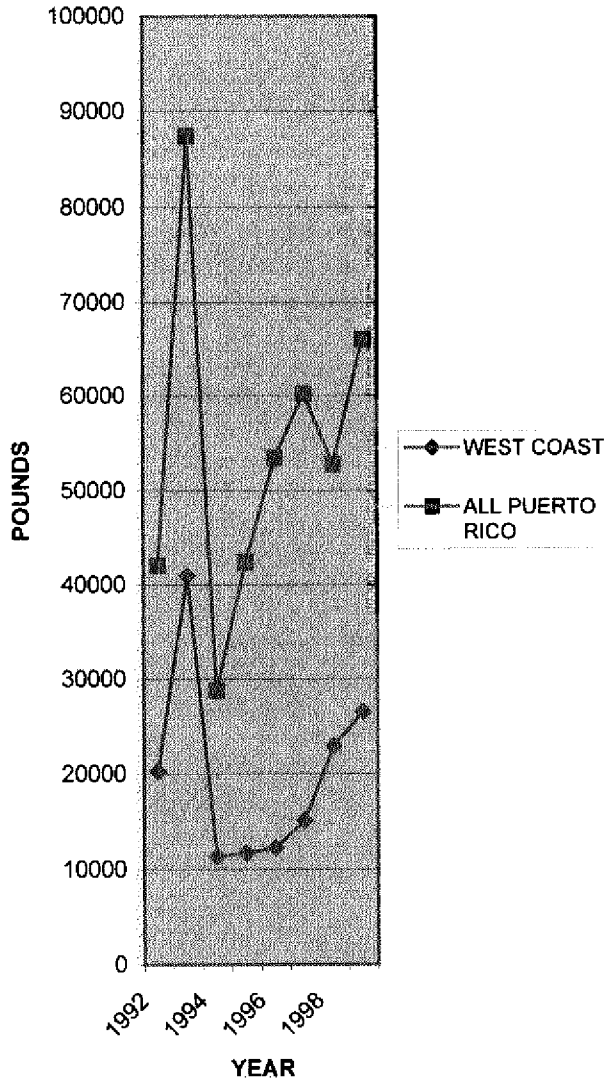


Figure 2. Landings reported (pounds) of red hind for all Puerto Rico and for the west coast during 1992 - 1999.

Catch per unit effort has been estimated in the red hind average pounds reported per trip. Figure 3 shows small differences among years 1992 -1999 in the

CPUE for the all Puerto Rico's red hind. On the other hand, for the west coast sample the CPUE shows an increase for years 1996-99. Another interesting fact observed in this figure is that the west coast sample caught higher average pounds landed per trip than the all Puerto Rico.

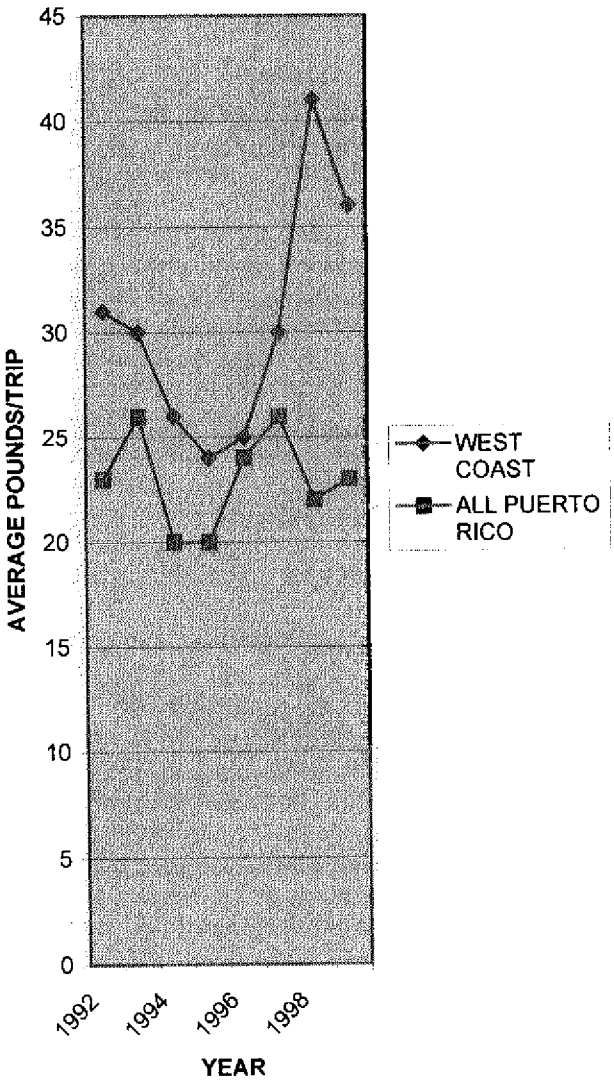


Figure 3. Catch per unit effort (average pounds/trip) of red hind for all Puerto Rico and west coast during 1992 - 1999.

Biostatistical Data

Average fork length (FL) for red hind from years 1992 - 1999, for all Puerto Rico and for the west coast only is shown in Figure 4. This figure shows that the average length for both categories ranged from 269 mm to 330 mm FL. For the years 1997, 1998 and 1999 both categories show a trend to increase the average reaching the peak of each category (330mm for the all Puerto Rico and 319 for west coast only).

Length frequency distribution (LFD) for red hind for all Puerto Rico (Figure 5) and for the west coast only (Figure 6) during 1992 - 1995, show that the peak of the frequencies occurred between 280 - 320 mm. LFD for red hind for all Puerto Rico (Figure 7) and for the west coast only (Figure 8) during 1996 - 1999, shows that the peak of the frequencies occurred very similar to the 1992 - 1995 (among 270 - 320 mm). The average FL of the red hind for the all Puerto Rico for the years 1992 - 1995, was 305 mm. The average for the individuals caught during 1996 - 1999 was 320 mm. Although it was observed a tendency to catch larger individuals during 1996 - 1999, the t-Test Two Sample Assuming Unequal Variances shows no significant difference between 1992 - 1995 and 1996 - 1999 ($t = 8.49$ and $p = 1.65$, alpha 0.05).

On the other hand the average FL of the red hind for the west coast only for the years 1992 - 1995, was 301 mm. This average for the individuals caught for 1996-99 was 314 mm. The t-Test Two Sample Assuming Unequal Variances shows a significant difference between 1992 - 1995 and 1996 -1999 ($t = -4.00$ and $p = 2.3$, alpha 0.01).

DISCUSSION

Commercial Landings

The FSP landings data collected from 1992 - 1999, indicates that more landings of the red hind were reported in Puerto Rico for years 1998 and 1999. The west coast CPUE shows an increasing trend in the average pounds landed/trip. Some commercial fishers of the west coast mentioned to the author that they noted that the size of the red hinds are larger after the closing of the spawning areas. This tendency is probably to the management action described in this paper. It is necessary to continue the collection of the data in the future years to observe if this trend continues.

Biostatistical Data

Results of LFD of the red hind indicate that the individuals of this species were larger for the years 1996 - 1999 (average FL of 320 mm) than for 1992 - 1995 (average FL of 304 mm). The statistical analysis confirmed this fact for the west coast during 1996 - 1999, and it is likely linked with the three closed areas in the west coast. Again this data collection must be continued for several years to determine if this trends will continue.

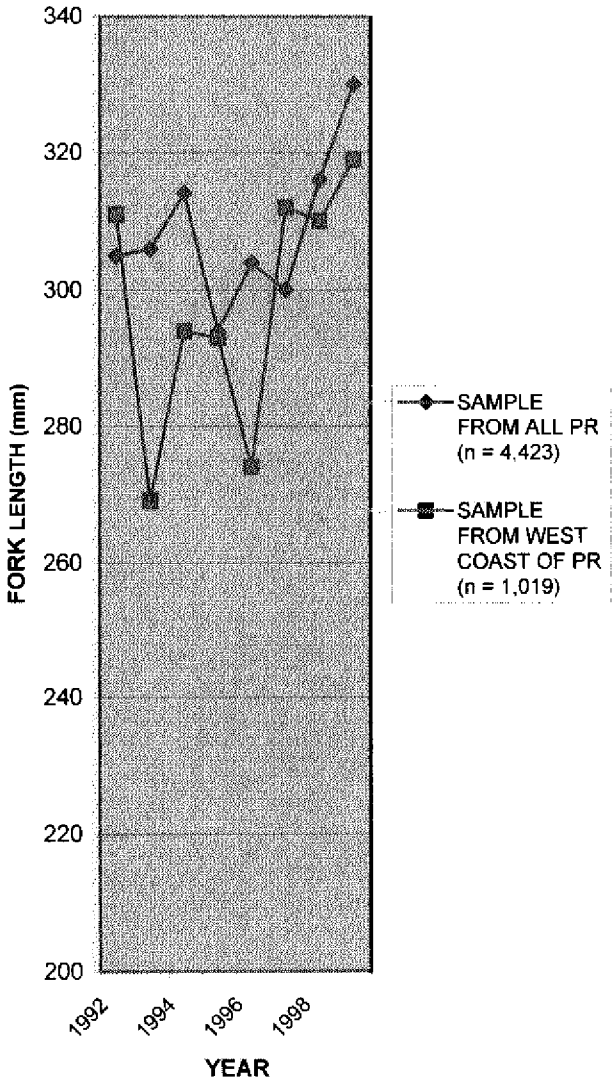


Figure 4. Red hind average fork length for all Puerto Rico samples and for the west coast during 1992 - 1999.

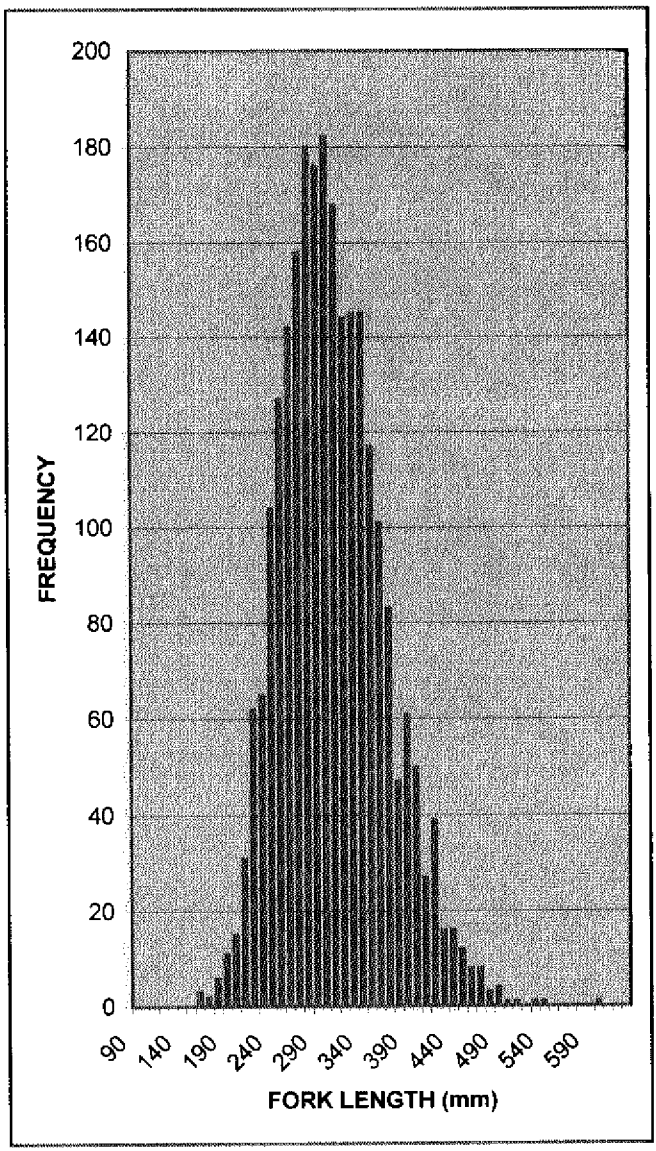


Figure 5. Length frequency distribution of red hind in all Puerto Rico during 1992 - 1995 (n = 2,463).

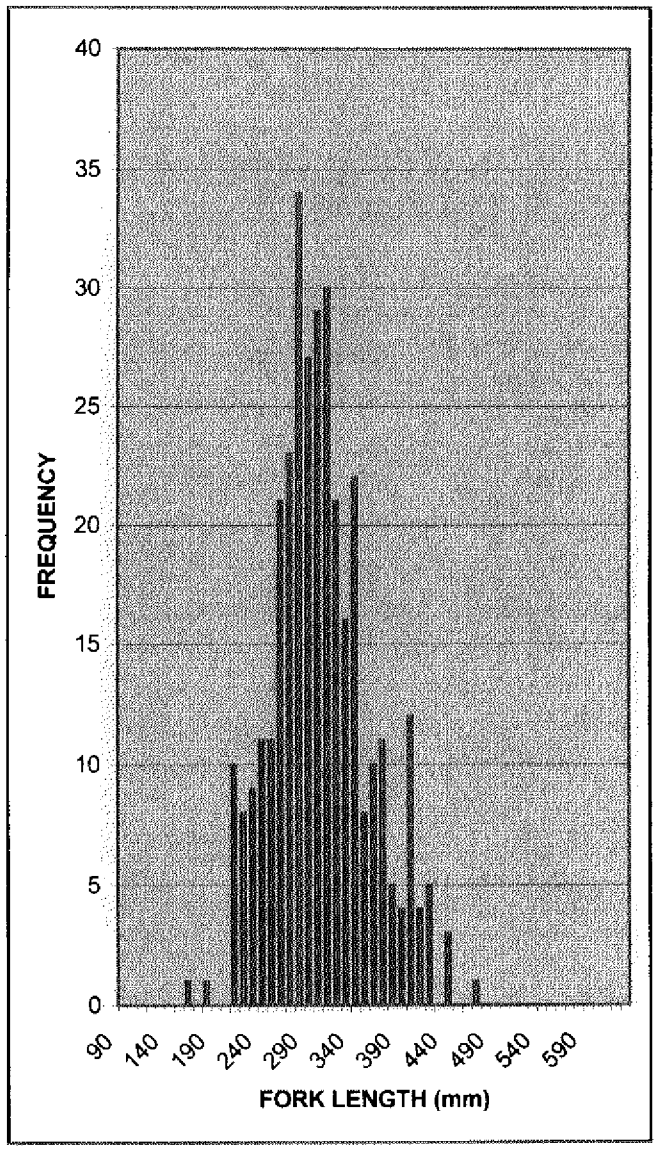


Figure 6. Length frequency distribution of red hind in the west coast of Puerto Rico during 1992 - 1995 (n = 336).

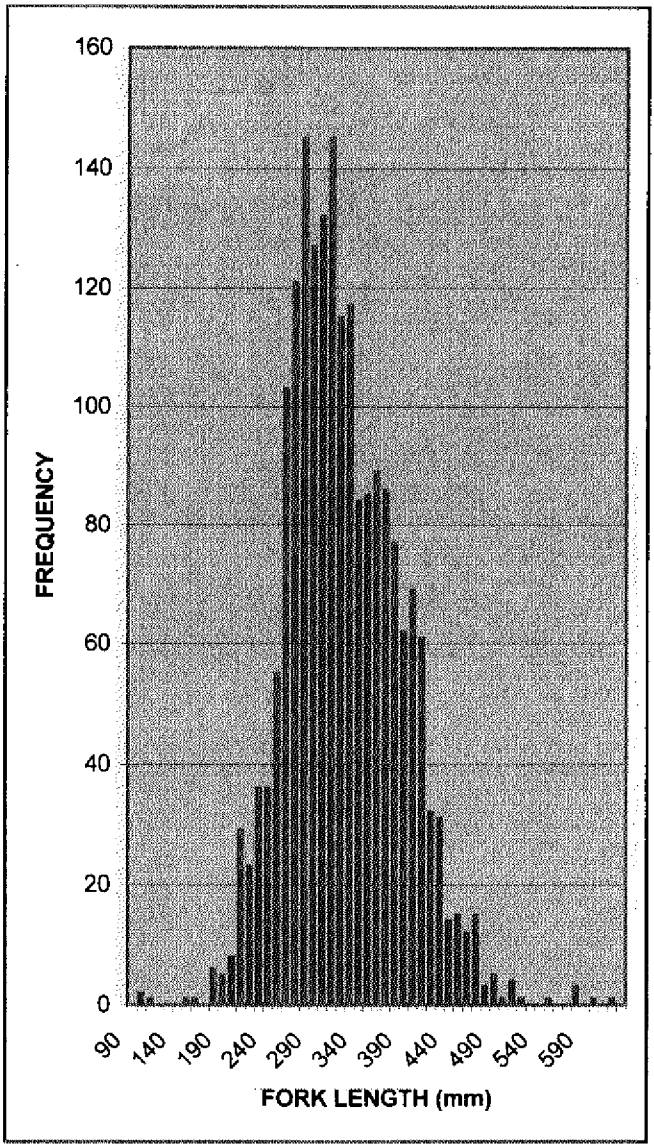


Figure 7. Length frequency distribution of red hind in all Puerto Rico during 1996 - 1999 (n = 1,960).

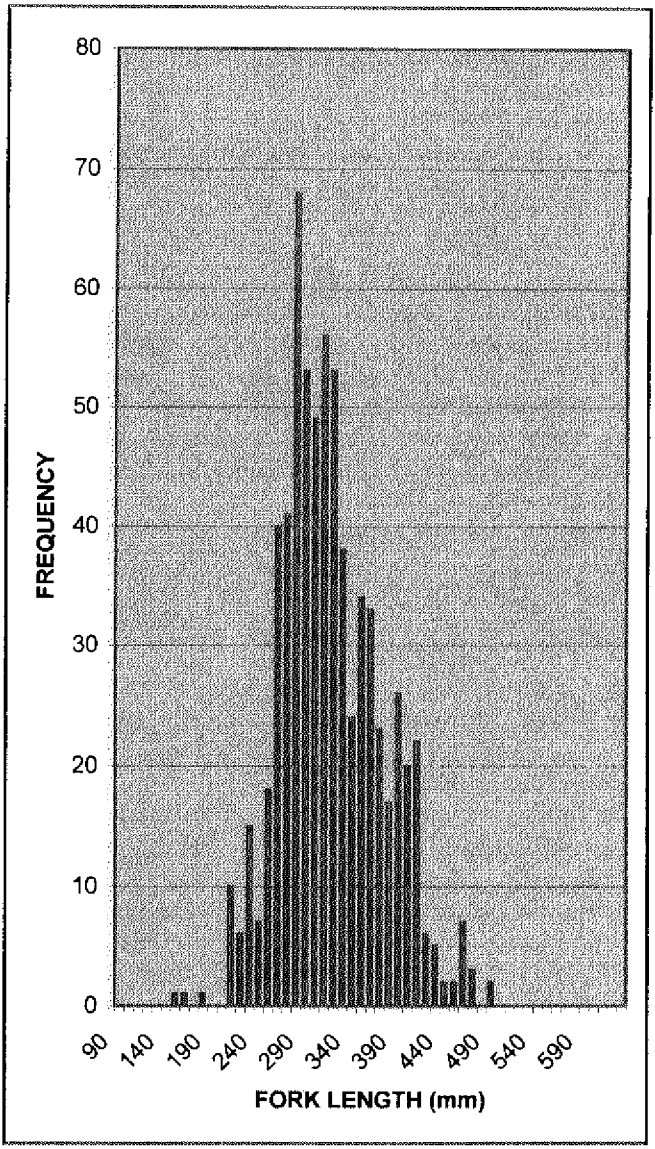


Figure 8. Length frequency distribution of red hind in the west coast of Puerto Rico during 1996 - 1999 (n = 336).

CONCLUSION

The red hind fishery resource of Puerto Rico seems to be improving for the years 1996 - 1999. The three spawning aggregations designated as closed areas for this species on the west coast of Puerto Rico, are helping to reduce the decline of this resource. However, more studies are necessary in the near future to see if this trend will continue. If this trend continues, the DNER must consider the action to close other areas in the east or south coast of Puerto Rico to help this important resource.

ACKNOWLEDGEMENTS

Thanks to the agencies that provided the funds to make possible this research, the Puerto Rico DNER and National Marine Fisheries Service's Cooperative Fisheries Statistics Program. Also I wish to express my gratitude to all the people who contribute to the completion of this report. Port samplers Walter Irizarry, Jesús León, Héctor Y. López, and Luis A. Rivera, collected the data. Statistics clerk Lucía T. Vargas handled and entered the data. To Miguel Figuerola for reviewing this manuscript. In particular, I wish to acknowledge the cooperation of the commercial fishermen for assisting the FSP: without their help this report would not have been possible.

LITERATURE CITED

Appeldoorn, R., J. Beets, J. Bohnsack, S. Bolden, D. Matos-Caraballo, S. Meyers, A. Rosario, Y. Sadovy and W. Tobias. 1992. Shallow water reef fish stock assessment for the U.S. Caribbean. NOAA Technical Memorandum. NMFS-SEFSC-304. 70 pp.

Evermann, B.W. 1900. *Fishes and Fisheries of Puerto Rico*. United States Commission of Fish and Fisheries, Washington, D.C. USA. 350 pp.

Manooch, C.S., III. 1987. Age and growth in snappers and groupers. Pages 329 - 373 in: J.J. Polovonia and S. Ralston (Eds). *Tropical Snappers and Groupers: Biology and Fisheries Management.* West View Press, Boulder, Colorado.

Matos-Caraballo, D. 1997. Status of the Groupers in Puerto Rico, 1970 - 1995. *Proceedings of the Gulf and Caribbean Fisheries Institute* 47:340-353.

Matos-Caraballo, D. [2000] Puerto Rico/NMFS Interjurisdictional Fisheries Program 1997-99. Final Report to NMFS. P.R. Dept. Nat. Env. Res. 73 pp.

Matos-Caraballo, D. and Y. Sadovy. 1990. Overview of Puerto Rico's small scale fisheries statistics 1988 - 1989. Technical Report. CODREMAR. 1(14):1-17.

Rosario, A. [1996] Caribbean/NMFS Cooperative SEAMAP Program. Annual Report to NMFS. January, 1996. 133 pp.

Sadovy, Y. 1994. Summary of papers presented at the grouper symposium of the 43rd annual meeting of the Gulf and Caribbean Fisheries Institute in Miami, Florida (November 6, 1990). *Proceedings of the Gulf and Caribbean Fisheries Institute* 43:482-486.

Sadovy, Y. 1999. The case of disappearing grouper: *Epinephelus striatus*, the Nassau grouper in the Caribbean. *Proceedings of the Gulf and Caribbean Fisheries Institute* **45**:5-22.

Sadovy, Y. [1993] Biology and Fishery of the red hind in Puerto Rico and the United States Virgin Islands. Technical Report. CFMC. July, 1993. 66 pp.

Sadovy, Y. and M. Figuerola. 1992. The status of the red hind fishery in Puerto Rico and St. Thomas, as determined by yield-per-recruitment analysis. *Proceedings of the Gulf and Caribbean Fisheries Institute* **42**:23-38.

Suárez-Caabro, J.A. 1970. Estadísticas Pesqueras de Puerto Rico 1968-69. Reporte técnico del Departamento de Agricultura de Puerto Rico. *Contribuciones Agropecuarias y Pesqueras* **2** (1):1-38.

Genetic Characterization of Red Hind, *Epinephelus guttatus*, Collected from Three Spawning Aggregations in Western Puerto Rican Waters - Variation in Allozymes

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ABSTRACT

Red hind (*Epinephelus guttatus*) is a heavily exploited reef fish which form short-term spawning aggregations beginning in January in western Puerto Rican waters. Reproductively active individuals were collected from three aggregations and examined for variation in genetic characteristics using horizontal starch-gel electrophoretic techniques. Eighteen putative loci were found to be informative. A fixation value (F_{ST}) of 0.022 was estimated, indicative of minimal population subdivision. Estimates of Nei's unbiased genetic distance (Nei 1978)suggested red hind are nearly identical genetically within this limited grouping of aggregations. These results suggest red hind spawning aggregations, at least within the context of the sampled groupings, may not represent biologically significant genetic subdivisions.

KEY WORDS: Red hind, genetic variation, population genetics

INTRODUCTION

Growth and recruitment overfishing have been implicated in recent declines of grouper stocks in tropical Atlantic waters (Sadovy 1994). Declines have often been precipitous (Olsen and LaPlace 1978) and recoveries of fisheries have been minimal (Butler et al. 1993). As fisheries for preferred species such as Nassau grouper (*Epinephelus striatus*) and red grouper (*E. morio*) become unproductive, local efforts often are shifted towards other species such as red hind (Heemstra and Randall 1993). Increased pressure on these stocks increase the probability that they too will decline. The potential for overexploitation is increased in some grouper species, including red hind, by the formation of spawning aggregations which are

heavily targeted by local fishermen (Aguilar-Perera and Aguilar-Davila 1996, Coleman et al. 1996). Overfishing of spawning aggregations have been suggested to result in reduced age at sexual maturity and changes in sex-ratio among some protogynous hermaphroditic groupers (Coleman et al. 1996) resulting in increased ratios of females to males within an aggregation. One immediate consequence of changes away from a 1:1 sex ratio is to lower effective population size, with concomitant effects on important genetic factors such as inbreeding, genotypic diversity, and population structuring.

Little information is available on levels of genetic variability or population structure in protogynous hermaphroditic spawners such as red hind. This information is important to the understanding of effects of overfishing on red hind populations and has far-reaching implications for the evolutionary potential of an exploited population (Soulé 1980, Smith and Chesser 1981). Equally important, the effects of aggregation formation during reproduction on genetic structure may be critical to understanding stock structure in species employing this strategy and becomes crucial as proposals for artificial propagation and enhancement are made. Small-scale stocking of Nassau grouper already has occurred without determination of existing stock structure (Roberts et al. 1995), putting at risk the genetic integrity of this species. As natural stocks continue to decline and culture techniques are improved, such attempts will become attractive to management agencies (Brulé et al. 1996, Fukuhara 1989, Tucker 1994, Tucker and Woodward 1994). It is critical that such programs, if pursued, be guided by adequate knowledge of genetic variation within populations and genetic differentiation among populations.

As a first step in providing this information, the present study has three basic goals. First, to assess the genetic variability inherent in red hind spawning aggregations. Second, to examine differentiation among aggregations by comparing polymorphic genetic markers. Third, to generate a baseline with which future genetic data may be compared.

METHODS

Electrophoretically detectable allelic variants were surveyed in samples collected from three spawning aggregations located off the west coast of Puerto Rico. Collection sites are described in Sadovy, et al. (1994). Sampled aggregations were close enough geographically that within group differences could be attributed to normal variability and not to broad-based differences across the distribution of the species. This was important in assessing spatial stability of the genetic parameters chosen to characterize the aggregations.

During June - October of 1996, red hind were collected using fish traps from each breeding aggregation. All fish were immediately placed on ice until transported to the Laboratorio de Investigaciones Pesqueras in Mayaqüez, Puerto Rico. Whole fish were maintained at -20°C until shipment to the Perry R. Bass Marine Fisheries Research Station (PRBMFRS) where individuals were measured and samples of skeletal muscle, liver, heart, kidney, fin, gill, and eye were excised. Tissues were

homogenized in an equivalent ammount of buffer (0.01 M tris-HCl, 0.001 M EDTA, pH 7.5; modified from Selander et al. 1971) and centrifuged for 10 minutes at 10,000 rpm. Supernatants were stored at -80°C until needed for electrophoretic examination.

Variation in electrophoretic characteristics of proteins was assayed using horizontal starch gels (Selander et al. 1971, Morizot and Siciliano 1984, Murphy et al. 1996) prepared as 12% suspensions of hydrolyzed starch (StarchArt Company, Smithville, Texas). Gel and electrode buffers used were tris-citrate, pH 8 (TC-8; Selander et al. 1971); tris-borate-EDTA, pH 8 (TVB; Selander et al. 1971); tris-citrate/borate (POU; Selander et al. 1971; tris-citrate, pH 7 (TC-7; Ayala et al. 1972); amine-citrate, pH 6.1 (AC-6; Clayton and Tretiak 1972); and lithium hydroxide, pH 8.2 (RW; Ridgway et al. 1970). Histochemical staining followed, with minor modifications, the methods of Manchenko (1994). Protein nomenclature and abbreviation followed the recommendations of Manchenko (1994) and electromorph designation followed Shaklee et al. (1990). Loci were abbreviated like the proteins they govern, but in italic form with a terminal asterisk. Allele codes were italicized and proceded by an asterisk. The allele of each locus which migrated most anodally was designated **A* and all other alleles were sequentially labeled in accordance with their mobility.

A gene locus was considered polymorphic for statistical purposes if the most common allele frequency was 0.99 or less in any of the three aggregations. Gene frequencies and summary statistics were determined using the Fortran program BIOSYS-1 (Swofford and Selander 1981). Heterogeneity chi-square tests of genotype distributions were used to test for gene frequency differences among spawning aggregations. In all chi-square tests comparing gene frequencies among samples or testing conformation to Hardy-Weinberg expectations were calculated using the computer program GenePop (Raymond and Rousset 1995) and appropriate corrections for significance values of multiple simultaneous tests were employed (Miller 1966).

Partitioning of genetic variation into within population (F_{IS}) and between population (F_{ST}) components followed Weir and Cockerham (1984). Chi-square was used to test significance of *F*-statistics. Calculation of chi-square followed Waples (1987). The average number of migrants exchanged between spawning aggregations was calculated as $N_em = ((1/ F_{ST})-1)/4$. The variance of N_em was estimated by jackknifing loci (Reynolds et al. 1983, Weir and Cockerham 1984) to obtain 95% confidence limits for F_{ST} and then employing these values to estimate N_em. Nei's genetic distance (Nei 1978) was determined and examined as an index of population differentiation (Rogers 1972)

Correlation analysis (SAS Institute 1985) were used to examine trends in heterozygosity and allele frequency across aggregations. Significance of relationships between degrees west longitude and degrees north latitude with genetic variation were determined by the probability associated with Spearman's correlation coefficient. Probabilities less than 0.05 were considered statistically significant (Snedecor and Cochran 1980).

RESULTS

Consistently scorable electromorphs were resolved for 75 enzymes and structural proteins allowing genotypes to be determined for 106 putative gene loci. Eighteen loci were scored as polymorphic at one or more aggregations (Table 1) and were used in statistical analyses. The same common allele predominated for all loci at all aggregations.

Table 1. Gene frequencies at 18 polymorphic loci examined in three spawning aggregations of red hind in Puerto Rican waters. Means of measures of genetic variability (with standard errors in parentheses) are provided.

Locus/allele	Abrir la Sierra	Bajo el Cico	Tourmaline
*AAT-1**			
N	35	47	62
**A*	0.057	0.064	0.048
**B*	0.943	0.936	0.952
*CAT-1**			
n	35	47	60
**A*	0.314	0.372	0.350
**B*	0.686	0.628	0.650
*EST-1**			
n	34	48	63
**A*	1.000	1.000	0.992
**B*	0.000	0.000	0.008
*EST-2**			
n	34	48	63
**A*	0.132	0.188	0.095
**B*	0.868	0.813	0.905
*GD-1**			
n	34	48	63
**A*	0.000	0.021	0.032
**B*	1.000	0.979	0.968
*GP-2**			
n	33	48	66
**A*	0.727	0.833	0.523
**B*	0.273	0.167	0.477
*G6PD-3**			
n	36	50	64
**A*	0.111	0.120	0.242
**B*	0.889	0.880	0.750
**C*	0.000	0.000	0.008
*GRI-2**	34	51	74
**A*	0.088	0.216	0.277
**B*	0.912	0.775	0.723
**C*	0.000	0.010	0.000
*IDDH-1**			
n	34	50	61
**A*	0.044	0.080	0.098
**B*	0.956	0.920	0.902
*LDH-1**			
n	35	48	63
**A*	0.043	0.021	0.016
**B*	0.014	0.010	0.016
**C*	0.943	0.969	0.968

Table 1 (continued)

Locus/allele	Abrir la Sierra	Bajo el Cico	Tourmaline
*PEPA**			
n	33	50	63
**A*	0.000	0.010	0.000
**B*	1.000	0.090	1.000
*PEPB**			
n	33	50	63
**A*	0.000	0.000	0.008
**B*	0.000	0.000	0.992
*PEPD**			
n	33	45	60
**A*	0.348	0.378	0.317
**B*	0.606	0.578	0.658
**C*	0.045	0.044	0.025
*PEPF**			
n	28	35	39
**A*	0.196	0.057	0.205
**B*	0.714	0.757	0.654
**C*	0.089	0.186	0.141
*PEPT-1**			
n	33	50	63
**A*	0.015	0.000	0.008
**B*	0.985	1.000	0.984
**C*	0.000	0.000	0.008
*PEPT-2**			
n	33	50	63
**A*	0.000	0.010	0.000
**B*	1.000	0.990	1.000
*PFK**			
n	34	48	63
**A*	0.971	1.000	0.992
**B*	0.029	0.000	0.008
*PGLM-1**			
n	33	50	63
**A*	0.076	0.050	0.095
**B*	0.924	0.950	0.905
Mean alleles / locus	1.86 (0.16)	2.00 (0.16)	2.17 (0.15)
Polymorphic loci %	72.22	77.78	72.22
Heterozygosity			
Direct Count	0.125 (0.032)	0.139 (0.032)	0.170 (0.037)
Expected	0.163 (0.041)	0.170 (0.042)	0.198 (0.042)

The percentage of polymorphic loci ($P_{0.99}$) ranged from 72.22% at Abrir la Sierra and Tourmaline to 77.78% at Bajo el Cico. Significant deviations from Hardy-Weinberg (Table 2) were detected in 7 of 54 (13.0 %) possible comparisons. No locus was found to deviate from Hardy-Weinberg expectations in all aggregations (Table 2), though *EST-2** was not in Hardy-Weinberg at Abrir la Sierra ($\chi^2 = 14.59$, df = 1, $P < 0.01$) and Bajo el Cico ($\chi^2 = 5.27$, df = 1, $P = 0.04$). In nearly every instance, loci failing to meet Hardy-Weinberg expectations had

observed frequencies of heterozygous genotypes which were less than expected. Heterozygote deficiencies may be attributed to one or more of four factors: negative heterosis, the Wahlund effect, the presence of null alleles, or misscoring of heterozygous individuals as homozygous.

Table 2. Breeding aggregation/locus combinations failing to meet Hardy-Weinberg expectations.

Aggregation	Locus	*P*	allele	Observed	Expected
Abrir la Sierra	*EST-2**	0.008	AA	3	0.600
			AB	4	8.800
			BB	31	28.600
	*IDDH**	0.040	AA	1	0.040
			AB	1	2.920
			BB	36	35.040
	*PEPD**	0.001	AA	6	1.813
			AB	5	12.693
			AC	0	0.680
			BB	24	20.433
			BC	3	2.240
			CC	0	0.040
Bajo el Cico	*EST-2**	0.038	AA	4	1.577
			AB	10	14.845
			BB	35	32.577
	*PEPF-1**	<0.001	AA	2	0.464
			AB	3	7.732
			AC	3	1.340
			BB	34	28.608
			BC	4	10.052
			CC	3	0.804
Tourmaline	*CAT**	0.022	AA	11	6.674
			AB	20	28.651
			BB	34	29.674
	*GP-2**	0.006	AA	24	18.186
			AB	21	32.628
			BB	20	14.186

Three loci, *CAT**, *LDH-1**, and *PFK**, exhibited changes in allele frequency and average heterozygosity from north to south across the three aggregations which were not statistically significant. This is partially attributable to the limited array of units of analysis; however the three loci that did change in allele frequency did not vary by more than 10% between peripheral aggregations.

Heterogeneity chi-square examinations indicated allele frequencies at *GP-2**, *G6PD-3**, and *GPI-2** were not distributed homogeneously among the three aggregations (Table 3) as were allele frequencies of combined loci. Distributions of allele frequencies for each of the 15 other loci were not found to differ significantly

from homogeneity. The three loci exhibiting statistically significant differences in allele frequencies among aggregations were not the same loci which had apparent (though statistically insignificant) clines in allele frequency.

Table 3. F-statistics (Weir and Cockerham 1984) estimating within-group structuring (F_{IS}) and between-group structuring (F_{ST}), gene-flow estimates (NeM, effective number of migrants per generation), and heterogeneity chi-square tests (degrees of freedom in parentheses) in three spawning aggregations of red hind in Puerto Rican waters. *P < 0.05; **P < 0.01;***P < 0.001; n.s., not statistically significant.

Locus	F_{IS}	F_{ST}	Chi-square
AAT-1*	-0.061 n.s.	0.001 n.s.	0.247 (2) n.s.
CAT-1*	0.202 *	0.003 n.s.	0.597 (2) n.s.
EST-1*	-0.008 n.s.	0.005 n.s.	1.306 (2) n.s.
EST-2*	0.356 **	0.012 n.s.	3.988 (2) n.s.
GD-1*	-0.028 n.s.	0.010 n.s.	2.197 (2) n.s.
GP-2*	0.267 **	0.078 **	25.514 (2) ***
G6PD-3*	0.098 n.s.	0.028 *	9.798 (4) *
GPI-2*	-0.066 n.s.	0.040 **	11.907 (4) *
IDDH-1*	0.056 n.s.	0.007 n.s.	1.760 (2) n.s.
LDH-1*	-0.036 n.s.	0.004 n.s.	1.318 (4) n.s.
PEPA*	-0.010 n.s.	0.007 n.s.	1.927 (2) n.s.
PEPB*	-0.008 n.s.	0.005 n.s.	1.322 (2) n.s.
PEPD*	0.333 **	0.004 n.s.	1.867 (4) n.s.
PEPF*	0.243 **	0.017 n.s.	8.923 (4) n.s.
PEPT-1*	-0.014 n.s.	0.005 n.s.	1.540 (4) n.s.
PEPT-2*	-0.010 n.s.	0.007 n.s.	1.927 (2) n.s.
PFK*	-0.025 n.s.	0.013 n.s.	3.490 (2) n.s.
PGLM-1*	-0.085 n.s.	0.005 n.s.	1.638 (2) n.s.
Mean	0.173 *	0.022 n.s.	81.266 (48) **
Unbiased F_{ST}		0.0244 ± 0.0048	
N_eM		48.87 (6.00 -249.75)	

The standardized variance of allele frequencies, F_{ST}, suggested little genetic differentiation among the three spawning aggregations of red hind from waters off western Puerto Rico. F_{ST} estimates for three loci, *GP-2**, *G6PD-3**, and *GPI-2**, were found to be significant but the mean F_{ST} for all loci was 0.022 and insignificant (Table 3). Several loci had statistically significant F_{IS} estimates and mean F_{IS} was significant, suggesting some degree of within aggregation genetic structuring. High levels of gene flow were inferred among spawning aggregations in Puerto Rican waters. Quantitative estimation of the effective number of migrants per generation (N_em), calculated using the fixation index of Wright (1943), ranged from 6 to 250 individuals per generation (Table 3).

DISCUSSION

Red hind collected from three spawning aggregations off the western coast of Puerto Rico did not demonstrate patterns or levels of allozymic variability suggestive of genetic differentiation between aggregations. Tentatively, red hind spawning

aggregations are viewed as spatially distinct components of a single local population. This does not suggest the species is panmictic. The present study is limited to the issue of genetic differentiation of a small group of spatially separate but proximate aggregations of reproductive individuals.

Failure to find locally-important genetic variation in a reef fish such as red hind is not surprising. Nonanadromous marine fishes often have been shown to exhibit less genetic divergence between geographic locales than freshwater and anadromous species (Gyllensten 1985, Smith et al. 1990, Neigel 1994). Extended planktonic life-stages and highly mobile adults are life-history characteristics that predict limited or absent population subdivision among marine fish species (Shulman and Bermingham, 1995). When biologically significant population differentiation is found in marine fishes (e.g., Bell et al. 1982, King and Pate 1992, Gold et al. 1999) physical barriers exist or existed historically, behavioral and life history characteristics operate which result in natal area fidelity, or reproductive strategies effectively enhance stochastic processes (Hedgecock 1994, Chapman et al. 1999).

Much of what is know about grouper life history argues against formation of significant population structuring. Red hind eggs and early larvae are planktonic and subject to appreciable dispersion from spawning sites (Smith 1961, Beaumariage and Bullock 1976, Colin 1982, Jory and Iverson 1989). Unless natural selection is operating across the distribution of the species or if fidelity is shown to aggregate sites it is not surprising that local structuring is minimal or absent. The present data suggest levels of gene flow among aggregations is of sufficient magnitude to mask any effects of selective and stochastic processes operating within the aggregates examined.

Based on these interpretations, management decisions treating the three aggregations as a single management unit may be justified. It may also be reasonable to generalize from this study to suggest that other spatially proximate red hind spawning aggregations will tend to be genetically similar and representative of the same population, and that if enhancement efforts are deemed necessary nearby aggregates are the best sources of donor individuals. These results do not justify transfer of red hind from one portion of the species' distribution into another prior to a thorough investigation of the genetic resources of potentially impacted populations. Surveys of mitochondrial DNA variation in this species are currently underway and may provide greater resolution of among-aggregates genetic differentiation (Avise 1987) and information concerning stock structure in red hind over a wider portion of its range and across time.

An additional issue should be addressed. Exploited species, by their very nature, may be characterized by genetic variation that is biased and which may fail to adequately describe the species prior to overfishing. Overfishing may alter life-history and population parameters making conclusions about within and/or among population variation tentative. When possible, genetic surveys should be conducted prior to biologically significant anthropogenic impacts. When this is not possible results must be interpreted with considerable caution.

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LITERATURE CITED

Aguilar-Perera, A., and W. Aguilar-Dávila. 1996. A spawning aggregation of Nassau grouper *Epinephelus striatus* (Pisces: Serranidae) in the Mexican Caribbean. *Environmental Biology of Fish* **45**:351-361.

Avise, J. C. 1987. Identification and interpretation of mitochondrial DNA stocks in marine species. Pages 105-136 in: *Proceedings of the Stock Identification Workshop, Panama City Beach, FL, 5-7 November 1985.* NOAA Tech. Mem. NMFS SEFC-199.

Ayala, F. J., J. R. Powell, M. L. Tracey, C. A. Mourao, and S. Perez-Salas. 1972. Enzyme variability in the *Drosophila willistoni* group. IV. Genetic variation in natural populations of *Drosophila willistoni*. *Genetics* **70**:113-139.

Beaumariage, D. S., and L. H. Bullock. 1976. Biological research on snappers and groupers as related to fishery management requirements. Pages 86-94 in: H. R. Bullis and A. C. Jones (eds.). *Proceedings: Colloquium on snapper-grouper fishery resources of the western central Atlantic Ocean.* Florida Sea Grant Report 17.

Bell, L. J., J. T. Moyer, and K. Numachi. 1982. Morphological and genetic variation in Japanese populations of the anemonefish *Amphiprion clarkii*. *Marine Biology* **72**:99-108.

Brulé, T., D. A. Aranda, M. S. Crespo, and T. C. Marrufo. 1996. A preliminary study on the growth performance of juvenile red grouper reared in a recirculating-water system. *Progressive Fish Culturist* **58**:192-202.

Butler, J. N., J. Burnett-Herkes, J. A. Barnes, and J. Ward. 1993. The Bermuda fisheries: a tragedy of the commons averted? *Environment* **35**:6-15, 25-33.

Chapman, R. W., G. R. Sedberry, C. C. Koenig, and B. M. Eleby. 1999. Stock identification of gag, *Mycteroperca microlepis*, along the southeast coast of the United States. *Marine Biotechnology* **1**:137-146.

Clayton, J. W., and D. N. Tretiak. 1972. Amine-citrate buffers for pH control in starch gel electrophoresis. *Journal of the Fisheries Board of Canada* **29**:1169-1172.

Coleman, F. C., C. C. Koenig, and L. A. Collins. 1996. Reproductive style of shallow-water groupers (Pisces: Serranidae) in the eastern Gulf of Mexico and the consequences of fishing spawning aggregations. *Environmental Biology of Fish* **47**:129-141.

Colin, P. L. 1982. Aspects of the spawning of western Atlantic reef fishes. Pages 69-78 in: G. R.Huntsman, W. R. Nicholson, and W. W. Fox (eds.) *The*

Biological Bases forReef Fishery Management. NOAA Technical Memo NMFS-SEFC-80.

Fukuhara, O. 1989. A review of the culture of grouper in Japan. *Bulletin Nansei Regional Fisheries Research Laboratory* **22**:47-57.

Gold, J. R., L. R. Richardson, and T. F. Turner. 1999. Temporal stability and spatial divergence of mitochondrial DNA haplotype frequencies in red drum (*Sciaenops ocellatus*) from coastal regions of the western Atlantic Ocean and Gulf of Mexico. *Marine Biology* **133**:593-602.

Gyllensten, U. 1985. The genetic structure of fish: differences in the intraspecific distribution of biochemical genetic variation between marine, anadromous and freshwater fishes. *Journal of Fish Biology* **26**:691-699.

Hedgecock, D. 1994. Does variance in reproductive success limit effective population sizes of marine organisms? Pages 122-134 in: A. R. Beaumont (ed.) *Genetics and Evolution of Aquatic Organisms*. Chapman and Hall, London, England.

Heemstra, P. C., and J. E. Randall. 1993. FAO species catalogue. Volume 16. Groupers of the world. *FAO (Food and Agriculture Organization of the United Nations) Fisheries Synopsis* 125(16).

Jory, D. E., and E. S. Iversen. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (south Florida) - black, red, and Nassau groupers. U. S. F. W. S. Biol. Rep. 82(11.110). U. S. Army Corps. Eng., TR EL-82-4.

King, T. L., and H. O. Pate. 1992. Population structure of spotted seatrout inhabiting the Texas Gulf coast: an allozymic perspective. *Transactions of the American Fisheries Society* **121**:746-756.

Manchenko, G. P. 1994. *Handbook of Detection of Enzymes on Electrophoretic Gels*. CRC Press, Boca Raton, Florida USA.

Miller, R. G. 1966. *Simultaneous Statistical Inference*. McGraw-Hill, New York, New York USA

Morizot, D. C., and M. J. Siciliano. 1984. Gene mapping in fishes and other vertebrates. Pages 173-234 in: B. J. Turner (ed.). *Evolutionary Genetics of Fishes*. Plenum. New York, New York USA.

Murphy, R. W., J. W. Sites, Jr., D. G. Buth, and C. H. Haufler. 1996. Proteins: Isozyme electrophoresis. Pages 51-120 in: D. M. Hillis, C. Moritz, and B. K. Mable (eds.) *Molecular Ssystematics*. Sinauer Associates, Inc., Sunderland, Massachusetts USA.

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. *Genetics* **89**:583-590.

Neigel, J. E. 1994. Analysis of rapidly evolving molecules and DNA sequence variants: Alternative approaches for detecting genetic structure in marine populations. California Cooperative Ocean Fisheries Investigation, Report **35**:82-89.

Olsen, D. A., and J. A. LaPlace. 1978. A study of a Virgin Islands grouper fishery based on a breeding aggregation. *Proceedings Gulf and Caribbean Fisheries*

Institute **31**:130-144.

Raymond, M., and F. Rousset. 1995. GENEPOP (version 1.2): population genetics software for exact tests and ecumenicism. *Journal of Heredity* **86**:248-249.

Reynolds, J., B. S. Weir, and C. C. Cockerham. 1983. Estimation of the coancestry coefficient: basis for a short-term genetic distance. *Genetics* **105**:767-779.

Ridgway, G. J., S. W. Sherman, and R. D. Lewis. 1970. Polymorphism in the esterases of Atlantic herring. *Transactions of the American Fisheries Society* **99**:147-151.

Roberts, C. M., N. Quinn, J. W. Tucker, Jr., and P. N. Woodward. 1995. Introduction of hatchery-reared Nassau grouper to a coral reef environment. *North American Journal of Fisheries Management* **15**:159-164.

Rogers, J. S. 1972. Measures of genetic similarity and genetic distance. *Studies in Genetics* **7213**:145-153.

Sadovy, Y. 1994. Grouper stocks of the western central Atlantic: the need for management and management needs. *Proceedings Gulf and CaribbeaFisheries Institute* **43**:43-64.

Sadovy, Y., A. Rosario, and A. Román. 1994. Reproduction in an aggregating grouper, the red hind, *Epinephelus guttatus*. *Environmental Biology of Fishes* **41**:269-286.

SAS Institute. 1985. *SAS/STAT Guide forPpersonalCcomputers*. Version 6 edition. SAS Institute. Cary, North Carolina USA.

Selander, R. K., M. H. Smith, S. Y. Yang, W. E. Johnson, and J. B. Gentry. Biochemical polymorphism and systematics in the genus Peromyscus. I. Variation in the old field mouse (*Peromyscus polionotus*). *Studies in Genetics* **7103**:49-90.

Shaklee, J. B., F. W. Allendorf, D. C. Morizot, and G. S. Whitt. 1990. Gene nomenclature for protein-coding loci in fish. *Transactions of the American Fisheries Society* **119**:2-15.

Shulman, M. J., and E. Bermingham. 1995. Early life histories, ocean currents, and the population genetics of Caribbean reef fishes. *Evolution* **49**:897-910.

Slatkin, M. 1987. Gene flow and the geographic structure of natural populations. *Science* **236**:787-792.

Smith, C. L. 1961. Synopsis of biological data on groupers (*Epinephelus* and allied genera) of the western North Atlantic. FAO Fishery Biology Synopsis No. 23.

Smith, M. H., and R. K. Chesser. 1981. Rationale for conserving genetic variation of fish gene pools. *Ecological Bulletin* **34**:13-20.

Smith, P. J., A. Jamieson, and A. J. Birley. 1990. Electrophoretic studies and the stock concept in marine teleosts. *J. Cons. Int. Explor. Mer* **47**:231-245.

Soulé, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169 in: M. E. Soulé and B. A. Wilcox (eds.) *Conservation Biology*. Sinauer Associates, Sunderland, Massachusetts USA.

Snedecor, G. W., and W. G. Cochran. 1980. *Statistical Methods*. Iowa State University Press, Ames.

Swofford, D. L., and R. B. Selander. 1981. BIOSYS I: a Fortran program for the comprehensive analysis of electrophoretic data in population genetics and systematics. *Journal of Heredity* **72**:282-283.

Tucker, J. W. 1994. Spawning by captive serranid fishes: a review. *Journal of the World Aquaculture Society* **25**:187-191.

Tucker, J. W., and P. C. Woodward. 1994. Growth and development of domestic Nassau groupers. *Proceedings Gulf and Caribbean Fisheries Institute* **43**:389-391.

Waples, R. S. 1987. A multispecies approach to the analysis of gene flow in marine shore species. *Evolution* **41**:385-400.

Weir, B. S., and C. C. Cockerham. 1984. Estimating *F*-statistics for the analysis of population structure. *Evolution* **38**:1358-1370.

Wright, S. 1943. Isolation by distance. *Genetics* **28**:114-138.

Size, Sex Ratio, and Fecundity of Nassau Grouper (*Epinephelus striatus*) Landed during Spawning Season in the Central Bahamas

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ABSTRACT

This collaborative research was initiated to collect basic fisheries data on Nassau grouper (*E. striatus*) landed in New Providence and Long Island. Although The Bahamas has a comprehensive fisheries management plan in place for *E. striatus*, there are few programs in place to judge the success of size limits, regulation on gear used, limited closures of spawning sites and some marine fisheries reserves. Data was collected on whole fish landed by day fishers in four categories:

i) Profile of the fishers including age, length of time fishing and economic dependence on fishing,
ii) Capital investment of fishers in boats and equipment,
iii) Catch data for the day including total number of species caught, fishing location, and time spent fishing, and
iv) The whole weight, length, gonad weight, and gonad sample from *E. striatus* landed.

From 24 November 1999 to 15 February 2000, 311 groupers were measured and weighed at points of landing, 258 gonad samples collected, and 26 fishermen interviewed. Of all fish landed, over 30% were immature, with a 1:1 sex ration between the remaining identified males and females. Female gonads were examined and identified as one of five stages from immature, maturing, ripening, ripe, and spent. Most females examined were "ripening" with a mean oocyte diameter of 1200 microns. No ripe females were landed, and only a small number of spent females were collected. Mean length of all females was 637 mm, but spent females were significantly larger at a mean total length of 673 mm. Of all fish with a gonad-somatic index of greater than 10%, females outnumbered males almost 2:1.

KEYWORDS: *Epinephelus stri*atus, grouper, spawning

INTRODUCTION

The Nassau grouper (*Epinephelus striatus*) represents the most important finfish resource in the Bahamas. This species is recognized not only for its commercial value and cultural importance in the Bahamas, but also its ecological contribution to healthy coral reefs as a top reef predator. With the establishment of the Exuma Cays Land and Sea Park in the central Bahamas in 1986 as a marine fisheries reserve, the country had some base-line information on the size and abundance of groupers on unfished reefs. For the past 14 years, managers and the general public have grown more concerned about the decline in the abundance of large groupers on coral reefs outside this park, and the decline in the number of groupers reported at known (and fished) spawning aggregations. The Department of Fisheries (DOF), Government of The Bahamas, has recently closed fishing on some spawning aggregations and proposed five new marine fisheries reserves to protect grouper stocks in the country (DOF 2000). This paper reports a field investigation to document size, sex ratio and fecundity of locally landed catch on the islands of New Providence and Long Island.

The Nassau grouper is a large serranid that is widely distributed throughout the western tropical Atlantic. Its role as a top predator of reef communities makes it an important but vulnerable species for the health of coral reefs. This species is targeted for both recreational and commercial fishing, and populations of *E. striatus* are depleted or locally extinct throughout much of its tropical northwestern Atlantic range (Sadovy 2000). A comprehensive program to conserve grouper stocks in The Bahamas requires fisheries-dependent and independent data.

Fecundity and sex ratio of female groupers entering spawning aggregations is critical to know, but tedious in data collection. In The Bahamas, most of the fishing effort for grouper occurs from November to February, and fishers target the spawning aggregations. Most fishers use spear and surface-supplied air (hookah) and can fish very efficiently over a broad depth range along the carbonate platform margins. Larger boats that land their catch for commercial export typically return landing points after a week or more fishing with frozen eviscerated fish. A sizable fishing fleet of smaller boats operates from the islands on New Providence (with the capital city, Nassau) and Long Island. These fishers return daily with whole fish that can be measured and used for fecundity monitoring. Fishing pressure on groupers in the Bahamas is significant and increasing, but this area is considered one of the healthiest stocks in the wider Caribbean in terms of fish abundance and size. In 1999, 841,044 pounds of grouper were landed in the commercial export market, with a value of almost $B 2,000,000 (DOF, 2000). Local landings and recreational catch are not accounted for.

Nassau grouper is very vulnerable to heavy exploitation; these fish are large in size, slow growing and conveniently aggregate for reproduction. Overfishing can theoretically change the population dynamics of a species by decreasing abundance, and selecting the largest and most fecund individuals. The Nassau groupers in the central Bahamas may represent a discreet metapopulation of reef fishes. There is likely no location with more field research completed on this species. Research has

been done on describing:

i) The location and behavior of spawning aggregations (Colin 1992),
ii) The abundance of groupers on reef habitats (Sluka et al. 1996),
iii) The distribution and collection of post-settlement groupers (Eggleston, 1995),
iv) The energetics, activity and behavior of juveniles (Sullivan and de Garine 1994),
v) Home range and migration (Bolden unpub), and
vi) The development of new microsatellite markers for examining population subdivision within the range of the Nassau grouper for evidence of stock separation (Stevenson, et al. 1997).

Much information has been collected on the biology and ecology of this species. However, if the policy of closing spawning aggregation to fishing was to be imposed, data needed to demonstrate that fishing practices were not only impacting the abundance of fish at spawning aggregations, but that the individual groupers were smaller, less fecund, and not present in a 1:1 sex ratio.

MATERIALS AND METHODS

The goal of this project was to twofold:

i) To collect sufficient gonad samples to characterize size/fecundity relationships in Nassau groupers landed in New Providence and Long Island by day fishers, and
ii) To develop the method for monitoring size and fecundity changes in *E. striatus* in response to management actions such as closures of spawning aggregations.

There were two data forms used:

i) A fisher interview form with three parts, and
ii) A fish survey data sheet for recording fish measurements and gonad sample number.

This information was put into a relational database (ACCESS) to relate information of groupers, fishers and locations of catch (Table 1).

The following equipment was prepared for each sampling trip: cooler with ice, sample jars, labels for gonad samples, data sheets on water-resistant paper with fisher identification numbers, fish measuring board, large fish scale (25 kg), smaller scales for gonad weights (1000g and 100 g), ziplock bags for weighing gonads, marker pen and tape for labeling fish, latex gloves, scissors for dissection and magnifying glass for visual inspection of fresh gonad tissue. Identification codes were used to keep fisher identity anonymous in data reporting.

During the data collection, whole landed fish were measured and tagged, as they were unloaded. Lengths were then recorded in millimeters by holding the tail flat to measure total length then flexing caudal rays to determine standard length. Often the dissection and collection of gonad material could not be done until the fish was sold as venders preferred to present whole fish to customers. Data collection could

take several hours for this reason. Field notes were reviewed within two days of collection and complete summary completed in the database. Gonad samples were collected from fresh fish, and kept on ice during the surveys, Bouin's fixative was added in the laboratory that same day to just cover sample, samples were kept small enough to be well saturated with fixative inside of sample jars. Bouin's fixative was prepared as 75% saturated picric acid solution, 20% buffered formalin and 5% Glacial acetic acid. An attempt was made to collect a small cross-section of the gonadal tissue. Gonad samples were examined under a microscope using an ocular micrometer. The micrometer was calibrated to give oocyte diameter in microns. 100 oocytes from each sample were measured, and female groupers were ranked according to maturity stages (FAO 1979, Table 2). Diameters of preserved oocytes could be assigned to the stages.

Table 1. Information needed to relate fishers to catch and location for monitoring size, sex ratio and fecundity of Nassau groupers fished from spawning aggregations.

FISHERS	FISH	CATCH LOCATION
Personal information # of years fishing, age % income from fishing, Months of year fishing, Targeted species, Boat ownership	**Length** in millimeters Total, standard	Record location where the fisher was that day as reported by fishermen – using local names. Later this information can be related to the Department of Fisheries regions and to known aggregation locations Record the depth of fishing as reported by the fisher Record whether fisher was located in an aggregation, many fishers report a cluster" or aggregation of large groupers numbering from 5 to 50 individuals.
Daily Catch Data Catch per Effort Information Date of catch, Total number of finfish, Gear Used Catch location, Hours Fishing, Species Caught Number of Nassau grouper	**Total Weight** in kg	
Opinion on status of fishery Four questions	**Gonad Weight** in grams Gonadal-Somatic Index	
	Gonad Sample Sex, Fecundity Histology	

Table 2. A five-point maturity scale for potential spawners with an estimate of oocyte diameter from this study.

STAGE	STATE	DESCRIPTION	SIZE OF OOCYTES
I	Immature	Gonad about 1/3 of the length of the body cavity. Ova not visible to the naked eye	Ova not measured
II	Maturing virgin or recovering spent	Ovaries about ½ of body length of body cavity, Ovary pinkish, ova may be just visible to the naked eye,	Gonad up to 7% of body weight, Ova up to 150 microns
III	Ripening	Ovary about 2/3 of body cavity, pinkish yellow with obvious granular texture – Ova not translucent	Gonad from 7 to 20% of body weight Ova 150 to 1500 microns
IV	Ripe	Ovaries over 2/3's the length of the body. Ova hydrated and translucent in color	Gonad over 23% of body weight Ova greater than 1500 microns
V	Spent	Ovary shrunken to about ½ of body cavity length. Walls of gonad loose, ova size very variable, remnants of opaque ova	Ova diameters variable

RESULTS

Sampling of daily catches was carried out at two landing locations in New Providence: Montagu Ramp and East Street South. Four days were spent sampling the daily catch from Long Island fishers. In both sites, local fishers cooperated with field staff to allow their catches to be weighted and measured.

From 24 November 1999 to 15 February 2000, 311 groupers were measured and weighed at points of landing, 258 gonad samples collected, and 26 fishermen interviewed. Of all fish landed, 80 groupers were identified as females, 57 were males, with 64 fishes immature (Stage 1). 16 spent individuals were collected from the Long Island fishers (Figure 1). No ripe or spent groupers were seen from the sampling in New Providence. The average total length of females was 637 ± 49 mm, males collected were slightly larger at 644 ± 58 mm, and spent individuals were significantly larger at 673 ± 35 mm. Immature groupers were significantly smaller with a mean total length of 528 ± 61. The smallest individual grouper that could potentially spawn (Stage 2- 3) was 560 mm. The legal size limit for groupers in the Bahamas is set at 3 pounds total body weight (1.9 kg). No groupers landed were smaller than the legal size, with the smallest fish sampled being 2.0 kg or 415 mm

total length. The largest grouper landed was 12.3 kg or 774 mm total length. All males and females were present in a sex ratio of males to females of 1:1.4. However, if only ripening and ripe individuals were considered, male to female ratio was 1:2. Female gonads were examined and identified as one of five stages from immature, maturing, ripening, ripe, and spent. Most females examined were "ripening" with a mean oocyte diameter of 1200 microns. No ripe females were landed, and only a small number of spent females were collected from Long Island. Mean length of all females was 637 mm, but spent females were significantly larger at a mean total length of 673 mm. Of all fish with a gonad-somatic index of greater than 15%, females outnumbered males almost 2:1.

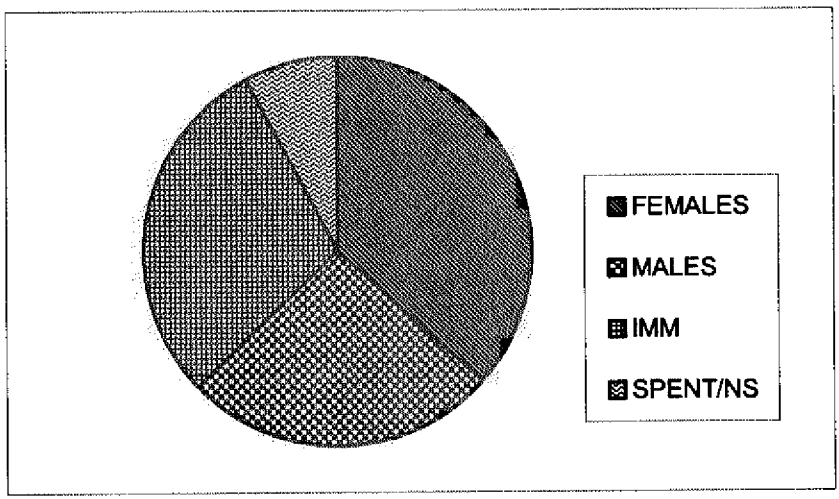


Figure 1. Distribution of male, female, immature and spent groupers sampled from daily catches landed in the central Bahamas during the spawning aggregations.

Fishers reported targeting aggregations, but the definition of "aggregation" was quite broad. "Aggregations" are defined by the fishers as any group of five or more fishes; they report that aggregations form in November, and occur at many locations along the platform margin, with 5 to 50 groupers "clustered" along the drop-off. Their fishing depths were reported to be from 40 to 120 feet (12 to 38 meters). Within a particular catch (representing one aggregations, or individual groupers in the same vicinity) there was a mixture of males, females and immature individuals.

Looking at all female groupers, the gonad-somatic index (percent gonads of total body weight) and the oocyte diameter could be used to cluster the fish in Stage 1 (Immature), Stage 2 (Maturing) and State 3 (Ripening). No ripe individuals were collected (Figure 2).

Figure 2 illustrates the overlap in size range for groupers in the different stages of reproduction. Stage 3 (Ripening) females ranged from 560 mm to over 750 mm

(Figure 3) with Gonad-Somatic indices (GSI = gonad weight to total body weight) ranging from 10 to 23 %. Larger fishes had a larger GSI (Figure 4) and fecundity scaled with size. Using the mean diameter of Stage 3 oocytes, about 475 eggs would be in one gram of gonadal tissue. The smallest ripening females were developing approximately 199,900 eggs (a 4.2 kg individual with a GSI of 10%) compared to the largest individual developing 1,170,960 eggs (12.3 kg fish with a GSI of 20%).

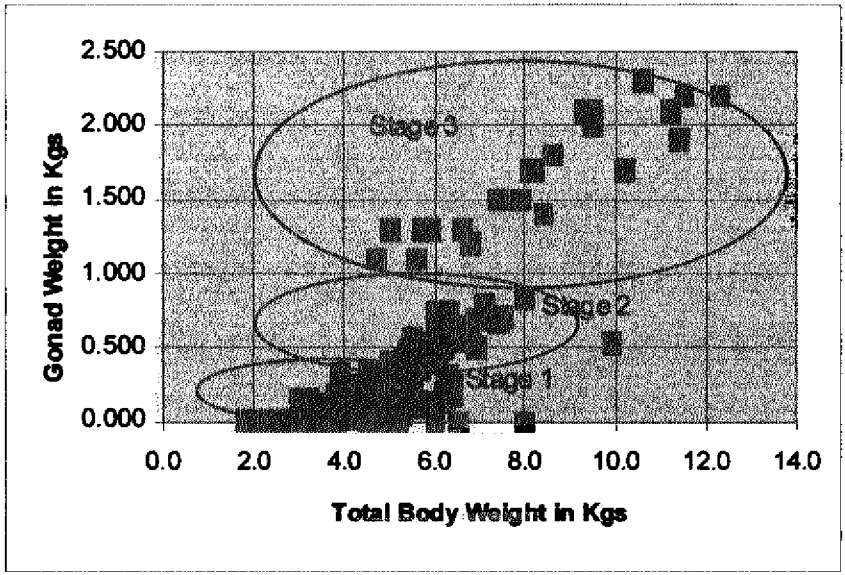


Figure 2. Distribution of body weight to gonad weight for female and immature groupers sampled from daily fishing of winter aggregations.

DISCUSSION

Nassau grouper fisheries throughout the Caribbean have collapsed over the past 30 years primarily from lack of reproductive output and recruitment (Bohnsack 1990). The trends observed have included dramatic decreases in the abundance and size of individual Nassau groupers caught at spawning aggregations. Very little information exists on size distributions of fishes on Bahamian aggregations, but there are clear reports on decline in the abundance of fishes at such aggregations (Sadovy, 2000), Sadovy, 1994). Reports on Nassau grouper sexual development and reproduction (Sadovy and Colin 1995) have emphasized the variability in populations examined, and speculated on the social or intra-specific interactions impacting sex reversal and participation on individuals in aggregations. Long term observations of groupers on reefs in The Bahamas confirm overlapping home ranges and close association of large adults and smaller sub-adults (Sluka and Sullivan

1996). The mixed size range and gonadal development state of fishes collected in this study again support the social nature of winter aggregation behavior in Nassau groupers, and the plasticity of sexual development.

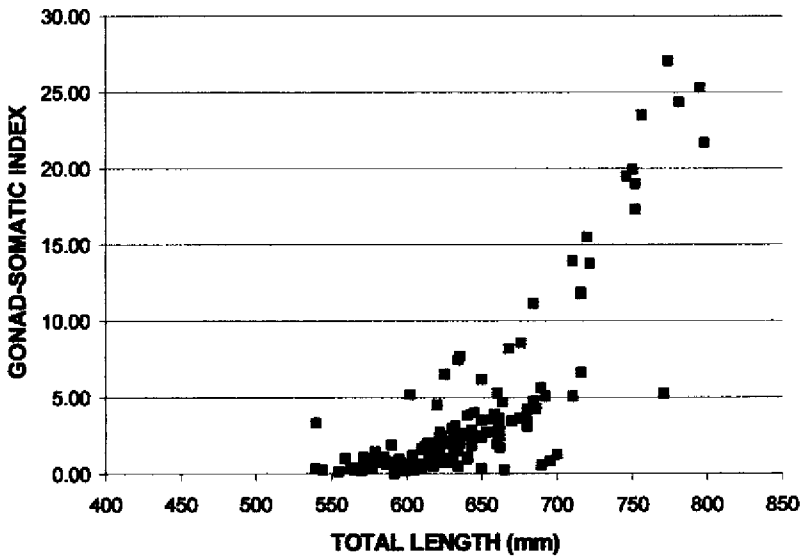


Figure 3. Mean oocyte diameter in microns plotted against total body length in millimeters for female groupers fished from winter spawning aggregations.

New Providence island is within range of day fishing for five reported Nassau grouper spawning aggregation sites, the two largest being reported off High Cay, Andros Island and in the northern Berry Islands. Fishers caught "aggregations" of groupers in many other locations, and reported movements of fish along the platform margin throughout the winter fishing months (November through February). The collection effort targeted the days before and week following the full moon to maximize our chances of collecting spawning groupers. Immature individuals were caught with ripening individuals, but very few fish were landed in a pre-spawning condition (Stage 4) and only a small number in spent condition (Stage 5). The near spawning and spent individuals were only collected from day fishers operating from Long Island, and these fishers were targeting a known spawning aggregation. It was surprising to observe that the majority of groupers landed in New Providence were not in spawning condition, but were associated with some sort of migration aggregation. More information about the seasonal movements of groupers to and from reef areas is critical to understanding the significance of these smaller aggregations targeted by fishers. This lack of larger aggregations and spawning individuals may already indicate a disruption of spawning aggregations by fishing.

Sadovy (2000) has reported that overfishing of large Nassau grouper spawning aggregations (reported in 100,000's of fishes) causes the aggregating fishes to move deeper and spread out over a much larger area in successive years. This dispersal of spawning aggregations makes estimating their size (in number of fishes) more difficult.

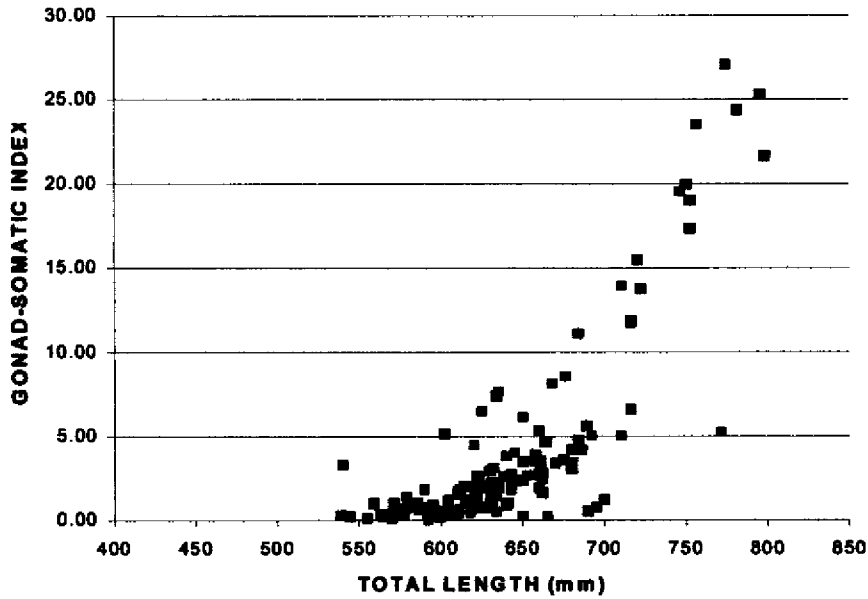


Figure 4. Gonad Somatic Index plotted against total length (mm) for groupers landed during winter spawning aggregations. Smaller groupers at a similar stage of oocyte development had much smaller GSIs.

In summary, this project was labor-intensive and time-consuming to accommodate fishers' schedules for cleaning grouper, but represents a relatively simple and low-technology protocol for monitoring the status of grouper stocks from land. This effort can compliment larger research initiatives that target a specific spawning aggregation. The local grouper fishery in the Bahamas is very dependent on demand and weather, thus fishing activities and intensity can be unpredictable from week to week. A simple, flexible program that can work with local fishers can help elucidate important information on the movement and behavior of the Nassau grouper. This monitoring is to be proposed as an annual program to compliment a larger Nassau grouper conservation initiative.

LITERATURE CITED

Bolden, S.K.[In press] Longdistance movement of a Nassau grouper (*Epinephelus striatus*) to a spawning aggregation in the central Bahamas. *Journal of Fish Biology.*

Bohnsack, J.A. 1990. Black and Nassau grouper fishery trends. NMFS-SEFSC, Miami.

Colin, P.L. 1992. Reproduction of Nassau grouper, *Epinephelus striatus* (Pisces: Serranidae) and its relationship to environmental conditions. *Environmental Biology of Fish* **34**:357-377

Department of Fisheries, Government of the Bahamas. 2000. Annual Report for 1999. Nassau, Bahamas.

Sadovy, Y. 1994. Grouper stocks of the western central Atlantic: the need for management and management needs. *Proceedings of the Gulf and Caribbean Fisheries Institute* **43**:43-64.

Sadovy, Y. 2000. The case of the disappearing grouper: *Epinephelus striatus*, the Nassau group er in the Caribbean and Western Atlantic. *Proceedings of the Gulf and Caribbean Fisheries Institute* **45**:5-22.

Sadovy, Y and Colin, P. 1995. Sexual development and sexuality in the Nassau grouper. *Journal of Fish Biology* **46**:961-976.

Sluka, R. M. Chiappone, K. Sulivan and R. Wirhgt. 1997. The benefits of a marine fishery reserve for the Nassau grouper, *Epinephelus striatus*, in the central Bahamas. *Proceedings of the 8th International Coral Reef Symposium* **2**:1961-1964.

Age Structure of Red Snapper (*Lutjanus campechanus*) in the Gulf of Mexico by Fishing Mode and Region

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ABSTRACT

Red snapper were sampled from the commercial and recreational fisheries of the Gulf of Mexico from Texas to the west coast of Florida during 1998 and 1999. Sectioned sagittal otoliths (n = 8,169) were used to estimate the age structure of the commercial and recreational fisheries and to compare ages between the western and eastern gulf. Ages of red snapper ranged from 1 to 47 years. Age 3 fish dominated the commercial and recreational hand-line fishery in 1998. In contrast, full recruitment to the commercial long-line fishery did not occur until age 5. In 1999, four year old fish were most common in the commercial long-line and hand-line catches, while three and four year old fish dominated the recreational catches. Similar to 1998, the commercial sector consisted of the largest percentage of older fish in 1999. In 1998 red snapper age structure landed by the commercial hand-line fishery was similar between the eastern and western Gulf of Mexico, while the commercial long-line and "for hire" data suggested older fish were collected from the western gulf. The commercial hand-line and "for hire" fisheries both indicated older fish were collected in the western Gulf of Mexico in 1999.

KEY WORDS: Age structure, otoliths, red snapper

INTRODUCTION

Red snapper (*Lutjanus campechanus*) are large, carnivorous reef fish which commonly occur along the U.S. Atlantic coast to North Carolina and throughout the Gulf of Mexico. This species is an important component of the commercial and recreational fishery in the Gulf of Mexico (Wells 1975, Hoese and Moore 1977). Commercial landings in the Gulf of Mexico have declined from a high of over 14 million pounds in 1965 to a low of 2.2 million pounds in 1991. Similarly, recreational landings have declined from 6.5 million pounds in 1981 to 1.2 million pounds in 1990 (Schirripa and Legault 1999). Despite restrictions placed on the commercial and recreational fisheries since 1991, controversy recently existed over the status and management of red snapper in the Gulf of Mexico (MRAG Americas Inc. 1997). This controversy led to a congressional mandate for an independent

scientific stock assessment and funding was made available for increased sampling of the recreational and commercial fishery in 1998 and 1999.

Understanding the age structure of the red snapper fishery is crucial for accurate stock assessments and for determining year class strength. Previous studies have used otoliths to age red snapper and provide basic information on growth and annulus formation (Futch and Bruger 1976, Bortone and Hollingsworth 1980, Nelson and Manooch 1982, Wilson et al. 1994, Manooch and Potts 1997). Our objectives were to compare the age and size structure of red snapper collected from the commercial and recreational fishery in the Gulf of Mexico by fishing mode and sampling region.

MATERIALS AND METHODS

Red snapper were sampled from the commercial and recreational fisheries of the Gulf of Mexico from Texas to the west coast of Florida. All fish were measured to total length TL (mm) or measurements converted to total length TL(mm) = 1.061 x FL(mm) + 2.651, $r^2 = 0.99$. Sagittal otoliths were collected with corresponding fishery data from January 1998 to November 1999. We followed the otolith processing method of Cowan et al. (1995). The sectioned otoliths were viewed under a dissecting microscope (25X), and three readers made independent age determinations with 20% of the otoliths aged by all readers for estimates of precision. Ages were assigned based on the count of annuli (opaque zones observed with reflected light) and the degree of marginal edge completion. For example, otoliths were advanced a year in age after January 1st if their edge-type was a nearly complete translucent zone. After June 30, when opaque zone formation is typically complete in the Gulf of Mexico (Wilson et al. 1998), all fish were assigned an age equal to the annulus count by convention. By this traditional method, an annual age cohort is based on a calender year rather than time since spawning (Jearld 1983).

Prior to beginning aging the 1998 samples we participated in age calibration and otolith exchange exercises with investigators at two laboratories (Louisiana State University and the University of South Alabama). In addition we made exchanges of a small otolith set (100 otoliths) with investigators at the National Marine Fisheries Service, Beaufort laboratory and South Carolina Marine Resources Research Institute.

RESULTS AND DISCUSSION

A total of 24,626 red snapper were sampled for otoliths during 1998 and 1999. Both the recreational fishery (i.e., charter boat, head boat and private boat) and commercial fishery (i.e., hand-line and long-line) were sampled and a random subsample of 8,169 otoliths (33%) was chosen for sectioning and age determination. This subsample approximately corresponded to the landings in the fishery by fishing sector; that is ½ commercial and ½ recreational (Figure 1). In addition, the resulting subsample reflected the landings by state. Approximately ½ of the samples

were drawn from eastern gulf states (Florida, Alabama and Mississippi) and ½ from western gulf states (Louisiana and Texas).

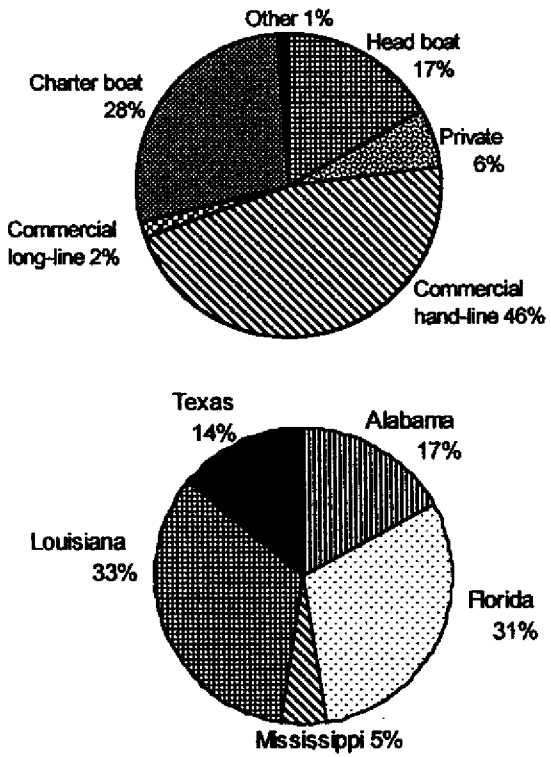


Figure 1. Percent composition of 1998 and 1999 subsample selected for age determination

In 1998 red snapper ages ranged from 1 to 39 years. Age-3 red snapper dominated the commercial hand-line and recreational sectors (Figure 2) and age-3 appeared to be the age at recruitment into these fisheries during 1998. The age proportions of hand-line caught fish (i.e., commercial hand-line, charter boat, head boat and private boat) appeared to be very low beyond age eight or nine dropping to less than 1% of the ages within each fishing sector. In contrast, red snapper reached age five or six before they fully recruited to commercial long-line gear which correlated to the larger sizes recorded from long-line catches. Similarly, red snapper caught by long-line gear were commonly much older with fish reaching age 18 before the proportion of age was less than 1%. Size-at-age data indicated that rare and relatively old fish (ages in the 20s and 30s) were caught in all fishing sectors but more commonly in the commercial sectors (Figure 3).

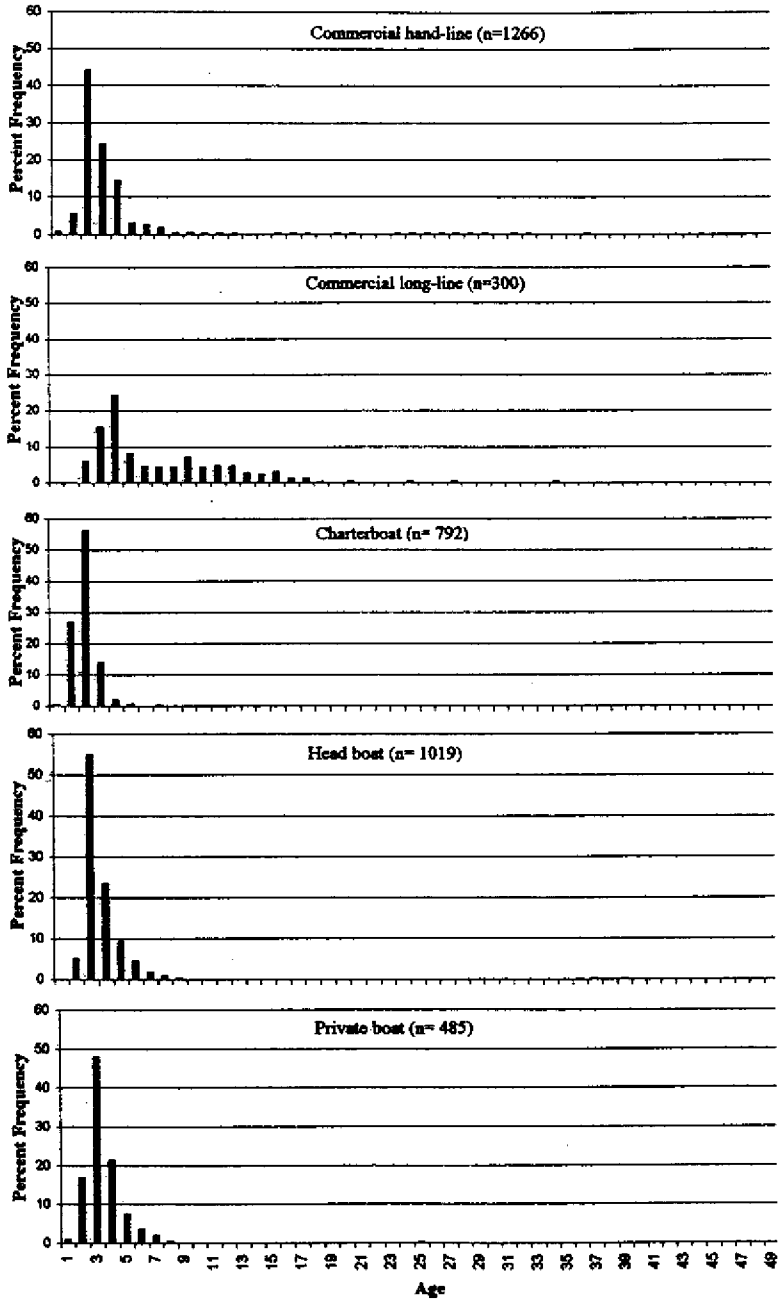


Figure 2. Age frequency of red snapper by fishing mode in 1998

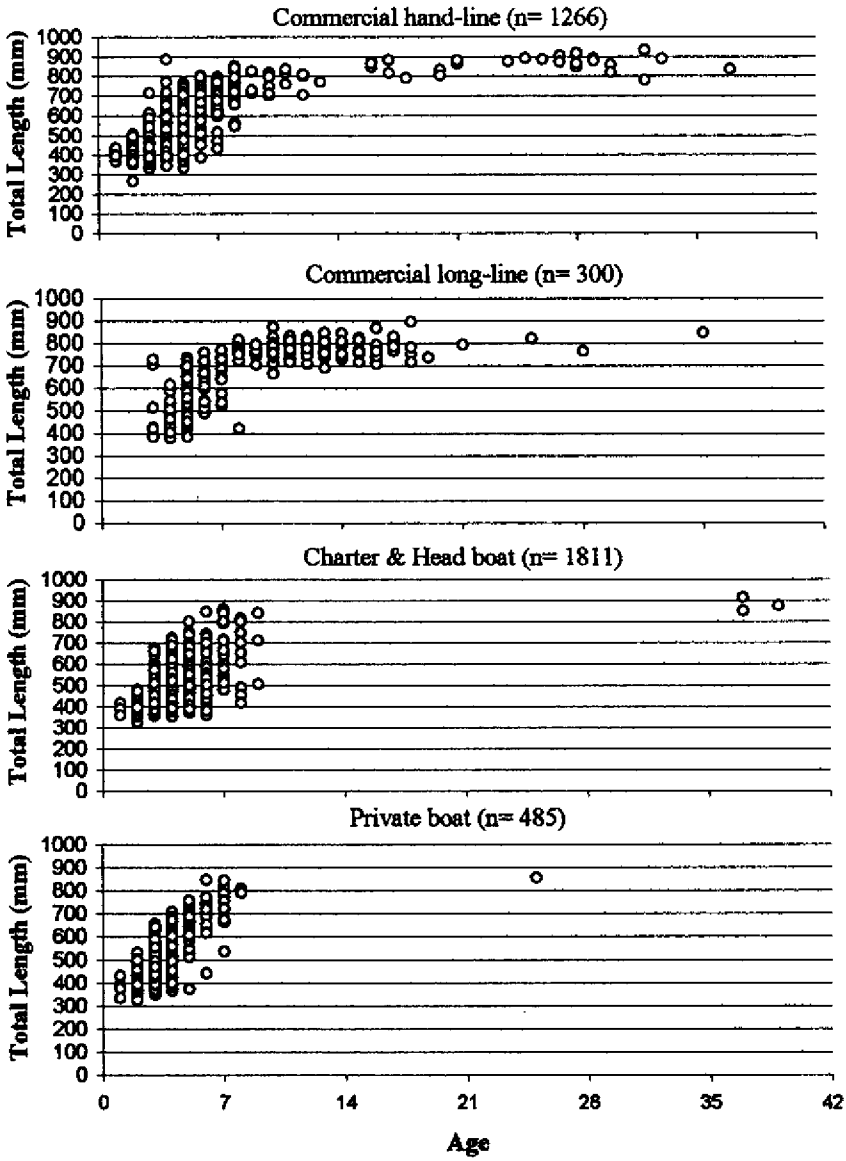


Figure 3. Size at age of red snapper from 1998

Red snapper collected in 1999 ranged in age from 2 to 47 years with age-3 or 4 appearing to be the age of recruitment to the fishery. Age frequency distributions indicated that age-4 red snapper dominated the commercial long-line and hand-line catches, while approximately equal numbers of age 3 and 4 year old fish were most abundant in the recreational catches (Figure 4). The commercial catches included the largest percent of older fish with fish reaching age 10 before the proportion was less than 1%. In contrast, the recreational caught fish only reached seven before the proportion was at 1%. Size at age data reflected this trend indicating that larger and older fish were most common in the commercial sector (Figure 5). We were somewhat puzzled to discover a few relatively old but small fish (e.g., 30 years and 500 mm TL) from the "for hire" (i.e., charter boat and head boat) fishery. These fish were re-aged and the original data checked to determine if an error had been made. Barring an error in the recorded TL from the port agent, it seems that these apparent outliers reflect a few very slow growing fish.

We compared ages by region across the eastern and western Gulf of Mexico. Western gulf fish consisted of fish landed in Louisiana and Texas while, the eastern gulf fish consisted of fish landed in Florida, Alabama and Mississippi. In 1998 red snapper age structure landed by the commercial hand-line fishery was similar between the east and west. Three year old fish dominated both regions with few fish recorded beyond five years (Figure 6). The commercial long-line fishery did suggest some age differences between east and west. The eastern gulf long-line ages had no fish beyond seven years, while in the western gulf 45% of the fish were greater than seven years. However, long-line fish from the eastern gulf consisted of a relatively small number of individuals (n = 25) in 1998. The western "for hire" catch consisted of older fish with approximately equal numbers of three and four year old fish, while the eastern gulf was dominated by three year old fish (Figure 7). Private boat age distributions were not compared regionally due to small sample size. It is not surprising that larger older fish were collected from the commercial long-line fishery since this fishery generally exploits deeper water out of reach of most recreational anglers.

The age structure of the commercial hand-line fishery from 1999 was fairly similar between east and west however, the Western Gulf of Mexico indicated a slightly larger proportion of older fish (> four years) (Figure 8). The "for hire" fishery in the western Gulf of Mexico also consisted of a greater percentage of older fish (32% > four years) than the "for hire" fishery in the eastern gulf (7% > four years). In 1999 the commercial long-line samples were comprised of fish exclusively from the eastern gulf (Figure 4). From this study it appears that older and larger red snapper from the western gulf may reflect a geographic pattern. This is consistent with anecdotal evidence from commercial fishers and port samplers claiming that red snapper west of the Mississippi River are larger than their eastern counterparts. However, in a smaller sampling area Wilson et al. (1998) found no significant difference in age distributions between fish collected from Eastern Louisiana and Western Louisiana (i.e., east and west of the Atchafalaya River). Our data also

reflected the presence of a potentially strong 1995 year class which was expressed in the dominance of age 3 fish in 1998 and age 4 fish in 1999. Preliminary aging results from red snapper landed in 1997 also indicated a large number of 2 year old fish. Further evidence for a stronger year classes from 1995-1997 was suggested by juvenile abundance from the fall groundfish survey (Schirripa and Legault 1999).

Precision and accuracy are issues of importance for measures of age-structure, particularly for tracking year class strength and effective stock assessment (Beamish and McFarlane 1995). Validation of annulus formation from relatively young age classes of red snapper has been accomplished using marginal increment analysis (Manooch and Potts 1997, Patterson 1999). Age estimates of red snapper from the Gulf of Mexico as old as 50 years has recently been validated by radiometric dating (Baker 1999) and resolves an earlier controversy surrounding estimates of longevity in red snapper (see Rothschild et al. 1997). But even though basic validation of annulus formation and longevity has been accomplished for red snapper, judging the overall accuracy of age-structure determinations is very difficult in many fisheries (Beamish and McFarlane 1995).

Measures of reader error as inferred from precision estimates provides some ability to judge the aging results for red snapper. Generally, reader agreements increased between the 1998 and 1999 samples. We improved from better than 90 % ± 1 yr. agreement among readers to better than 96% ± 1 yr. for 1998 and 1999 respectively. Our in-house measurements of precision (average percent error; Beamish and Fournier, 1981) ranged from 8% in 1998 to 5.2% in 1999 approaching a suggested target of 5% for production aging programs (Morison et al. 1998). In our otolith exchanges between laboratories, all parties generally agreed upon interpretation of annulus structure. But while the mean size-at-age results were very similar within laboratory groups, there were some differences between groups of laboratories (the three Gulf laboratories versus the two Atlantic coast laboratories) based on an initial exchange of 100 otoliths. Mean size-at-age among our gulf group tended to reflect that at any size mode from about 400 to 700 mm (TL), ages were about 1 year younger on average, than those assigned by the Atlantic coast group. During a recent workshop reviewing these findings, all parties agreed that the most difficult interpretation centered around the variable appearance of the first annulus which seems to be a general problem for many reef fishes (Fowler, 1995). While our future efforts will focus on resolving this issue, we acknowledge that age determinations are certainly not made without error and we plan to continue to make exchanges and work towards standardized interpretations. Despite these efforts, inferences about good or poor year classes will be stronger if independent measures, such as juvenile surveys, are conducted for corroboration.

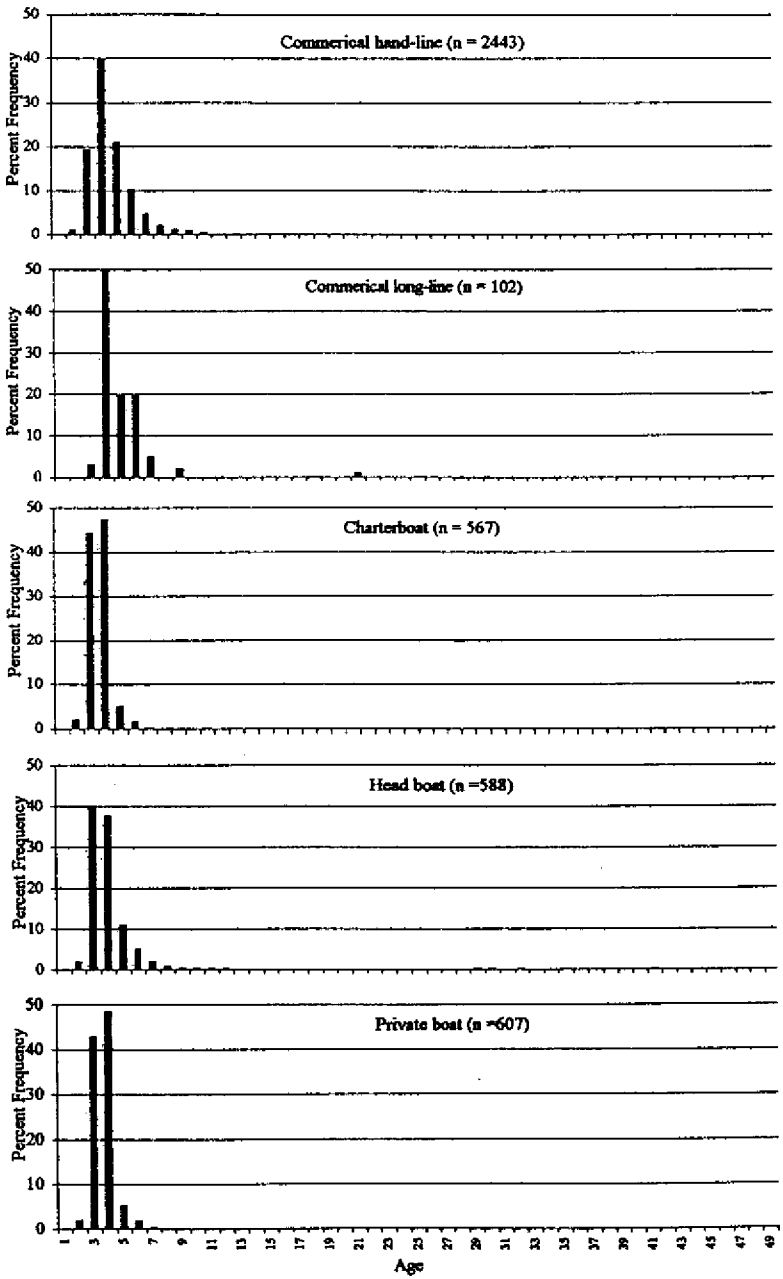


Figure 4. Age frequency of red snapper by fishing mode in 1999

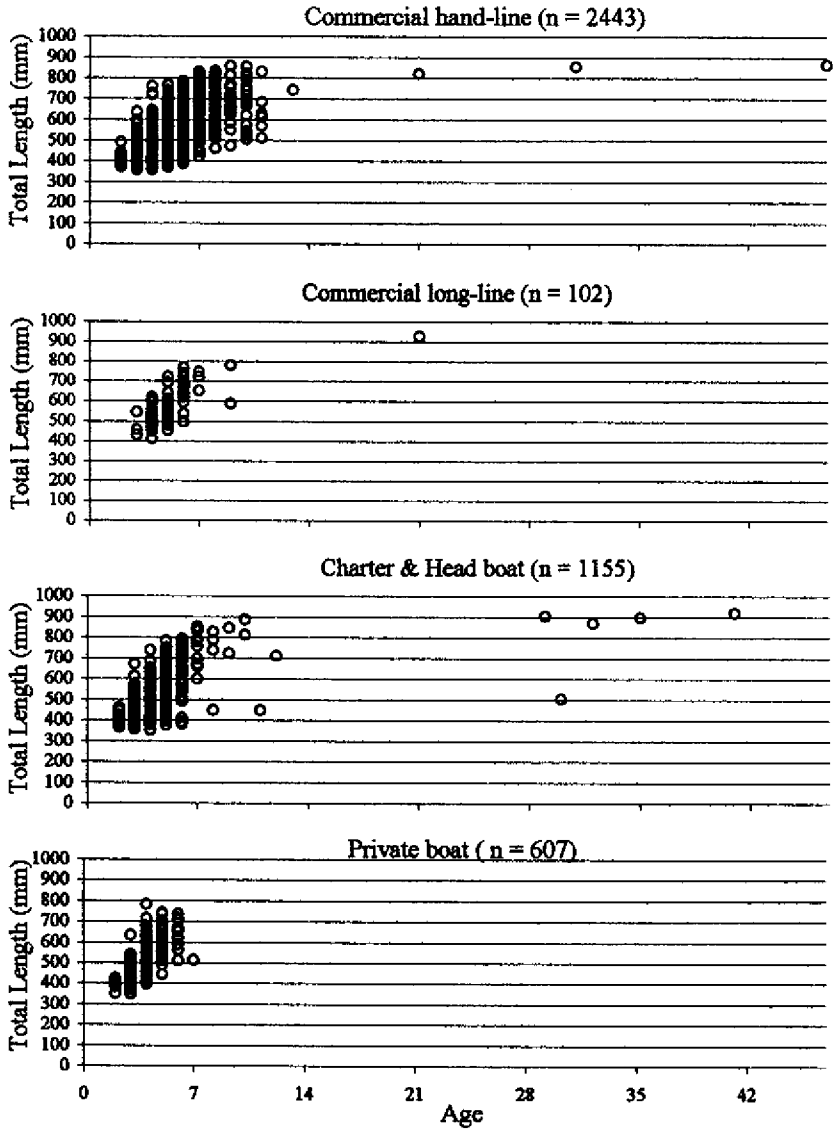


Figure 5. Size at age of red snapper from 1999

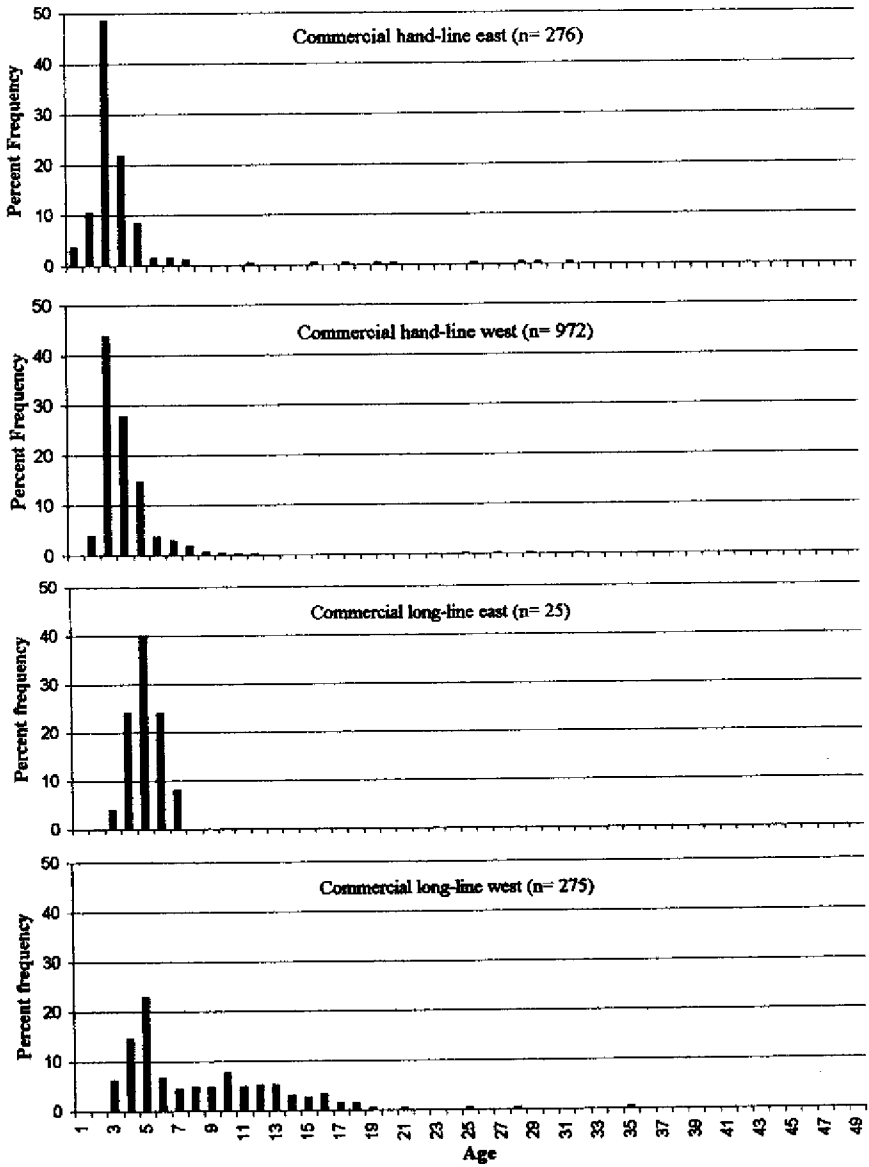


Figure 6. Age frequency of the commercial fishery by sampling region in 1998

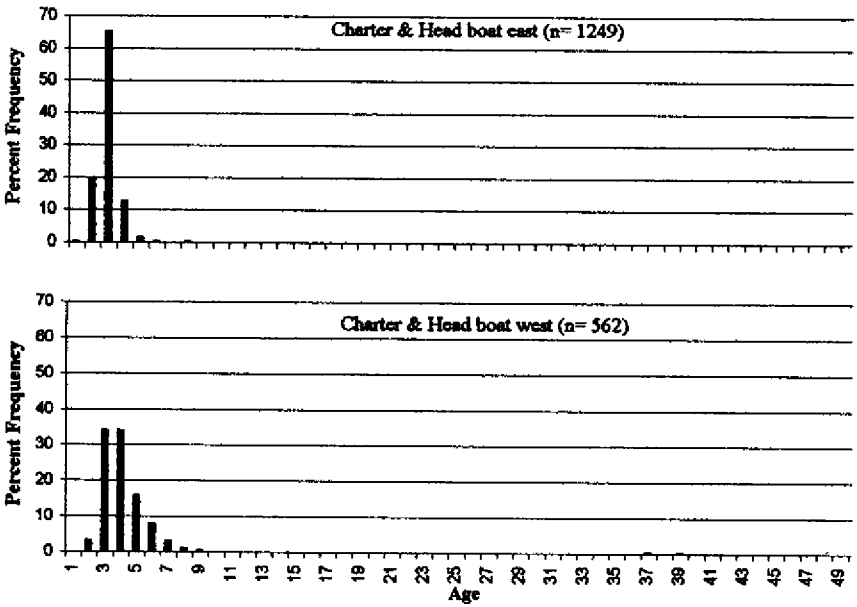


Figure 7. Age frequency of the recreational fishery by sampling region in 1998

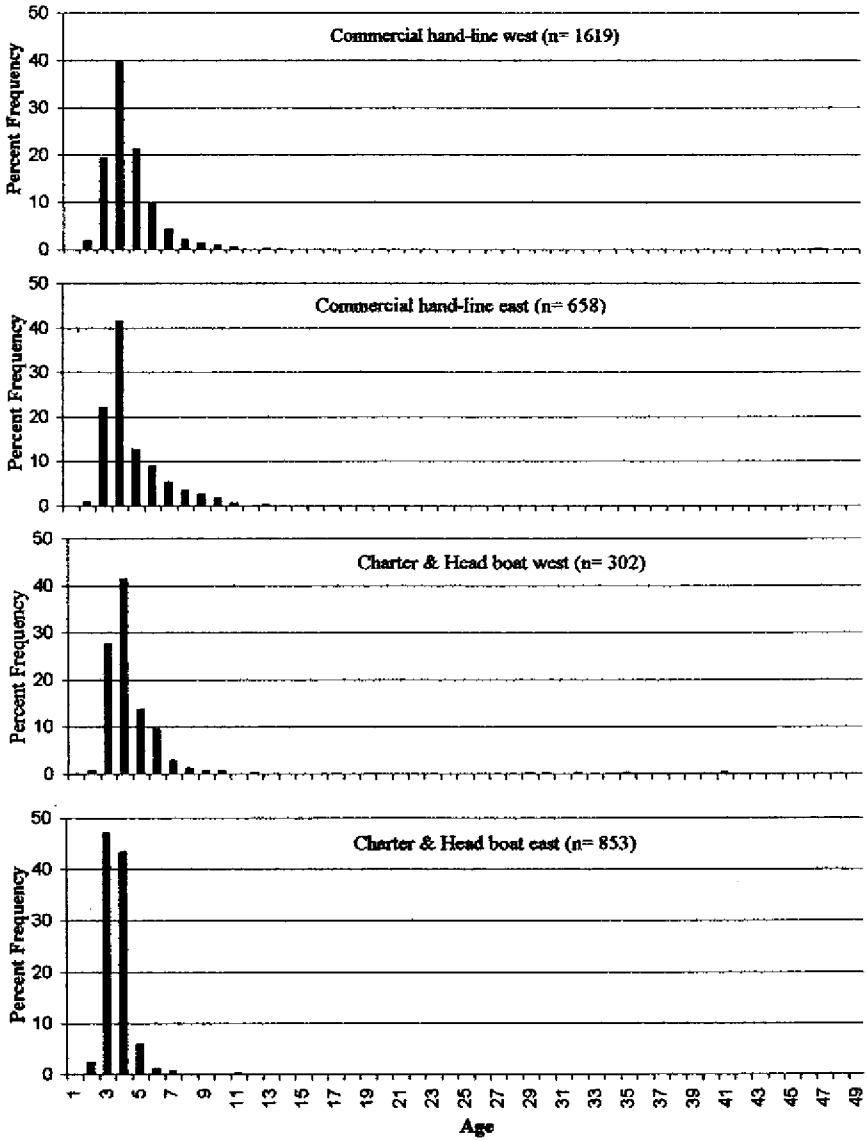


Figure 8. Age frequency of the commercial and recreational fishery by region in 1999

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LITERATURE CITED

Baker, M.S., Jr. 1999. Radiometric age validation of red snapper, *Lutjanus campechanus*, and red drum, *Sciaenops ocellatus*, from the northern Gulf of Mexico. M.S. Thesis. Louisiana State University, Baton Rouge, Louisiana USA. 59 pp.

Beamish, R.J. and D.A. Fournier. 1981. A method for comparing the precision of a set of age determinations. *Canadian Journal of Fisheries and Acuatic. Science* **38**:982-983.

Beamish, R.J. and G.A. McFarlane. 1995. A discussion of the importance of aging errors, and an application to walleye pollock: the worlds largest fishery. Pages 545-565 in: D.H. Secor, J. M. Dean and S.E. Campana (eds.) *Recent Developments in Fish Otolith Research.* Univ. of S. Carolina Press. Columbia, South Carolina USA.

Bortone, S.A. and C.L. Hollingsworth. 1980. Ageing red snapper, *Lutjanus campechanus*, with otoliths, scales and vertebrae. *Northeast Gulf Science* **4**(1):60-63.

Cowan, J.H. Jr., R.L. Shipp, H.K. Bailey IV, and D.W. Haywick. 1995. Procedurefor rapid processing of large otoliths. *Transactions of the American Fisheries Society* **124**:280-282.

Fowler, A.J. 1995. Annulus formation in otoliths of coral reef fish–a review. Pages 45-63 in: D.H. Secor, J. M. Dean and S.E. Campana (eds.) *Recent Developments in Fish Otolith Research.* Univ. of S. Carolina Press. Columbia, South Carolina USA.

Futch, R.B. and G.E. Bruger. 1976. Age, growth, and reproduction of red snapper in Florida waters. Pages 165-183 in: H.R. Bullis Jr., and A.C. Jones, (eds.) *Proceedings: Colloquium on Snapper-grouper Fishery Resources of the Western Central Atlantic Ocean.* Florida Sea Grant College Program Report No. 17.

Hoese, H.D. and R.H. Moore. 1977. *Fishes of the Gulf of Mexico.* Texas A&M University Press. College Station, Texas USA. 327 pp.

Jearld, A. Jr. 1983. Age determination. Pages 301-324 in: Nielsen, L.A. and D.L. Johnson, (eds.) *Fisheries Techniques*. Southern Printing Company, Inc., Blacksburg, Virginia USA.

Manooch, C.S. III and J.C. Potts. 1997. Age and growth of red snapper, *Lutjanus campechanus*, Lutjanidae, collected along the southeastern United States from North Carolina through the east coast of Florida. *Journal of the Elisha Mitchell Scientific Society*. **113**(3):111-122.

MRAG Americas Inc. 1997. Consolidated report on the peer review of red snapper (*Lutjanus campechanus*) research and management in the Gulf of Mexico. Prepared by: MRAG Americas Inc., St. Petersburg, Florida USA.

Morison, A.K., S.G. Robertson, and D.C. Smith. 1998. An integrated system for production fish aging: Image analysis and quality assurance. *North American Journal of Fisheries Management* **18**:587-598.

Nelson, R.S. and C.S. Manooch III. 1982. Growth and mortality of red snappers in the west-central Atlantic Ocean and northern Gulf of Mexico. *Transactions of the American Fisheries Society* **111**:465-475.

Patterson, W.F., III. 1999. *Aspects of the Population Ecology of Red Snapper, Lutjanus Campechanus, in an Artificial Reef Area off Alabama*. Ph.D. Dissertation. University of South Alabama, Mobile, Alabama USA. 164 pp.

Rothschild, B.J., A.F. Sharov and A.Y. Bobyrev. 1997. Red snapper stock assessment and management for the Gulf of Mexico. An independent assessment completed for the Office of Science and Technology, National Marine Fisheries Service, NOAA, Silver Springs, Maryland USA. 173 pp.

Schirripa, M.J. and C.M. Lagault. 1999. Status of the red snapper in the U.S. waters of the Gulf of Mexico: Updated through 1998. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory Miami, Florida USA. Cont. SFD-99/00-75. 86 pp.

Wells, J.G. 1975. *Fishes of the northern Gulf of Mexico*. T.F.H. Publications, Inc. Neptune City, New Jersey USA. 432 pp.

Wilson, C.A., J.H. Render and D.L. Nieland. 1994. Life history gaps in red snapper (*Lutjanus campechanus*), swordfish (*Xiphias gladius*), and red drum (*Sciaenops ocellatus*) in the northern Gulf of Mexico; age distribution, growth and some reproductive biology. Final report to U.S. Dept. Comm., Nat. Mar. Fish. Ser., Mar. Fish. Init. (MARFIN) Coop. Agreement NA17FF0383-02. 79 pp.

Wilson , C.A., D.L. Nieland, A.L. Stanley and A.J. Fischer. 1998. Age and size distribution of commercially harvested red snapper *Lutjanus campechanus* in the northern Gulf of Mexico. Final report to U.S. Dept. Comm., Nat. Mar. Fish. Ser., Mar. Fish. Init. (MARFIN) Coop. Agreement NA57FF0287. 65 pp.

Age and Growth of Red Snapper, *Lutjanus campechanus*, in the Northwestern Gulf of Mexico: Implications to the Unit Stock Hypothesis

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ABSTRACT

Red snapper, *Lutjanus campechanus*, in the northwestern Gulf of Mexico are being examined for differences in age and growth parameters among populations east and west of the Mississippi River. In the first year of this three-year study, nearly 2,100 specimens from the recreational fisheries of Alabama, Louisiana, and Texas were sampled for morphometric data and otoliths. Red snapper ranged in age from 1 to 34 years (199 - 916 mm FL), from 1 to 37 years (345 - 913 mm FL), and from 2 to 45 years (315 - 846 mm FL) for Alabama, Louisiana, and Texas, respectively. Regression analyses of fork length (FL in mm) – total weight (TW in kg) relationships did not differ significantly between sexes but did differ between states (TW unavailable from Texas): $TW = 2.57 \times 10^{-8} FL^{2.94}$ ($r^2 = 0.96$) for Alabama and $TW = 1.54 \times 10^{-8} FL^{3.03}$ ($r^2 = 0.96$) for Louisiana. Von Bertalanffy growth models derived from FL at age were $L_\infty = 884\,(1 - e^{(-0.21(t-0.12))})$ for Alabama, $L_\infty = 873\,(1 - e^{(-0.24(t-0.26))})$ for Louisiana, and $L_\infty = 1{,}017(1 - e^{(-0.07(t+3.39))})$ for Texas. Elevated L_∞ and t_0 values for Texas are due to a lack of larger individuals in the sample population. Regression analysis on the first ten years of life indicated that red snapper in Texas waters grow at a slower rate then those from Alabama and Louisiana.

KEY WORDS: Growth model, otolith, red snapper

INTRODUCTION

The red snapper, *Lutjanus campechanus* (Family Lutjanidae), inhabits the continental shelves of the Atlantic coast of the United States as far north as Massachusetts and the Gulf of Mexico from Florida to the Yucatan Peninsula. It is also found in the waters off Bermuda, the Bahamas, and off Northern Cuba but is absent in the Caribbean Sea (Rivas 1966, Robins and Ray 1986, Hoese and Moore 1998).

Red snapper support an important recreational fishery in the Gulf of Mexico and the most important commercial fishery in the snapper/grouper complex from Florida to southern Texas (Goodyear 1995a). Both the commercial and recreational red snapper fisheries went essentially unregulated prior to 1990 resulting in a decrease in landings from historic highs of about 6,389 metric tons (mt) in 1965 to 1,015 mt in 1991 and from 4,734 mt in 1979 to 581 mt in 1990 for the commercial and

recreational fisheries, respectively (Schirripa and Legault 1999). These declines prompted the Gulf of Mexico Fishery Management Council (GMFMC) to institute harvest quotas, minimum size limits, trip quotas for commercial fishers, creel limits for recreational fishers, and moratoria on issuing commercial reef fish permits in 1991. However, pressure on the fishery persists (Goodyear 1995a, Schirripa and Legault 1999).

An underlying critical assumption to any fisheries management strategy is that the fish being managed belong to a single unit stock. Currently red snapper in the Gulf of Mexico are managed under that assumption (Camper et al. 1993, Gold and Richardson 1994, Goodyear 1995a, Gold et al. 1997). Herein, we present our preliminary interpretations of data from the first year of a three-year, multi-institutional study investigating the stock structure of red snapper in the northern Gulf of Mexico and examining whether their management as a single unit stock is justified. We determine the ages of fish sampled from recreational sources in the northwestern Gulf of Mexico and examine these data for differences in age distributions east and west of the Mississippi River. We also use size at age information to determine and compare growth rates of red snapper from across the Gulf of Mexico.

METHODS AND MATERIALS

Red snapper from recreational catches were sampled in Alabama, Louisiana, and Texas from April through September 1999. Morphometric measurements (fork length (FL) in mm, total weight (TW) in kg, and eviscerated body weight (BW) in kg), both sagittal otoliths, and gonads were removed (and sex determined).

All undamaged sagittal otoliths were weighed to the nearest 0.1mg. The left otolith from each individual was thin sectioned with the Hillquist model 800 thin-sectioning machine equipped with a diamond embedded wafering blade and precision grinder (Cowan et al. 1995). In those instances where the left otolith was damaged or unavailable, the right otolith was used. Examinations of otolith sections were made with a dissecting microscope with transmitted light and polarized light filter.

Counts of annuli (opaque zones) were made on the medial surface of the transverse section along the ventral side of the sulcus groove (Figure 1). Annulus counts were done by two independent readers without knowledge of date of capture or morphometric data of the fish. The appearance of the otolith margin, or edge condition, was coded as opaque or translucent (Beckman etal. 1989). Sections were recounted by both readers when initial counts disagreed. When a consensus could not be reached on the second reading, annulus counts of the more experienced reader were used. Ages of red snapper were estimated from opaque annulus count and adjusted for edge condition when necessary. A uniform hatching date of 1 July was assigned based on previous studies of red snapper reproduction (Render 1995; Collins et al 1996).

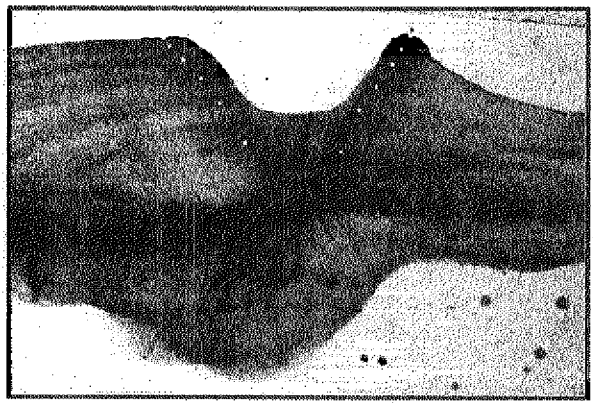


Figure 1. Photomicrograph of a transverse section at the core of a red snapper sagittal otolith. White squares indicate annuli counted for age estimation.

Length – weight regressions were fit with linear regression (SAS,1985) to the model $TL = a\ TW^{b}$ with $\log_{10}$ transformed data for Alabama and Louisiana specimens (weight data not available for Texas specimens). Analysis of covariance was used to compare sexes and sample sources (states). Von Bertalanffy growth models were fit for FL with nonlinear regression (SAS 1985) in the form: $L_t = L_\infty(1 - e^{[-k(t-to)]})$ where L_t is estimated fork length at age t, L_∞ is the theoretical maximum fork length, k is the growth coefficient, and t_0 is a hypothetical age when length is zero. Growth of red snapper in the first ten years of life appears to be linear (Szedlmayer and Shipp 1994, Patterson 1999), therefore, growth was also evaluated by performing a linear regression of FL at age with a general linear model (GLM) (SAS 1985). Significance level for statistical analyses was 0.05.

RESULTS

During the first year of this three-year project, 2,098 red snapper were sampled from recreational sources including charter boats and dive and fishing tournaments (AL = 786, LA = 737, TX = 575). Among the 1,037 males and 1,014 females sampled from the three states, males ranged from 240 - 868mm, 345 - 913mm, and 315 - 844mm FL for Alabama, Louisiana, and Texas, respectively (Figure 2). Females ranged from 254 - 916mm, 365 - 910mm, and 315 - 795mm FL for Alabama, Louisiana, and Texas, respectively. Komolgorov-Smirnov two sample

tests (Tate and Clelland 1957) indicated no significant differences in length distributions between sexes or among sample sources.

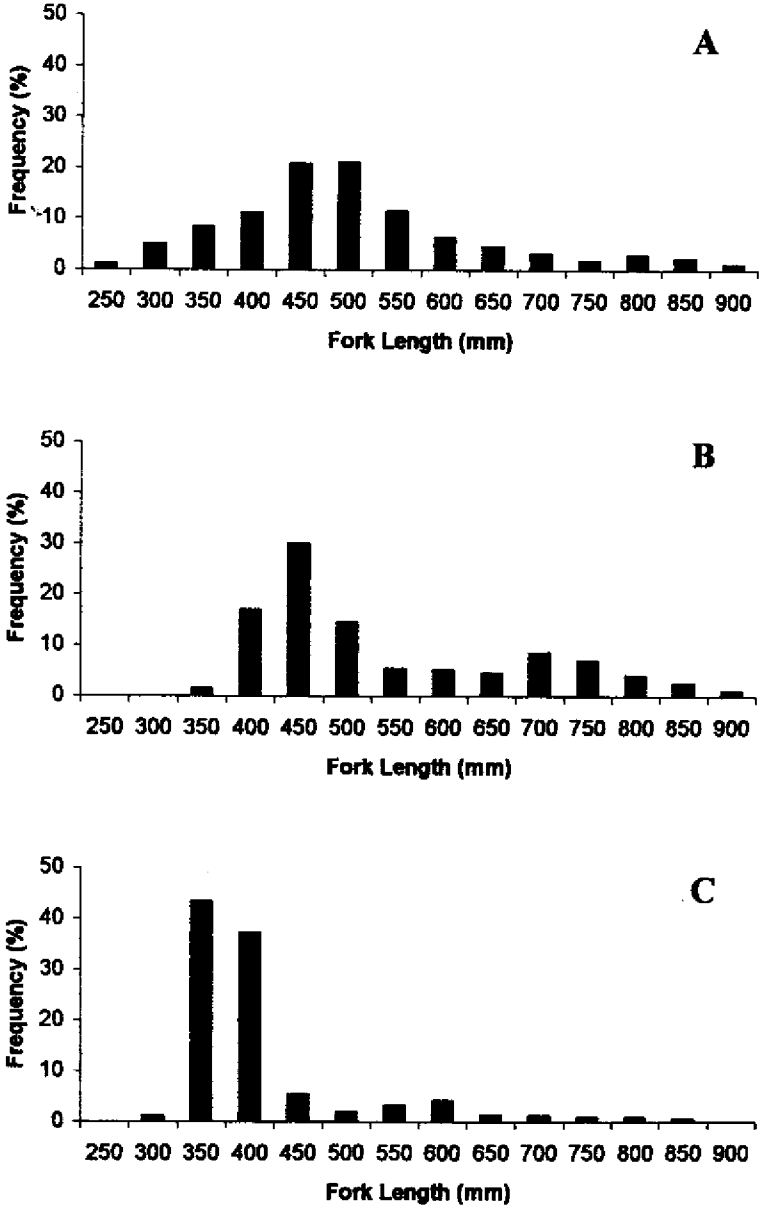


Figure 2. Length frequency distribution of red snapper sampled from recreational catches in A) Alabama (199 - 916mm FL), B) Louisiana (345 - 913mm FL) , and C)Texas (315 - 846mm FL).

Regression analyses of FL–TW relationships did not differ significantly between sexes. Neither the slopes (df = 1, 1524; F = 2.76; P < 0.096) nor the intercepts (df = 1,1524; F = 2.18; P < 0.1397) were found to be significantly different; thus data for the two sexes were combined. Regression analysis between states did differ, however, for slopes (df = 1,1524; F = 77725.47; P < 0.001) and for intercepts (df = 1,1524; F = 153.11; P < 0.001), so predictive models were generated for each state:

$TW = 2.57 \times 10^{-8} FL^{2.94}$ ($r^2 = 0.96$) for Alabama
$TW = 1.54 \times 10^{-8} FL^{3.03}$ ($r^2 = 0.96$) for Louisiana
(TW unavailable from Texas).

Two thousand and fifty-nine otoliths were available and sectioned for age determination. Of those, nine were deemed unreadable by both readers 1 and 2 and were excluded from further analysis. Of the remaining 2050 sections, consensus was reached in the initial count on 1,841 (89.8%) individuals. A second reading produced consensus on 2,045 (99.8%) individuals. Red snapper in this study ranged in age from 1 to 45 years (Figure 3). Alabama fish ranged in age from 1 to 34 years; only 18 of the 772 fish (2.3%) aged from Alabama were over 15 years old. Louisiana red snapper ranged from 2 to 37 years with only 27 out of 712 fish (3.8%) over 15 years. Texas fish ranged from 2 to 45 years with only 4 out of 567 (0.7%) aged individuals over 15 years. Komolgorov-Smirnov two sample tests indicated no significant differences in age distributions between sexes or among sources.

Von Bertalanffy growth models to describe red snapper size at age were fitted for each state (Figure 4). The resultant models for FLat age are:

AL: $FL(mm) = 884[1 - e^{-0.21(t - 0.63)}]$ ($r^2 = 0.99$)
LA: $FL(mm) = 873[1 - e^{-0.24(t - 0.73)}]$ ($r^2 = 0.99$)
TX: $FL(mm) = 1023[1 - e^{-0.07(t + 2.92)}]$ ($r^2 = 0.98$)

Predicted FL at age for red snapper from the three states generated with each of the models above illustrate rapid growth to an age of approximately 10 years after which an asymptote is approached and growth is in length is negligible.

Regression analysis of FL at age to evaluate growth of red snapper in the first ten years of life indicated significant differences among states (Figure 5). Alabama and Louisiana differed significantly for slopes (df = 1,1378; F = 2898.54; P < 0.0001) and intercepts (df = 1,1378; F = 30.29; P < 0.0001). Alabama and Texas also exhibited significant differences in both slopes (df = 1,1282; F = 1993.79; P < 0.0001) and intercepts (df = 1,1282; F = 72.01; P < 0.0001). Not surprisingly, Louisiana and Texas showed significant differences in slopes (df = 1,1188; F = 1711.34; P < 0.0001) and intercepts as well (df = 1,1188; F = 164.4; P < 0.0001).

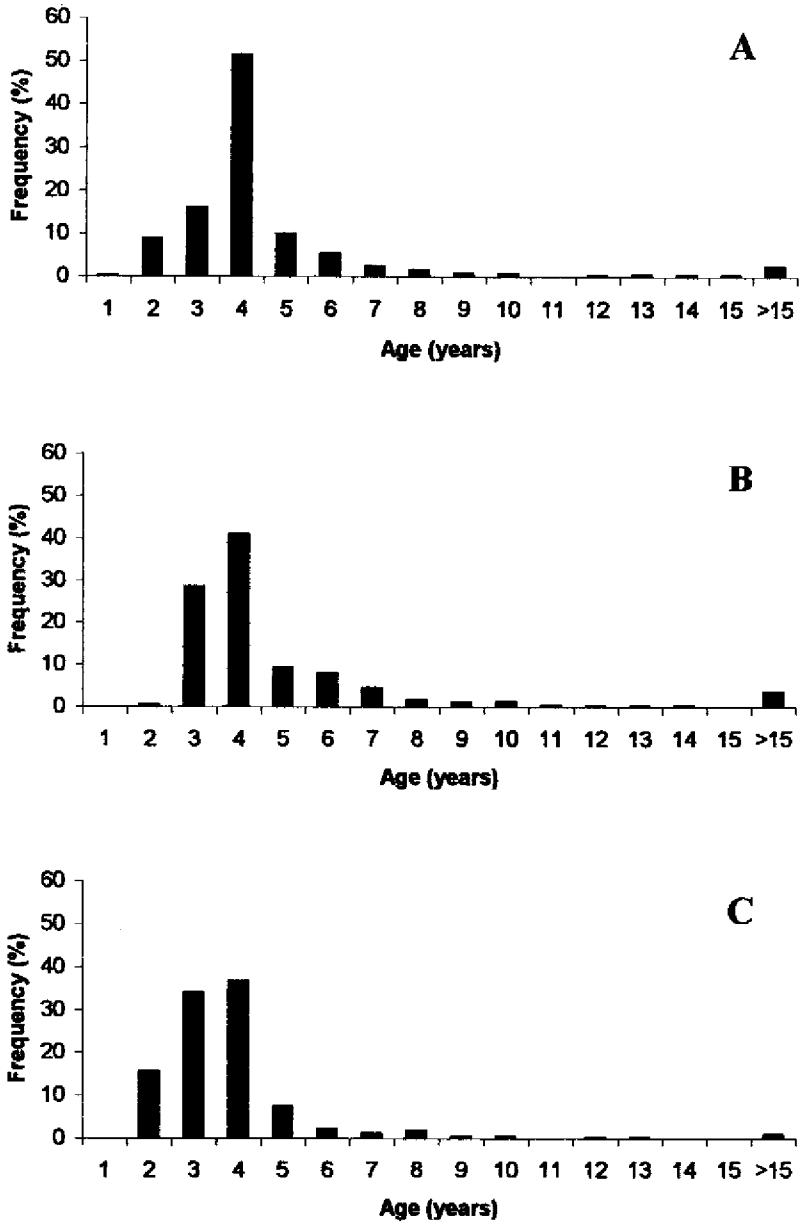


Figure 3. Age frequency distribution for red snapper sampled from recreational sources in April to September 1999 in A) Alabama, B) Louisiana, and C) Texas.

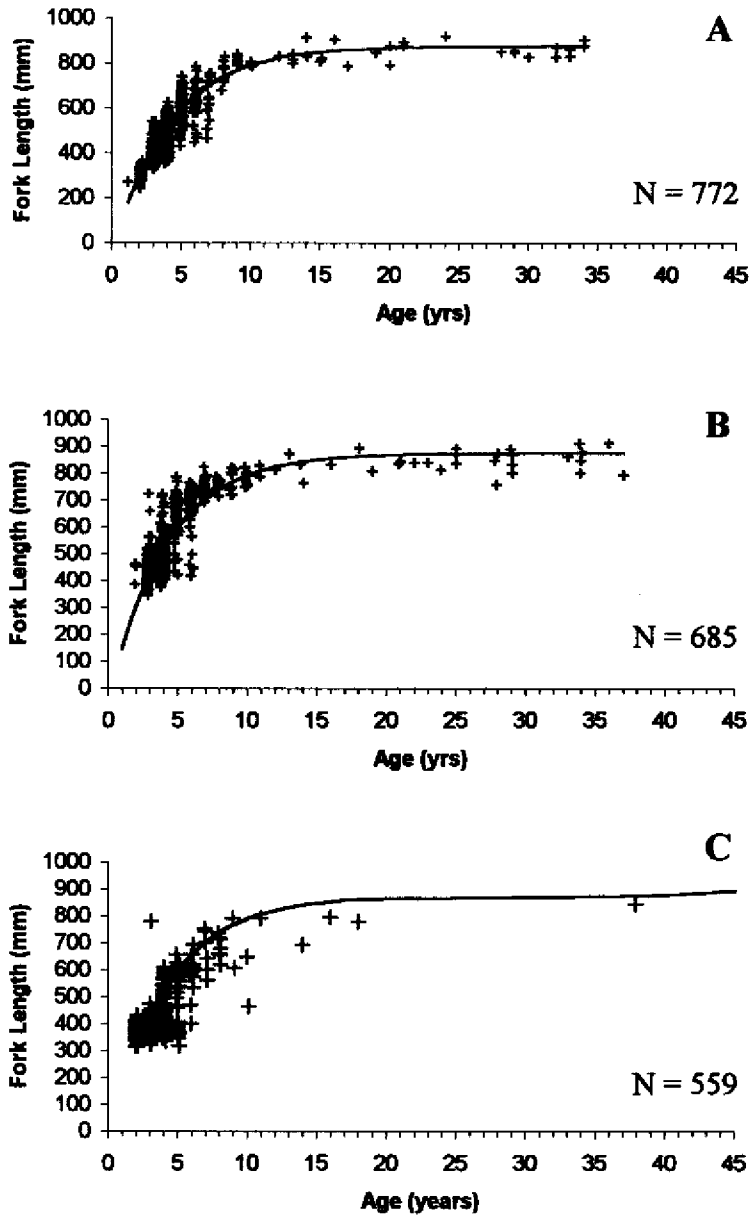


Figure 4. von Bertalanffy growth models fit for red snapper sampled from recreational catches in April – September 1999 for A) Alabama, B) Louisiana, and C) Texas.

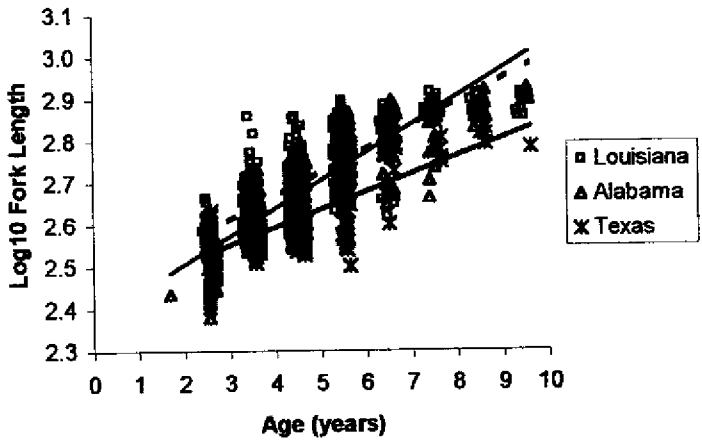


Figure 5. Linear regression of Log_{10} transformed fork length on age examining growth rates in the first ten years of life of red snapper sampled from Alabama (thin, solid black line), Louisiana (dotted black line), and Texas (thick gray line) in April through September 1999.

CONCLUSIONS

Several studies of red snapper age and growth mentioned herein have validated that otoliths do accrete one annulus per year during the winter and spring and can therefore be accurately used to determine age (Wilson et al. 1994, 1997, Render 1995, Manooch and Potts 1997, Patterson 1999). The pattern of winter-spring annulus formation is consistent with that reported for other long-lived fish in the northern Gulf of Mexico (Beckman et al. 1989, Beckman et al. 1990, Beckman et al. 1991). In addition, Baker (1999) used radiometric age estimates to validate the continued use of otolith sections as the best method to estimate age for red snapper.

The age distributions from this study are not representative of the red snapper population in the Gulf of Mexico. Due to minimum size limits on the recreational fishery, age 0 and age 1 snapper are not represented adequately in our sample population. The majority of fish sampled in all three states fall between the ages of 2 – 5 years (76% of aged fish) perhaps reflecting migratory aspects of red snapper life history. After migration from shallow waters, these fish reside around structures such as oil and gas platforms to seek refuge from large predators (Render 1995). Because these platforms harbor large populations of red snapper as well as other species (Stanley and Wilson 1996 , 1998), they are preferred destinations of recreational and commercial fishermen. In addition, few old red snapper were sampled. Though large adults were targeted at fishing and dive tournaments, only

49 fish (2.9%) were found to be over 15 years old. The small numbers of older adults could be due to natural or fishing mortality, or due to emigration away from the platforms where they are less susceptible to capture.

The growth models in this study produced results similar to those in previous red snapper studies (Nelson and Manooch 1982, Szedlmayer and Shipp 1994, Patterson 1999). All show a rapid growth in the first ten years of life followed by a leveling of growth rate. The models' fit for Alabama and Louisiana differ, however, from the Texas model in that they produced lower L_∞ and higher K values. This may be an artifact of sampling. Both Alabama and Louisiana personnel sampled fishing tournaments targeting larger, older individuals. These fish pull the vonBertalanffy curve down producing a smaller maximum theoretical size. Goodyear (1995b) warned that non-random, or selective sampling such as fishing tournaments could introduce significant bias into growth functions. The lack of larger individuals in the sample population resulted in elevated L_∞ and t_0 values for Texas. Szedlmayer and Shipp (1994) reported an L_∞ of 1025. This value is likely due to a small sample size (n = 409) in which only 11 fish were aged over 10 years old. The range in values of parameters derived from these various growth models are more a reflection of the size and age distribution of the sample population of each study than true growth effects of red snapper from different regions.

The regression analysis of FL at age indicated a difference in growth rates of red snapper among Alabama, Louisiana, and Texas in the first ten years of life. Although this difference was significant between all three states, red snapper from Texas clearly show a slower rate of growth than those from Alabama and Louisiana. Texas fish also display a smaller maximum size at 846 mm FL compared to 916 mm FL for Alabama and 913 mm FL for Louisiana red snapper. This slower rate of growth does not, however, have an affect on longevity as the oldest fish in this study (aged at 45 years) came from Texas waters. These differences in growth rates could be an indication of possible biologically meaningful management stocks within the fishery and could have profound affects on how the fishery is managed in the future. Should separate stocks exist, fishery units could be assessed and managed on a sub-regional basis, providing the opportunity to adjust regulations to the unique needs of sub-regional populations and resource users.

LITERATURE CITED

Baker, M.S., Jr. 1999. Radiometric age validation of red snapper *Lutjanus campechanus* and red drum *Sciaenops ocellatus* from the northern Gulf of Mexico. M.S. thesis. Louisiana State University, Baton Rouge, Louisisana USA. 65 pp.

Beckman, D.W., C.A. Wilson, and A.L. Stanley. 1989. Age and growth of red drum, *Scienops ocellatus*, from offshore waters of the northern Gulf of Mexico. *Fishery Bulletin*, U.S. **87**:17-28.

Beckman, D.W., A.L. Stanley, J.J. Render, and C.A. Wilson. 1990. Age and growth of black drum in Louisiana waters of the Gulf of Mexico. *Transactions of the American Fisheries Society*. **119**:537-544.

Beckman, D.W., A.L. Stanley, J.H. Render, and C.A. Wilson. 1991. Age and growth-rate estimation of sheephead *Archosargus probatocephalus* in Louisiana waters using otoliths. *U.S. Fishery Bulletin* **89**:1-8.

Camper, J.D., R.C. Barber, L.R. Richardson, and J.R. Gold. 1993. Mitochondrial DNA variation among red snapper (Lutjanus campechanus) from the Gulf of Mexico. *Molecular Marine Biology and Biotechnology* **2**:154-161.

Collins, L.A., A.G. Johnson, and C.P. Keim. 1996. Spawning and annual fecundity of the red snapper (*Lutjanus campechanus*) from the northeastern Gulf of Mexico. Pages 174-188 in: F. Arreguin-Sanchez, J.L. Munro, M.C. Balgos, and D. Pauly (eds.) *Biology, Fisheries and Culture of Tropical Groupers and Snappers*.. ICLARM. Manila, Philippines.

Cowan, J.H. Jr., R.L. Shipp, H.K. Bailey IV, and D.W. Haywick. 1995. Procedure for Rapid Processing of Large Otoliths. *Transactions of the American Fisheries Society* **124**:280-282.

Gold, J.R., L.R. Richardson, C. Furman, and F. Sun. 1994. Mitochondrial DNA diversity and population structure in marine fish species from the Gulf of Mexico. *Canadian Journal of Fisheries and Aquatic Science* **51**(supp. 1):205-214.

Gold, J.R., F. Sun, and L.R. Richardson. 1997. Population structure of red snapper from the Gulf of Mexico as inferred from analysis of mitochondrial DNA. *Transactions of the American Fisheries Society* **123**:386-396.

Goodyear, C.P. 1995a. Red snapper in U.S. waters of the Gulf of Mexico. Contr. #MIA-95/96-05. Southeast Fisheries Center, Miami Laboratory. Miami, Florida USA. 171 pp.

Goodyear, C.P. 1995b. Mean size at age: an evaluation of sampling strategies using simulated red grouper data. *Transactions of the American Fisheries Society* **124**(5):746-755.

Hoese, H.D. and R.H. Moore. 1998. *Fishes of the Gulf of Mexico*. Texas A & M University press, College Station, Texas USA. 422 pp.

Nelson, R.S. and C.S. Manooch III. 1982. Growth and mortality of red snappers in the west central Atlantic ocean and the northern Gulf of Mexico. *Transactions of the American Fisheries Society* **111**:465-475.

Patterson, W.F. III. 1999. *Aspects of the Population Ecology of Red Snapper Lutjanus campechanus in an Artificial Reef Area off Alabama*. PhD. Dissertation. University of South Alabama. Mobile, Alabama USA. 164 pp.

Render, J.H. 1995. *The Life History (Age, Growth, and Reproduction) of Red Snapper (Lutjanus campechanus) and its Affinity for Oil and Gas Platforms*. PhD. Dissertation. Louisiana State University. Baton Rouge, Louisiana USA. X + 76 pp.

Rivas, L.R. 1966. Snappers of the western Atlantic. *Commercial Fisheries Review*. **32**(1):41-44.

Robins, C.R. and G.C. Ray. 1986. *A Field Guide to Atlantic Coast Fishes of North America.* Houghton Mifflin Company. Boston, Massachusetts USA. 354 pp. + 64 pl.

SAS (Statistical Analysis System). 1985. *Sas User's Guide: Statistics, Version 5 Edition.* SAS Institute. Cary, North Carolina USA. 956 pp.

Schirripa, M.J., and C.M. Legault. 1999. Status of the red snapper in U.S. waters of the Gulf of Mexico: Updated through 1998. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory, Sustainable Fisheries Division, Cont. SFD-99/00-75.

Stanley, D.R., and C.A. Wilson. 1996. Abundance of fishes associated with a petroleum platform as measured with dual-beam hydroacoustics. *ICES Journal of Marine Science* 53:743-745.

Stanley, D.R., and C.A. Wilson. 1998. Spatial variation in fish density at three petroleum platforms as measured with dual-beam hydroacoustics. *Gulf of Mexico Science* 16:73-82.

Szedlmayer, S.T. and R.L. Shipp. 1994. Movement and growth of red snapper, *Lutjanus campechanus*, from an artificial reef area in the northeastern Gulf of Mexico. *Bulletin of Marine Science* 55:887-896.

Tate, M.W. and R.C. Clelland. 1957. Pages 93-94 in: *Non-parametric and Shortcut Statistics in the Social, Biological, and Medical Sciences.* Interstate Printers and Publishers, Inc. Danville, Illinois USA.

Wilson, C.A., D.L. Nieland, A.L. Stanley, and A.J. Fischer. 1997. Age and size distribution of commercially harvested red snapper *Lutjanus campechanus* in the northern Gulf of Mexico. Final report to USDOC, NMFS, Marine Fisheries Initiative, Cooperative Agreement NA57FF0287. Coastal Fisheries Institute, Louisiana State University. Baton Rouge, Louisiana USA. 43p. + 22 figures.

Wilson, C.A., and D.L. Nieland. [In press]. Age and growth of red snapper *Lutjanus campechanus* from the northern Gulf of Mexico. *U.S. Fisheries Bulletin.*

Zastro, C.E. 1984. Age and growth of the red snapper, *Lutjanus campechanus*, and the vermillion snapper, *Rhomboplites aurorubens*, from the northwestern Gulf of Mexico. M.S. thesis, Texas A&M Univ, College Station, Texas USA. 78 pp.

Análisis de la Pesqueria de Huachinango (*Lutjanus campechanus*) en el Banco de Campeche

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RESUMEN

La pesquería de huachinango es una de las más importantes del estado de Yucatán, México. Se realizó una evaluación del estado actual de la pesquería y se simularon estrategias de manejo. Se utilizó un modelo de biomasa dinámico en tiempos discretos. Se hicieron proyecciones a partir de 1999 y se establecieron dos Punto de Referencia 1) contrastar la biomasa actual y futura con la biomasa inicial (riesgo del stock), para que la biomasa actual se mantenga por arriba del 50% de la biomasa inicial (Bo/2); y 2) mantener el Máximo Rendimiento Sostenible (MRS) (riesgo de la pesquería), en donde la mortalidad por pesca no sea mayor a u_{MRS} (0.08/año). Los resultados indican una disminución de la biomasa a través del tiempo. Se estimó una biomasa inicial (1984) de 32,957 t y para 1999 una biomasa de 16,877 t, en los últimos 16 años la biomasa presentó un decremento del 51.2%. De acuerdo a los resultados del modelo se estimó el RMS en 1,271t año^{-1} y una tasa de explotación de 0.04/añohasta alcanzar un valor de 0.15/año en 1992, año en que se registró una captura de 3,083 t. De ésta, la flota yucateca capturó 1,334 t y la flota del estado de Campeche 1,749 t. Esto significa que ambas flotas capturaron en 1992, 1,850 t. por arriba del MRS. En los últimos 5 años se estimó un valor promedio de la tasa de explotación de 0.08/año, con una captura promedio de 1,384 t. La serie histórica de la captura (1984 a 1999), siempre excedió el MRS y por consecuencia la biomasa presenta un fuerte decremento. Además, se aplicó un análisis de Monte Carlo para evaluar la probabilidad de alcanzar los puntos de referencia ante diferentes cuotas de captura.

PALABRAS CLAVES: Huachinango, *Lutjanus campechanus*, Campeche, Mexico

ABSTRACT

The red snapper fishery is one of the most important fisheries in Yucatan, Mexico. The current state of the fishery was evaluated with a biomass dynamic model in discreet times to assess the stock size and the yield. Management strategies were simulated, starting from 1999, and two options were proposed:

i) Contrast the current and future stock biomass with the initial biomass (risk of the stock), it must be 50% of the initial biomass (Bo/2), and
ii) Maintain the Maximum Sustainable Yield (risk of the fishery) using the exploitation rate U_{MSY}.

The results indicate a biomass decline from an initial biomass of 32,957 tons (t) in 1984 to 16,877 t in 1999, 51.2% in the last 16 years. The model estimates that the exploitation rate increased from 0.04/year in 1984 to 0.15/year in 1992, when the yield was 3,083 t. The Yucatan fleet catch was 1,334 t, and the Campeche fleet catch was 1,749 t. Both fleets catches exceeded the MSY in those years. In the last five years the estimated exploitation rate averaged 0.08/year, or an average catch of 1,384 tons. The historical catch series show from 1984 to 1999, always exceeded the MSY and like consequence the biomass presents a decrease. Montecarlo analysis was applied to evaluate the risk of reaching the points of reference with alternative quotas scenarios

INTRODUCCION

En el estado de Yucatán la pesca de especies de escama (Serránidos, Lutjánidos, Spáridos, Haemúlidos, etc.) ha sido la más importante, por su volumen de captura y el número de empleos que genera. El huachinango *Lutjanus campechanus* es una de las especies principales de esta pesquería, la cual por la calidad de su carne la mayor parte de su captura es de exportación (Estados Unidos), siendo generadora de divisas para el estado,

El Banco de Campeche una de las áreas de mayor abundancia de *Lutjanus campechanus,* ha sido objeto de una intensa pesquería comercial; en ésta han participado las flotas de Estados Unidos, Cuba y México (Camber 1955). Es un recurso que en México se captura todo el año. Actualmente participan en la pesca la flota mayor del estado de Yucatán, la flota cubana, la flota menor del estado de Campeche y la flota camaronera que captura juveniles de esta especie en forma incidental.

En la administración de los recursos pesqueros, los modelos matemáticos son una herramienta importante para evaluar el status y productividad de una población. Uno de los métodos más usados son los modelos de biomasa dinámicos. En su forma más simple, solo requieren de una serie de captura y un índice de la abundancia relativa (CPUE) para estimar los parámetros del modelo. De estas estimaciones pueden ser derivados dos parámetros de manejo: el máximo rendimiento sostenible (MRS) y el esfuerzo de pesca en el cual se alcanza el MRS (F_{MRS}). Estos modelos son ampliamente usados y más confiables que los modelos estructurados por edades cuando la información sobre la estructura por edades de la población es pobre o no existe, además de que pueden ser aplicados en situaciones donde solo existan datos de captura y un índice de la abundancia relativa (Punt y Hilborn 1996).

MODELO DINAMICO DE BIOMASA

Para evaluar el estado actual de la pesquería de huachinango (*Lutjanus campechanus*) en el Banco de Campeche y simular algunas estrategias de manejo,

se utilizó un modelo de biomasa dinámico, propuesto por Punt y Hilborn (1996). La información con la que se cuenta es una serie de capturas y un índice de la abundancia relativa (captura por unidad de esfuerzo, CPUE) entre 1984 a 1999.

El supuesto fundamental del modelo es que los efectos de los factores de crecimiento, mortalidad natural y reproducción, pueden ser incorporados en una sola función y ésta proporciona un solo valor del tamaño del stock. De esta forma la función de biomasa dinámica, determina el efecto neto en la combinación de estos factores a un tamaño particular del stock. En el cual, se asume que el cambio en el tamaño de la población de un año a otro, es la diferencia entre la biomasa dinámica y la captura generada por la pesquería. El planteamiento del modelo, propuesto por Punt y Hilborn (1996) es de la siguiente forma:

$$B_{t+1} = B_t + g(B_t) - C_t \qquad (1)$$

$$I_t = q\, B_t\, e^{\eta t} \qquad (2)$$

Donde B_t es la biomasa explotable al empezar el tiempo t, $g(B_t)$ es la función de la biomasa dinámica o del crecimiento poblacional, que toma la forma de Schaefer (1954): $g(B) = rB(1-B/K)$, r es la tasa intrínseca de crecimiento de la población, K es la capacidad de carga (biomasa promedio antes de ser explotar), q es el coeficiente de capturabilidad, Ct es la captura en el tiempo t, I_t es el índice de abundancia relativa en el tiempo t (CPUE) y ηt es el error de observación en el tiempo t.

Para el ajuste del modelo, se consideró un estimador de error de observación (Ludwig y Walters 1985, Polacheck et al. 1993). Que asume que el modelo dinámico de la población, es determinístico y que el error ocurre entre la relación de la biomasa del stock y el índice de abundancia. La serie de tiempo de la biomasa del stock, es estimada proyectando la biomasa al iniciar la serie de captura, empezando con la biomasa inicial (Bo) y continuando con toda la serie histórica de la captura. El error en el modelo observacion se considera que es multiplicativo, con una distribución log-normal (v.g., $I_t = q\, B_t\, e^{\eta t}$, $\eta t \sim N(0;\sigma^2)$). La estimación de los parámetros del modelo (Bo, r, y K) se obtuvieron minimizando una función de verosimilitud y se consideró que la biomasa inicial era igual a la capacidad de carga ($B_o = K$:)

$$L(Bo,r,K/datos) = \Pi \exp\left[-\frac{\hat{u}_t^2}{2\sigma_u^2}\right] * \left[\frac{1}{\sqrt{2\pi\sigma_u^2}}\right] \qquad (3)$$

Donde el producto es sobre todos los años para los cuales existan datos disponibles de la CPUE.

$$\hat{u}_t = log\ (CPUE_{obs})_t - log(CPUE_{est})_t \qquad (4)$$

$$\hat{\sigma}_u^2 = \sum \frac{\hat{u}_t^2}{n} \qquad (5)$$

$$CPUE_{est} = \hat{q}\,\hat{B}_t \qquad (6)$$

$$\hat{q} = exp\left[\frac{1}{n}\sum_t log\frac{CPUE_{obs,t}}{\hat{B}_t}\right] \qquad (7)$$

Donde n es el número de datos, $CPUE$ es la captura por unidad de esfuerzo, q es el coeficiente de capturabilidad que se obtiene minimizando la ecuación (3) con la siguiente ecuación

RESULTADOS DE LA EVALUACION

La estimaciones de los parámetros de la población y de manejo de la pesquería, obtenidos de la evaluación se presentan en la Tabla 1. Los resultados indican una tendencia decreciente de la biomasa a través del tiempo, con una biomasa en 1999 alrededor de las de 16,877 t. Lo cual significa, que en los últimos 16 años la biomasa presentó un decremento alrededor del 50%. Esta disminución también se presentó en el índice de abundancia (CPUE), con un CPUE promedio entre 1984 a 1987 de 1,183 kg de huachinango / viaje, mientras que entre 1988 a 1999 fue de 713 kg de huachinango / viaje (Figura 1). Esto es un reflejo de que las capturas registradas entre 1984 a 1999, siempre excedieron el MRS.

La tasa de explotación se incrementó de 0.04/año hasta alcanzar un valor de 0.15/año en 1992, año en que se registró una captura de 3,083 t. De ésta, la flota yucateca capturó 1,334 t. y la flota del estado de Campeche 1,749 t. Esto significa que ambas flotas capturaron en 1992, 1,850 t por arriba del MRS. En los últimos cinco años se registró una captura promedio de 1,384 t con un promedio de 150 t por arriba del MRS y una tasa de explotación de 0.08/año. A partir de 1999 se hicieron proyecciones analizando tres diferentes cuotas de captura.

A partir de 1999 se hicieron proyecciones del comportamiento dinámico de la biomasa y la tasa de explotación al aplicar tres medidas de regulación; mantener la captura promedio de los últimos cinco años y disminuir e incrementar un 20% esta captura promedio (Tabla 2). Para lo cual se consideró un intervalo de simulación de 12 años, corto (2002), mediano (2005) y largo plazo (2011) (Figuras 2 y 3).

Tabla 1. Estimación de los parámetros de la población y de manejo pesquería, obtenidos con el modelo de biomasa dinámica de Schaefer (1954).

Parametros	Valor estimado
Biomasa inicial (Bo)	33,048 (t)
Capacidad de carga (k)	33,048 (t)
Tasa de crecimiento poblacional (r)	0.16
Coeficiente de proporcionalidad (q)	3.6E-05
Máximo Rendimiento Sostenible (MRS)	1,271 t año-1
Esfuerzo en el Máximo Rendimiento Sostenible (E_{MRS})	2,039 / viajes año

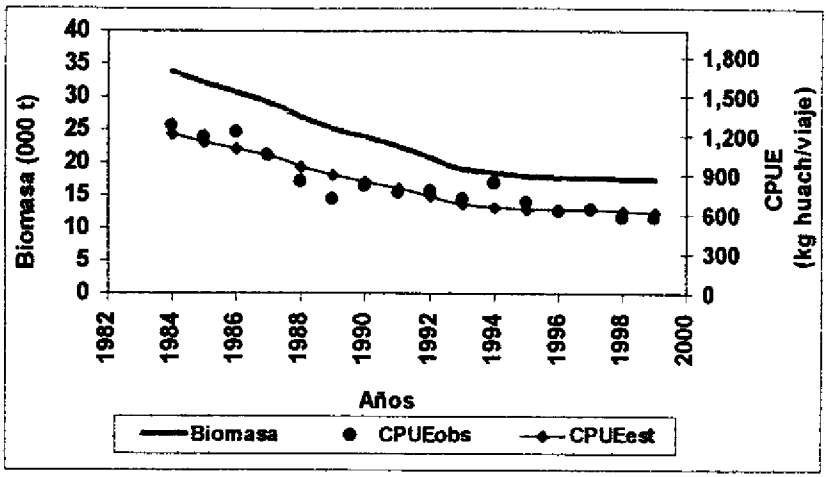


Figura 1. Comportamiento dinámico de la biomasa del stock de huachinango (*Lutjanus campechanus*), en el Banco de Campeche e índice de la abundancia relativa (CPUE) observados y estimados por el modelo.

Tabla 2. Análisis de riesgo de la pesquería de huachinango en el Banco de Campeche, como la probabilidad de alcanzar los PRL, ante diferentes medidas de regulación a corto, mediano y largo plazo (2002, 2005 y 2011).

Cuotas de captura	Probabilidad PRL £ Bo/2 (16,870 t)	Probabilidad PRL £ Bo/2 (16,870 t)	Probabilidad PRL £ Bo/2 (16,870 t)
-2002	-2005	-2011	
1117	0.36	0.14	0.02
1,384	0.68	0.86	0.88
1,661	0.93	1.00	1
	Probabilidad PRL > u_{MRS} 0.08 año-1	**Probabilidad PRL > u_{MRS} 0.08 año-1**	**Probabilidad PRL> u_{MRS} 0.08 año-1**
	(2002)	(2005)	(2011)
1,117	0.00	0.00	0.00
1,384	0.96	1.00	1.00
1,661	1.00	1.00	1

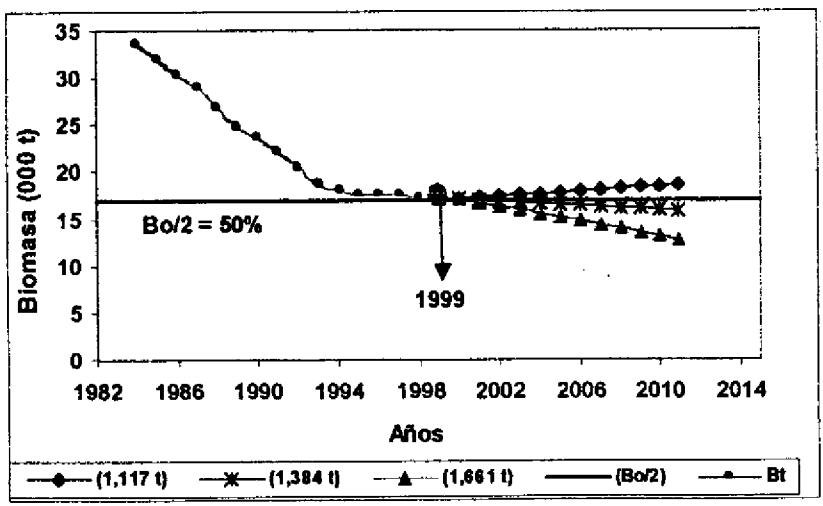


Figura 2. Comportamiento y proyecciones de la dinámica de la biomasa del stock de huachinango (*Lutjanus campechanus*), en el Banco de Campeche, ante diferentes cuotas de captura.

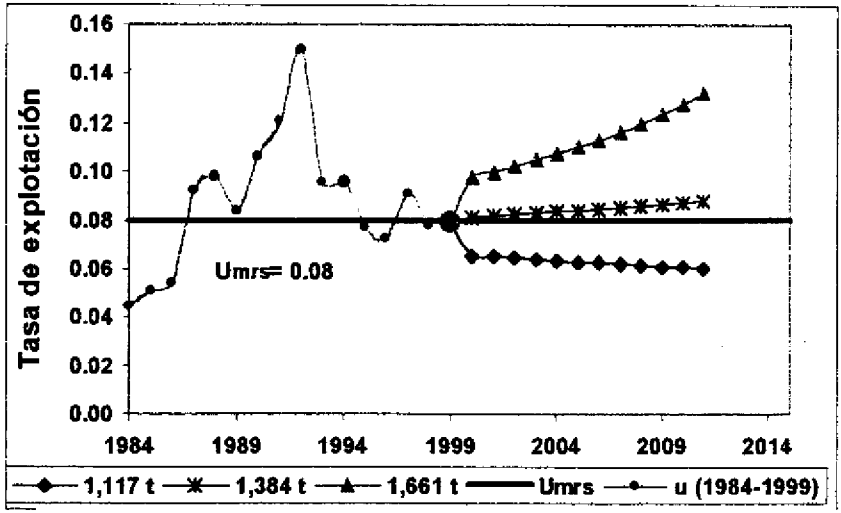


Figura 3. Comportamiento y proyecciones de la tasa de explotación de la pesquería de huachinango (*Lutjanus campechanus*), en el Banco de Campeche, ante diferentes cuotas de captura.

ANÁLISIS DE RIESGO

Se realizó un análisis de riesgo para evaluar el impacto de la pesquería al aplicar las cuotas de captura. Para lo cual se definieron dos Puntos de Referencia Limites, a) contrastar la biomasa actual y futura del stock con la biomasa inicial (riesgo del stock) de manera que la biomasa se mantenga por arriba del nivel de Bo/2 (16,870 t) y; b) mantener el Rendimiento Máximo Sostenible (riesgo de la pesquería), en donde la mortalidad por pesca no sea mayor a u_{MRS} (0.08/año). Se aplicó un análisis de Monte Carlo, para poder expresar el riesgo en términos probabilísticos y se consideró como fuente de incertidumbre la biomasa inicial (Bo) con una distribución normal como función de densidad probabilística, se realizaron 500 corridas de simulación.

Los resultados indican que disminuir un 20% la captura promedio de los últimos 5 años (1,117 t/año) representa la menor probabilidad de alcanzar el PRL de una biomasa igual o menor a las 16,870 t (riesgo del stock), tanto en el corto, mediano y largo plazo. Las otras estrategias de manejo presentaron mayor riesgo de alcanzar el PRL, con mayor probabilidad la cuota de captura 1,661 t/año (Tabla 2).

En cuanto a la probabilidad de alcanzar el PRL, de que la tasa de explotación sea mayor a u_{MRS}=0.08/año. Solo disminuyendo la captura registrada en la pesquería permitiría mantener una tasa de explotación menor o igual a 0.08 (u_{MRS}) y por lo tanto la cuota de captura de 1,117 t/año no presenta ninguna probabilidad de alcanzar este PRL. Así mismo, una cuota de captura de 1,661 t presenta mayor probabilidad de estar por arriba de este PRL (Tabla 2).

DISCUSION

Los modelos de simulación y el análisis de riesgo son una valiosa herramienta en la difícil tarea de evaluación de los recursos. Esto proporciona a los administradores mayor elementos en la toma de decisiones, que les permite evaluar las consecuencias de implementar una u otra estrategias de manejo. El modelo de biomasa dinámico utilizado para la pesquería de huachinango *Lutjanus campechanus* describió satisfactoriamente el sistema. Los resultados muestran una disminución en la biomasa vulnerable del stock y del índice de abundancia relativa de la población (CPUE). Esto puede ser el reflejo de que las capturas (1984 - 1999) siempre excedieron el RMS; a partir de 1993 se registró una caída paulatina en el rendimiento de la pesquería, tanto de la flotas de Yucatán como de Campeche.

Hay que mencionar que la captura de huachinango por la flota yucateca se realiza en zonas donde se distribuyen los organismos adultos. Esta flota se mantiene activa por la combinación de la captura de mero, huachinango y otras especies como pargos, coronado, mojarrones, cazones y pulpo que presentan un margen de ganancias. Sin embargo, es obvio que en el estado existe una sobrecapilazación; en 1999 de las 598 embarcaciones con permiso para pesca de escama, realizaron en promedio 308 viajes mensuales, que equivale a que sólo el 52 % de la flota estuvo activa. Lo que indica que los factores económicos están reajustándose y que se esperan tiempos difíciles para la actividad pesquera.

Respecto a la captura de las flotas de Campeche y principalmente el de la flota camaronera que es considerada una pesquería que captura una gran cantidad de juveniles de huachinango, ya que estos se distribuyen en las mismas zonas donde habita el crustáceo, se ha propuesto introducir excluidores de peces que tiene como fin la reducción de la captura de la fauna de acompañamiento. Sin embargo, la captura en el estado de Campeche ha disminuido a partir de los problemas que afronta la pesquería de camarón que ha obligado a establecer vedas a partir de 1993 y cada año son más prolongadas. Por otro lado, el esfuerzo de la flota menor se ha mantenido debido a la lejanía de la zona de pesca incrementa sus costos variables y requieren de instrumentos de navegación y ecodetección.

En México y en particular dentro de la Sonda de Campeche es probable que en la medida que el esfuerzo ejercido por la flota camaronera se contraiga, además de la salida de los barcos arrastreros que trabajaban dentro de la plataforma, se permitirá que los juveniles lleguen a tallas mayores, beneficiándose la flota yucateca a mediano plazo y probablemente se presente una recuperación en la población.

Para la pesquería de huachinango en el Banco de Campeche no existen medidas de regulación, los pescadores mexicanos solo deben de contar con un permiso oficial de la Secretaria del Medio Ambiente Recursos Naturales y Pesca (SEMARNAP). Sin embargo, dentro de un contexto de manejo precautorio de los recursos pesqueros, se sugiere que debido a que la pesquería de huachinango en el Banco de Campeche se encuentra ligeramente por arriba de su máximo rendimiento sostenible, es necesario establecer todas las medidas pertinentes para que el stock y la pesquería se mantengan en niveles que no sobrepasen los PRL, ya que de continuar pescando en estos niveles, se ocasionará un deterioro de la Biomasa, que puede llevar a una sobreexplotación del recurso. Tomando en cuenta la situación actual de la pesquería y los resultados obtenidos en el plan de manejo de esta especie en los Estados Unidos (Goodyear 1995, Baker et al. 1998), se hace necesario instrumentada una estrategia de manejo donde se integren diferentes medidas de regulación como: cuotas de captura, talla mínima y reducción de la captura incidental de la flota camaronera que opera en el Banco de Campeche.

LITERATURA CITADA

Baker, P., F. Cox, and P. Emerson. 1998. Managing the Gulf of Mexico Commercial Red Snapper Fishery. Presented to the Committee to Review Individual Fishing Quotas Ocean Studies Board National Rsearch Council.

Camber, I.C. 1955 . A survey of the red snapper fishery of the Gulf of Mexico, with special reference to the Campeche Bank. *Technical Series of the Florida State Board of Conservation* **12**:1-64.

Goodyear C.P. 1995. Red snapper in U.S. waters of the Gulf of Mexico, National Marine Fisheries service, Southeast Fisheries Sience Center, Miami Laboratory, Miami, Florida USA. MIAC95/96-05. 171 pp.

Ludwing, D. And C.J. Walters. 1985. Are age-structured models appropriate for catch-effort data? *Canadian Journal of Fisheries and Aquatic Science* **42**:1066-1072.

Polacheck, T., R. Hilborn, and A.E. Punt. 1993. Fitting surplus-production models: comparing methods and measuring uncertainty. *Canadian Journal of Fisheries and Aquatic Science* **50**:2597-2607.

Punt, A.E. and R. Hilborn. 1996. Biomass dynamic models. Use's manual. FAO. Computarized Information Series. Fish. FAO No. 10. FAO, Rome, Italy. 62 pp.

Schaefer, M.B. 1954. Some aspects of the dynamics of populations important to the management of comercial marine fisheries. *Bulletin of the Inter-American Tropical Tuna Commission* 1:27-56.

A Method for the Estimation of the von Bertalanffy Growth Rate Parameter by Direct Examination of Otolith Microstructure

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ABSTRACT

A method is introduced which uses otolith growth rate to provide a direct estimate of K, the von Bertalanffy growth rate parameter. We obtained estimates of K of 1.078 $\pm$ 0.687 y^{-1} and 0.621 $\pm$ 0.076 y^{-1} for the queen snapper, *Etelis oculatus*, by two variations of the method. There is no significant difference between the two estimates of K, or with an earlier value estimated with the use of ELEFAN 1. We suggest that this method may be used where otolith microstructure analysis does not allow for ageing the fish either by conventional counting of rings or even by analysing the width of growth increments. We acknowledge that from a statistical perspective, with one of the variations we may have violated the assumption regarding the independence of the observations used in the linear regression. Notwithstanding this, we propose that estimates of K by this general method can, at least, be a starting point or seed value for the use in other length-based methods.

KEY WORDS: *Etelis oculatus*, Growth rate parameter, otolith analysis

INTRODUCTION

Changes in otolith size, with few exceptions, are thought to closely reflect the somatic growth rate of fish, an observation which is of critical importance for studies of fish age and growth at the annual and daily levels of precision (Campana and Neilson 1985). Recently, workers have attempted to use the property of isometric growth with respect to somatic growth to develop approaches for investigations of age and growth which do not rely on conventional techniques for otolith microstructure examination. The latter techniques often involve complete enumeration of all increments along a standard axis of the otolith, a task which has proven difficult in older fish and in otoliths which have complex growth patterns.

Ralston and Miyamoto (1983) and Ralston (1984) have suggested that one can estimate the average width of daily increments at various points in the otolith, and

an estimate of this rate and total length of the otolith would allow one to estimate the age of the specimen by dividing the otolith length by its rate of growth. It is suggested (Ralston 1984) that this procedure works well if one takes into account otolith and fish size. Ralston and Miyamoto (1983), while admitting that some of the precision theoretically possible with daily increments is sacrificed in using this method, have suggested that it provides a reasonably reliable estimate of age.

This essay suggests a method for directly calculating von Bertalanffy growth rate parameter, K, based on a study of otolith growth rate for *Etelis oculatus* Val. landed at Vieux Fort in the south of St. Lucia during 1987. Consistent with the Ralston and Miyamoto (1983) method, we wished to develop an approach which did not entail complete enumeration of growth increments along a given radius of an otolith. Our suggested technique differs from that of Ralston and Miyamoto in that a direct estimate of K is derived rather than an estimate of age. In the latter case, further computations would be required to arrive at an estimate of K. The occasional inability to detect all growth increments using a light microscope (Morales-Nin 1988) means that otolith microstructure may not always give results that can be used directly for obtaining age-at-length. Thus, if the researcher is only able to easily access light microscopy, as may often be the case in developing countries, a reasonable estimate of the growth rate parameter can nonetheless be obtained.

METHODS

The Gulland and Holt plot (Gulland and Holt 1959) is a length-based method of von Bertalanffy growth parameter estimation which provides estimates of L_∞ and K through the feature that the difference between successive lengths of a fish, when divided by the difference in the corresponding ages can be plotted as a straight line against the mean of the successive lengths, with the modulus of he slope of the line being equal to K, L_∞ being the ratio between the y-intercept and the modulus of the slope. The method finds use when continuous growth lines cannot be traced, or when only unequal time intervals (for example, those that may be obtained from tagging and recapture data) are available (Pauly 1983).

Measurements taken for the Ralston and Miyamoto method on otolith thin sections (Figure 1) are used in a "quasi-Gulland and Holt" plot (after Murray 1989) wherein the regression of the otolith growth rate, assuming increments to be daily, for a given segment of the otolith against the distance of the mid-point of that segment to the focus of the otolith is calculated. This is done for all otoliths where at least two segments had been measured and where it could be seen that the otolith growth rate decreased with increasing distance from the nucleus. The absolute value of the slope of this curve is considered to be equal to K for that fish *(ibid.)*. Initially, the estimates of K were averaged over all the individual otolith determinations. For comparison, the regression was also done with the segments from all the otoliths (in other words, all nine fish) pooled into one regression. The two estimates of K thus obtained were in days $^{-1}$, and converted to years $^{-1}$ by multiplying by 365.25.

RESULTS

Table 1 is a summary of the otolith growth rate analysis for *Etelis oculatus* (after Murray, 1989). When data from the otolith thin sections of *E. oculatus* were used individually and the mean value of K, at the 95% confidence level calculated, the value obtained was 1.078 $\pm$ 0.687/year. The value obtained when the segments from all the otoliths were pooled (Figure 2) was 0.621 $\pm$ 0.076/year (dL/dt = 5.738 - 0.0017 L; n = 34; K = 0.0017 x 365.25). There is no significant difference (t_{calc} = 1.627; $t_{0.05(2),6}$ = 2.447) between the two estimates of K. The mean value of K estimated from the individual regressions is also not significantly different (t_{calc} = 1.310; $t_{0.05,(2),6}$ = 2.447) from the average of 0.71/year obtained (Murray, 1989) with the use of ELEFAN I (Gayanilo et al. 1988).

DISCUSSION

The "quasi-Gulland and Holt" plot may be a way of estimating K where otolith microstructure analysis does not allow for either conventional counting of rings or when the growth marks are not seen clearly enough for use of the Ralston and Miyatmoto method (1983). Such a circumstance may arise where, having attempted one of the "usual" methods it is found there is, for example, unevenness in the incremental plane such that increments cannot be observed clearly all along the otolith radius being used. This method can also be used where the data available for input into one of the length-based methods such as the ELEFAN I, Shepherd (1987), Ebert (1987), or Damm (1987) methods are such that there would be difficulty deciding among (say) multiple maxima, or was otherwise not of a quality that would allow them to be used without some type of "seed" value with which to start. If a few otoliths are available, our suggested method could then provide an estimate of K to serve as such a starting point or seed value.

Like other techniques of otolith microstructure study, our method may be considered to be limited by the assumption as to the periodicity of increment deposition. Additionally, if growth fluctuates on a seasonal basis, results may be biased if increments were selected from one part of the seasonal cycle only. It would seem likely that the period of faster growth, and hence more noticeable increments, could be chosen, thus leading to an overestimation of the growth rate parameter. To avoid this, it would be advisable to choose the segments at random.

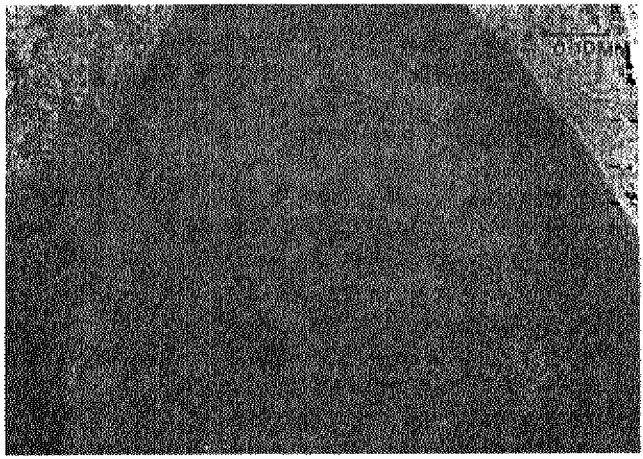


Figure 1. Photomicrograph of sagitta of *Etelis oculatus*.

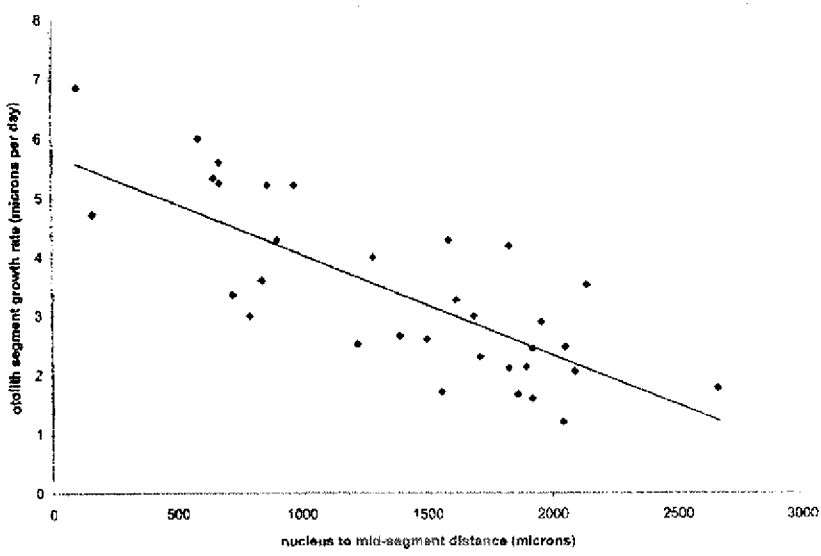


Figure 2. Graph showing otoliths segment growth rate versus nucleus to mid segment distance.

Table 1. Summary of growth rate analysis for *E. oculatus*. Individual estimates of growth rate parameter are shown

Length		# of Rings dt	Width of Segment dL (μm)	Otolith Growth Rate dl/dt (rings/day)	ln dL/dt	Nucleus to Mid-segment Distance l (μm)	K (per year)
Total Length of fish (mm TL)	Otolith length L (μm)						
570	2033	28	192	6.857	1.89	96	---
763	3216	17	432	25.412	3.235	288	(--)
		14	108	7.714	2.043	913	
577	2390	28	48	1.714	0.539	1558	1.549
		9	48	5.333	1.674	648	
		23	120	5.217	1.652	864	
452	3554	16	84	5.250	1.658	672	0.745
		30	120	4.000	1.386	1284	
542	1854	30	168	5.600	1.723	672	
		10	60	6.000	1.792	588	

Table 1 continued:

674	1944	42	180	4.286	1.455	1584	2.593
		43	180	4.186	1.432	1824	
		45	96	2.133	0.758	1896	
		30	48	1.600	0.470	1920	
635	1475	20	72	3.600	1.281	840	0.537
		14	60	4.285	1.455	900	
		23	120	5.217	1.652	972	
		19	48	2.526	0.927	1224	
		9	24	2.666	0.981	1392	
		54	132	2.444	0.894	1920	
		20	24	1.200	0.182	2040	
		17	60	3.529	1.261	2136	
632	2145	33	156	4.727	1.552	156	0.489
		25	84	3.360	1.212	720	
		20	60	3.000	1.099	792	

Table 1 continued:							
		20	60	3.000	1.099	1686	
		36	60	1.667	0.511	1860	
763	2090	14	60	2.609	1.455	1500	0.555
		17	36	2.118	0.750	1824	
763	2755	11	36	3.272	1.186	1615	0.416
		52	120	2.308	0.836	1710	
		58	168	2.897	1.604	1957	
		17	42	2.471	0.905	2052	
		35	72	2.057	0.721	2090	
		130	231	1.777	0.575	2660	

Key: – used in pooled version of plot, but not for calculation of individual K values
(--) not used in calculations of mean K value from individual calculations, neither used to calculate "pooled" K value: obvious outlier

It should be noted that Ralston and Miyamoto (1983) attempt to derive an absolute – the age of the individual fish. In such circumstances, precise and accurate knowledge of increment deposition rates are more crucial than for the estimation of a population parameter that is itself a mean value having a finite variability. Further, in this method the value used to estimate K is a slope and hence it is only if the time represented by one increment varies within any given otolith, that one would expect significant changes in the value. Our method has analogies to length-based approaches; in fact, the very name "quasi-Gulland and Holt plot" is suggestive of that fact. This implies that the theory derived for length-based methods could apply to this method. Thus, we note Isaac's (1990) suggestion that at least three length-based methods give accurate estimates of K when individual variability of this growth parameter is small (< 20%). Applying her observation to this method, the smaller variability, and therefore greater precision, of the growth rate parameter estimate derived by our pooled-segment determination makes it the preferable form of the method. We suggest that in this form, the method also provides a population estimate for K.

Given the possibility of underestimating the periodicity of increment deposition, a corresponding overestimate of K would not be surprising. The estimate of K obtained with our proposed pooled segment approach technique are comparable with Murray's (1989), but are among the highest recorded by Manooch (1987) in his comprehensive review of age and growth studies of tropical snappers and groupers. Manooch's (*ibid.*) review included values of K for snappers (but not including any estimate for *Etelis* sp.) ranging from 0.090 - 0.370/year. A more recent determination of K = 0.40/year for queen snapper has been made by Murray and Moore (1992).

The large, though not statistically significant, difference between our two estimates is noteworthy. This may in part be related to the high variance associated with the estimate obtained when using the mean of K values calculated from the nine otoliths. We acknowledge that from a statistical perspective we violate an assumption of linear regression with the approach using all individual segments, since they are not truly independent observations. The approach of using one datum from each fish may be better in this regard.

Consideration of the strengths and weaknesses of the two variations on the "quasi-Gulland and Holt" approach also begs the question of whether, to obtain an estimate of K that is representative over the life of the fish, the data collection should be length-stratified in some manner, or whether length segments should be collected at consistent points along the standard radius.

There is also now a need to confirm our estimates of K for queen snapper and to test the pooled segment form of our proposed approach with a species where K is well known from other approaches.

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LITERATURE CITED

Campana, S.E. and J.D. Neilson. 1985. Microstructure of Fish Otoliths. *Canadian Journal of Fisheries and Aquatic Sciences* **42**:1014-1032.

Damm, U.. 1987. Some modifications of Ebert's Method to estimate growth and mortality parameters from average lengths in a population. Pages 45-52 in: D. Pauly and G.R. Morgan (eds.) *Length-based Methods in Fisheries Research. ICLARM Conference Proceedings 13.* International Center for Living Aquatic Resources Management, Manilla, Philippines, and Kuwait Institute for Scientific Research, Safat, Kuwait.

Ebert, T.A. 1987. Estimating Growth and Mortality Parameters by Nonlinear Regression Using Average Size in Catches. Pages 35-44 in: D. Pauly and G.R. Morgan (eds). *Length-based Methods in Fisheries Research. ICLARM Conference Proceedings 13.* International Center for Living Aquatic Resources Management, Manilla, Philippines, and Kuwait Institute for Scientific Research, Safat, Kuwait.

Gayanilo, F.C., Jr., M. Soriano and D. Pauly. 1988. *A Draft Guide to the Complete ELEFAN. ICLARM Software 2.* International Center for Living Aquatic Resources Management, Manilla, Philippines. 65pp.

Gulland, J.A. and S.J. Holt. 1959. Estimation of growth parameters for data at unequal time intervals. *Journal of Conservation CIEM* **25**(I): 7-49.

Isaac, V.J. 1990. The accuracy of some length-based methods for fish population studies. *ICLARM Technical Report* **27**: 8 1 pp.

Manooch, C.S.III, 1987. Age and growth of snappers and groupers. Pages 329-373 in: J.J. Polovina and S. Ralston (eds.) *Tropical Snappers and Groupers: Biology and Fisheries Management.* Westview Press, Boulder, Colorado, USA.

Morales-Nin, B. 1988. Caution in the use of daily increment for ageing tropical fishes. *Fishbyte* **6** (2):5-6.

Murray, P.A. 1989. A comparative study of methods for determining mean length-at-age and von Bertalanffy growth parameters for two fish species. .MS Thesis. University of the West Indies, Cave Hill, Barbados. 222 pp.

Murray, P.A. and E.A. Moore. 1992. Recruitment and exploitation rate of *Etelis oculatus* Val. in the St. Lucian fishery. (abstract) *Proceedings of the Gulf and Caribbean Fisheries Institute* **42**:263

Pauly, D. 1983. Some simple methods for the assessment of tropical fish stocks.

FAO Fisheries Technical Paper **234**.

Ralston, S. 1984. Ageing long-lived tropical fish using daily growth increments. *Fishbyte* **2**(3):11-12.

Ralston, S. and G.T. Miyamoto. 1983. Analyzing the width of daily otolith increments to age the Hawaiian snapper, *Pristipomoides filamentosus*. *U.S. Fisheries Bulletin* **81**: 523-536.

Shepherd, J.G., 1987. A weakly parametric method for estimating growth parameters from length composition data. Pages 113-119 in: D. Pauly and G.R. Morgan (eds.) *Length-based Methods in Fisheries Research. ICLARM Conference Proceedings 13*. International Center for Living Aquatic Resources Management, Manilla, Philippines, and Kuwait Institute for Scientific Research. Safat, Kuwait.

Indirect Estimation of Red Snapper (*Lutjanus campechanus*) and Gray Triggerfish (*Balistes capriscus*) Release Mortality

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ABSTRACT

Release mortality was estimated indirectly for red snapper and gray triggerfish in the northern Gulf of Mexico from condition of tagged fish. Condition at release was assessed for tagged red snapper (n = 2,932) and gray triggerfish (n = 842) based upon their swimming behavior. Condition-1 was assigned to fish that oriented toward the bottom and swam down vigorously. Fish in condition-2 oriented toward the bottom but swam erratically. Fish in condition-3 swam very erratically and remained at the surface, while fish in condition-4 were unresponsive and presumed dead. Overall, 86.5% of red snapper and 99.2% of gray triggerfish were released in condition-1. Depth of capture, fish size, and transporting fish prior to release significantly affected red snapper release condition ($p < 0.01$). Of 550 recaptured red snapper, 98.4% were released in condition-1, while 100% of 160 recaptured gray triggerfish were released in condition-1. Release condition significantly affected recapture rate for red snapper ($p < 0.001$). Comparisons with reported estimates of release mortality for red snapper indicate that the cumulative percentage of fish released in conditions other than condition-1 may serve as a proxy for acute release mortality. Further research is required to validate this approach; however, it may prove to be a practical method to evaluate release mortality in recreational and commercial fisheries through observer programs.

KEY WORDS: Reef fish, release mortality, tagging

INTRODUCTION

Reef fishes support valuable commercial and recreational fisheries in the U.S. south Atlantic and Gulf of Mexico (GOM), but many economically and ecologically valuable species in the snapper/grouper complex currently are estimated to be overfished (Anon. 1998, Coleman et al. 1999, 2000, Collins et al. 1999). Management of these reef fisheries is complicated by fish life history characteristics that include slow growth, late maturity, high site fidelity, and protogyny (Coleman et al. 1999, 2000, Huntsman and Waters 1987, Parish 1987). Furthermore, reef fisheries in a given geographic area typically target a variety of species, thus, traditional single-species management is often difficult or untenable (Ault et al. 1997;

Bohnsack 1996; Coleman et al. 2000; Gobert 2000).

Red snapper (*Lutjanus campechanus*) support the most economically valuable fishery in the GOM snapper/grouper complex, and are among the most targeted fishes by GOM commercial and recreational fishers (Goodyear 1995, Minton and Heath 1998, Stanley and Wilson 1990). This species is a long-lived apex predator that ranges from North Carolina to Florida in the U.S. south Atlantic, and from Florida to Yucatan in the GOM (Hoese and Moore 1998). The GOM red snapper stock has been subjected to heavy fishing pressure since the 1800s and is currently estimated to be severely overfished (Goodyear 1995, Schirripa and Legault 1999). Management measures first were implemented in the late 1980s, and have evolved since then, to increase red snapper spawning stock biomass (GMFMC 2000) (Table 1). Despite overfished status, combined commercial and recreational landings of GOM red snapper averaged ($\pm$ SE) 3.26 ($\pm$ 0.35) x 10^3 metric tons from 1990 to 1998 (Figure 1). Also during this time period, estimates of recreational discards rose sharply (Figure 1), likely in response to increasing management regulations (Table 1).

Table 1. History of management regulations for recreational and commercial red snapper fisheries in the GOM since 1990. Recreational size limit in 1999 changed to 457 mm TL from June through August to extend the recreational season. Length of 2000 commercial season is projected.

	Recreational			Commercial	
Year	Size Limit mm TL	Bag Limit	Season days	Size Limit mm TL	Season days
1990	330	none	365	330	365
1991	330	7	365	330	236
1992	330	7	366	330	94
1993	330	7	365	330	104
1994	356	7	365	356	78
1995	381	5	365	356	52
1996	381	5	366	381	86
1997	381	5	330	381	71
1998	381	4	272	381	67
1999	381*	4	240	381	64
2000	406	4	200	381	60**

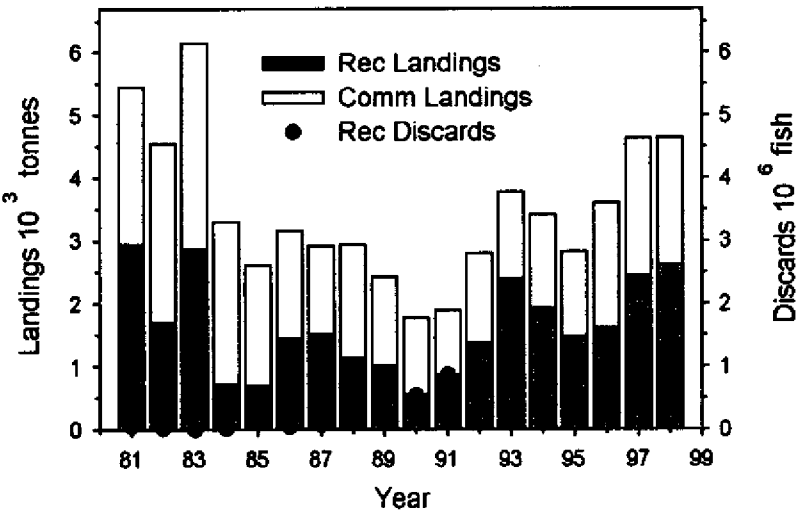


Figure 1. Reported recreational and commercial landings of red snapper in the U.S. GOM. Estimated numbers of live recreational discards are also given (Source of data: Schirripa and Legault (1999)).

Declining abundances of, as well as increasing management regulations on, red snapper and other overfished GOM reef fishes, such as gag grouper (*Mycteroperca microlepis*) and red grouper (*Epinephelus morio*), appear to have caused a shift in fishing effort to previously less exploited species (Ault et al. 1997, Schirripa 1996). Gray triggerfish (*Balistes capriscus*) experienced an increase in landings in the late 1980s and early 1990s, followed by a steady decline (Figure 2). Similar trends were observed for GOM vermilion snapper (*Rhomboplites aurorubens*) (Schirripa 1996), which is now considered to be approaching an overfished condition (Anon. 1998). The status of the GOM gray triggerfish stock is unknown, but concern over trends in landings of gray triggerfish and other reef fishes prompted the Gulf of Mexico Fishery Management Council (GMFMC) in 1995 to create a 20-fish aggregate recreational bag limit for reef fishes not covered by species-specific bag limits (GMFMC 1995). Most recently, the GMFMC introduced a 305 mm total length (TL) size limit for gray triggerfish (GMFMC 1999).

Traditionally, fisheries management measures such as size limits, fishing quotas, and seasonal closures have been used by managers in the southeastern U.S. and GOM to limit fishing mortality on reef fish resources; however, protected size ranges or species may incur incidental mortality due to hooking and release while fishers target legal-sized fish or other species (Collins et al. 1999, Gitschlag and Renaud 1994, Schirripa and Goodyear 1994). High rates of incidental catch coupled with high release mortality rates can negate potential gains of conservation measures (Goodyear 1995, Murphy et al. 1995, Schirripa and Goodyear 1994). As part of tagging studies conducted in the northern GOM off the coast of Alabama, we

indirectly estimated release mortality of tagged red snapper and gray triggerfish based upon visual assessment of their condition at the surface following release. The need for further validation of our approach is discussed, as well as its potential use for estimating release mortality through fishery observer programs.

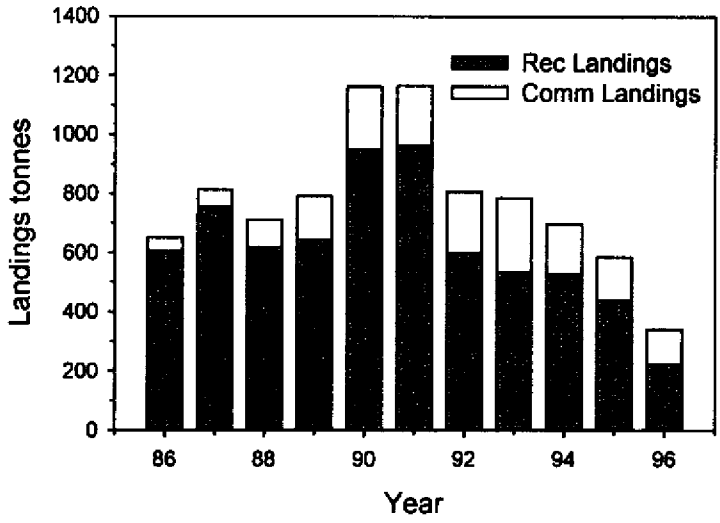


Figure 2. Reported U.S. GOM recreational and commercial landings of gray triggerfish from 1986 to 1996. (Source of data: Skip Lazauski, Alabama Department of Conservation, Marine Resources Division, Gulf Shores, AL 36524)

METHODS

Red snapper and gray triggerfish were tagged and released over reef sites off the coast of Alabama during two separate tagging studies. Red snapper were tagged over nine artificial reef sites on 28 tagging trips from March 1995 to July 1998 (Figure 3). Three sites each were located at water depths of 21, 27, and 32 m. Gray triggerfish were tagged over two natural hardbottom sites on 24 tagging trips from July 1997 to March 2000 (Figure 3). Gray triggerfish tagging sites were located at water depths of 24 and 35 m.

Tagging trips were made aboard a chartered fishing boat and methods were the same for each study except where noted below. Fish were captured over reef sites with rod and reel fished with straight-shank barbed hooks (3/0 size for red snapper and 1/0 size for gray triggerfish). Once hooked, fish were retrieved slowly from the bottom (approximate rate = 0.5 m/s) and placed in holding tanks with running seawater. Individuals were measured (TL and fork length (FL)) and then tagged by inserting an internal anchor tag through a small (< 5mm) incision made with a scalpel in the abdominal cavity. Tags were yellow Floy FM-89 anchor tags and each was marked with a tag number, the word "reward," and a phone number for fishers to

report tag recoveries. In each study, a $5 reward was offered for tag returns, with a chance to win $500 in a drawing of tag returners.

Once tagged, red snapper were either released immediately overboard or transported (up to 0.5 hours) in holding tanks to other tagging sites for release. All gray triggerfish were released over their site of capture. Condition of tagged fish was assessed visually based upon their swimming behavior at the surface (Table 2). The effect of fish size, season of capture (winter, spring, summer, fall), depth of capture, and transportation prior to release on red snapper release condition was tested with logistic regression (SAS, Inc. 1996). In the model, fish released in condition-1 were coded as a one and fish released in other conditions were coded as zeroes.

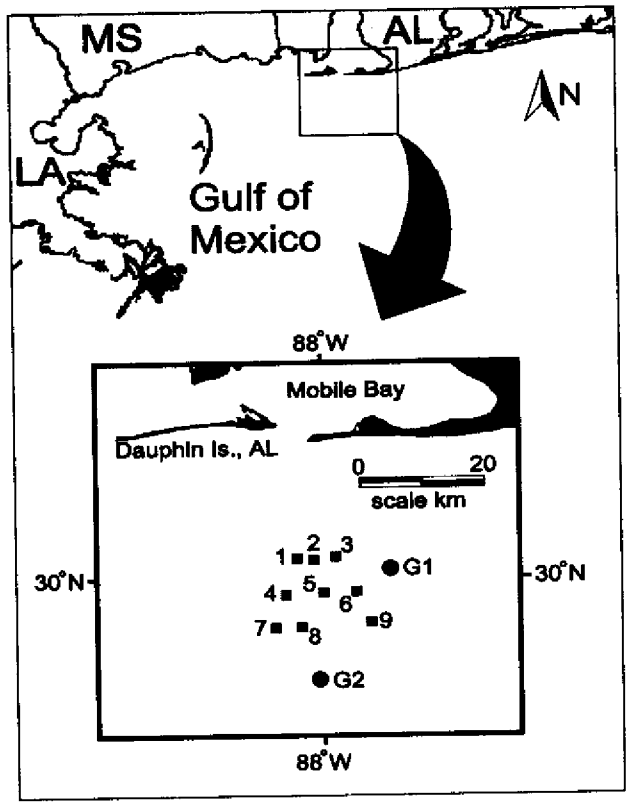


Figure 3. Map of region off the coast of Alam\bama where tagging studies were conducted. Red snapper tagging sites (labeled 1 - 9) and gray triggerfish tagging sites (labeled G1 and G2) are shown.

Tagged fish from both studies were recaptured at tagging sites on subsequent tagging trips and were reported by recreational and commercial fishers (through October 2000). The effect of release condition on red snapper recapture rate was tested with contingency table analysis (SAS, Inc. 1996).

Table 2. Release conditions for tagged red snapper and gray triggerfish.

Condition	Characteristics Displayed by Fish
1	Fish oriented toward the bottom and swam down vigorously.
2	Fish appeared disoriented upon entering the water, oriented toward the bottom, but swam erratically.
3	Fish appeared very disoriented upon entering the water and remained at the surface.
4	Fish was either dead or unresponsive upon entering the water.

RESULTS

Two thousand two hundred thirty-two red snapper were tagged; 879 were transported prior to release and 2,053 were not. Mean TL (± SE) of tagged individuals was 335.1 (± 1.34) mm. Overall, 86.5% of tagged red snapper were released in condition-1 (Table 3). The logistic regression computed on release condition was significant ($\chi^2_{d.f.=4} = 109.9, p < 0.001$). Depth of capture ($\chi^2_{d.f.=1} = 15.95, p < 0.001$), fish size ($\chi^2_{d.f.=1} = 8.52, p = 0.004$), and transportation prior to release ($\chi^2_{d.f.=1} = 53.39, p < 0.001$) all significantly affected whether tagged fish were released in condition-1; season was not significant ($\chi^2_{d.f.=1} = 1.20, p = 0.273$). The probability that fish were released in condition-1 significantly decreased with increasing depth, transportation prior to release, and decreasing fish size. Five hundred ninety-four recaptures were made of 550 tagged red snapper (Table 4); 42 fish were recaptured twice and one fish was recaptured three times. Two hundred thirty-five recaptures were made on tagging trips and 359 recoveries were reported by fishers. Of the 550 recaptured individuals, 98.4% were released in condition-1 at tagging. Release condition significantly affected red snapper recapture rate (contingency table analysis: $\chi^2_{d.f.=3} = 74.3, p < 0.001$).

Eight hundred forty-two gray triggerfish were tagged; 589 fish were tagged at the 24 m depth site (G1) and 253 were tagged at the 35 m depth site (G2). Mean FL (± SE) of tagged individuals was 297.1 (± 1.39) mm. Overall, 99.2% of gray triggerfish were released in condition-1. One fish in condition-2 and two fish in condition-3 were released at site G1, and one fish in condition-2 and three fish in

condition-3 were released at site G2.

Table 3. Number and percentage of tagged red snapper released in condition-1

Transport	Depth of Capture Site			Overall in Condition-1
	21 m	27 m	32 m	
Fish Transported	91.1% (113 of 124)	79.8% (280 of 351)	74.0% (299 of 404)	78.7% (692 of 879)
Fish not Transported	91.1% (856 of 940)	91.1% (460 of 505)	87.0% (529 of 608)	89.9% (1,845 of 2,053)
Mean in Condition-1	91.1% (968 of 1,064)	86.4% (740 of 856)	81.8% (828 of 1,012)	86.5% (2,537 of 2,932)

Table 4. Number and percentage of tagged and recaptured red snapper released in each condition. Percentages are of total sample size (n = 2,932).

Red Snapper Release Condition	Tagged Red Snapper not Recaptured	Recaptured Red Snapper	Total
1	1,996 68.1%	541 18.5%	2,537 86.6%
2	152 5.2%	5 0.17%	157 5.4%
3	134 4.6%	3 0.10%	137 4.7%
4	100 3.4%	1 0.03%	101 3.3%
Total	2,382 81.3%	550 18.7%	2,932 100.00%

One hundred ninety-six recaptures were made of 160 gray triggerfish . One hundred seventy-four recaptures were made on tagging trips and 22 recoveries were reported by fishers. Nineteen fish were recaptured twice, seven fish were recaptured three times, and one fish was recaptured four times. All recaptures were released

at tagging in condition-1.

DISCUSSION

Release condition of gray triggerfish generally was assessed to be excellent, as most tagged fish disappeared from sight immediately upon entering the water. No statistical tests were performed on gray triggerfish condition because nearly all fish were released in condition-1, and 100% of recaptured individuals were released in condition-1. The high return rate at tagging sites infers that gray triggerfish display high site fidelity. Moreover, multiple recaptures of some individuals provide further evidence that capture and release, as well as tagging, did not significantly affect the apparent health of gray triggerfish.

For red snapper, condition at release was significantly lower for fish transported prior to release. While it is unlikely that commercial and recreational fishers would transport fish prior to releasing them, this result illustrates that increased handling of fish decreased their condition. That release condition was significantly lower for smaller fish has important implications for size limits that are designed to protect young fish from fishing mortality. This result suggests that small fish may be more vulnerable to release mortality than larger fish; however, Gitschlag and Renaud (1994) reported there was no significant difference in red snapper release mortality estimates between fish smaller and larger than 30 cm TL. Lastly, decreasing release condition with increasing depth reflects trends in release mortality reported by Gitschlag and Renaud (1994) for red snapper and by Wilson and Burns (1996) for red grouper and scamp (*Mycteroperca phenax*).

Gitschlag and Renaud (1994) reported that estimates of red snapper release mortality rates inferred from the condition of released fish at the surface were similar to mortality estimates from *in situ* caging experiments conducted at similar depths. They and Render and Wilson (1994) reported that most of the mortality suffered by red snapper held in cages or laboratory tanks occurred soon after capture. Render and Wilson (1994) also reported there was no significant difference in mortality between tagged and untagged individuals. Szedlmayer and Shipp (1994) held 30 tagged red snapper in laboratory tanks for six months with no mortality or signs of infection, implying individuals that did not suffer acute tagging mortality (i.e., fish released in condition-1) likely would not suffer chronic injuries leading to death. Patterson et al. (in review) reported that fish tagged in the present study grew at similar rates as otolith-aged individuals, which also implies no chronic effects of tagging.

Based on these studies, and the fact that nearly all recaptures of tagged red snapper in the present study were of fish released in condition-1, we hypothesize that the cumulative percentage of tagged fish released in conditions other condition-1 may serve as a conservative (indirect) estimate of release mortality. Following this logic, estimated release mortality for gray triggerfish would be less than 1%. Overall, estimated release mortality for tagged red snapper would be 13.5%, which is within the range of release mortality estimates reported from previous studies.

Render and Wilson (1994) reported an overall release mortality rate of 20% for red snapper caught off Louisiana. Gitschlag and Renaud (1994) presented data from several studies of red snapper release mortality, and mean mortality rate (± SE) was 14% (± 4.5) for studies (n = 7) that were conducted at depths similar to the present study.

Our results, as well as those of Gitschlag and Renaud (1994), indicate that release condition of fish at the surface may serve as proxy for release mortality. Controlled experiments are needed, however, to validate that release condition of individual fish correlates to release mortality, especially over greater depth and fish size ranges than those of the present study. In particular, the likelihood of survival for fish that appear in poor condition at release and the likelihood of mortality for fish that appear healthy need to be examined.

Accurate estimation of discard rates and release morality rates is critical to fishery managers that must consider the effect of release mortality on stock-specific production while attempting to maximize yield per recruit (Goodyear 1995, Schirripa and Goodyear 1994). If it can be shown that release condition accurately approximates survival potential of individual fish, then the approach presented here may have broader applications for indirectly estimating release mortality. For example, observer programs could be established to estimate discard rates and release mortality of fish caught incidentally and released by recreational and/or commercial fishers.

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LITERATURE CITED

Anon. 1998. Report to Congress: status of fisheries of the United States. National Marine Fisheries Service. Washington, D.C. USA. September, 1998.

Ault, J.S., J.A. Bohnsack, and G.A. Meester. 1998. A retrospective (1979 - 1996) multispecies assessment of coral reef fish stocks in the Florida Keys. *U.S. Fishery Bulletin.* **96**:395-414.

Bohnsack, J.A. 1996. Maintenance and recovery of reef fishery productivity. Pages 283-314 in: N.V.C. Polunin and C.M. Roberts (eds.) *Reef Fisheries.* Chapman & Hall. London, England.

Coleman, F.C., C.C. Koenig, A.M. Ecklund, and C.B. Grimes. 1999. Pages 233-242 in: J.A. Musick (ed.) *Life in the Slow Lane: Ecology and Conservation*

of Long-lived Marine Animals. American Fisheries Society Symposium 23. Bethesda, Maryland USA.

Coleman, F.C., C.C. Koenig, G.R. Huntsman, J.A. Musick, A.M. Ecklund, J.C. McGovern, R.W. Chapman, G.R. Sedberry, and C.B. Grimes. 2000. Long-lived reef fishes: the grouper-snapper complex. *Fisheries* **25**:14-21.

Collins, M.R. J.C. McGovern, G.R. Sedberry, H.S. Meister, and R. Pardieck. 1999. Swim bladder deflation in black sea bass and vermilion snapper: potential for increasing postrelease survival. *North American Journal of Fisheries Management*. **19**:828-832.

Gitschlag, G.R. and M.L. Renaud. 1994. Field experiments on survival rates of caged and released red snapper. *North American Journal of Fisheries Management* **14**:131-136.

Gobert, B. 2000. Comparative assessment of multispecies reef fish resources in the Lesser Antilles. *Fisheries Research* **44**:247-260.

Goodyear, C.P. 1995. Red snapper in U.S. waters of the Gulf of Mexico. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory. Miami, Florida USA. MIA-95/96-05.

Gulf of Mexico Fishery Management Council. 1995. Amendment 12 to the reef fish fishery management plan. Tampa, Florida USA.

Gulf of Mexico Fishery Management Council. 1999. Amendment 16B to the reef fish fishery management plan. Tampa, Florida USA.

Gulf of Mexico Fishery Management Council. 2000. Regulatory amendment to the reef fish fishery management plan to set total catch and management measures for red snapper for the 2000 and 2001 season. Tampa, FL.

Hoese, H.D. and R.H. Moore. 1998. *Fishes of the Gulf of Mexico, 2nd edition*. Texas A&M University Press.College Station, Texas USA.

Huntsman, G.R. and J.R. Waters. 1987. Development of management plans for reef fishes–Gulf of Mexico and U.S. South Atlantic. Pages 533-560 in: J.J. Polovina and S. Ralson (eds.) *Tropical Snappers and Groupers: Biology and Fisheries Management*. Westview Press. Boulder, Colorado USA.

Minton, V. and S.R. Heath. 1998. Alabama's artificial reef program: building oases in the desert. *Gulf of Mexico Science* **16**:105-106.

Murphy, M.D., R.F. Heagey, V.H. Neugebauer, M.D. Gordon, and J.L. Hintz. 1995. Mortality of spotted seatrout released from gill-net and hook-and-line gear in Florida. *North American Journal of Fisheries Management* **15**:748-753.

Parrish, J.D. 1987. The trophic biology of snapper and groupers. Pages 405-465 in: J.J. Polovina and S. Ralson (eds.) *Tropical Snappers and Groupers: Biology and Fisheries Management*. Westview Press. Boulder, Colorado USA.

Patterson, W.F., III, J.H. Cowan, Jr., C.A. Wilson, and R.L Shipp. [2000]. Age and growth of red snapper, *Lutjanus campechanus*, from an artificial reef area in the northern Gulf of Mexico. *U.S. Fishery Bulletin*. in review.

Render, J. H. and C. A. Wilson. 1994. Hook-and-line mortality of caught and released red snapper around oil gas platform structural habitat. *Bulletin*

of Marine Science **55**:1106-1111.

SAS Institute, Inc. 1996. *Statistics Version 6.11.* SAS Institute, Inc. Cary, North Carolina USA.

Schirripa, M.J. 1996. Status of the vermilion snapper fishery of the Gulf of Mexico: assessment 3.0. NOAA/NMFS Southeastern Fisheries Science Center, Miami, Florida USA. MIA-95/96-61.

Schirripa, M.J. and C.P. Goodyear. 1994. Simulation modeling of conservation standards for spotted seatrout (*Cynoscion nebulosus*) in Everglades National Park. *Bulletin of Marine Science* **54**:1019-1035.

Schirripa, M. J. and C. M. Legault. 1999. Status of the red snapper stock in U.S. waters of the Gulf of Mexico: updated through 1998. NOAA/NMFS Sustainable Fisheries Division, Miami, Florida USA. SFD-99/00-75.

Stanley, D.R. and C.A. Wilson. 1990. A fishery-dependent based study of fish species composition and associated catch rates around oil and gas structures off Louisiana. *U.S. Fishery Bulletin* **88**:719-730.

Szedlmayer, S.T. and R.L. Shipp. 1994. Movement and growth of red snapper, *Lutjanus campechanus*, from an artificial reef area in the northeastern Gulf of Mexico. *Bulletin of Marine Science* **55**:887- 896.

Wilson, R.R., Jr. and K.M. Burns. 1996. Potential survival of released groupers caught deeper than 40 m based on shipboard and in-situ observations, and tag-recapture data. *Bulletin of Marine Science* **58**:234-247.

The Germinal Epithelium: Its Dual Role in Establishing Male Reproductive Classes and Understanding the Basis for Indeterminate Egg Production in Female Fishes

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ABSTRACT

The germinal epithelium in fish gonads is defined herein. An active germinal epithelium in the ovaries of mature fish is the basis for indeterminate egg production--the ability to produce an unlimited number of eggs. In males, changes that occur in testicular germinal epithelia during annual reproductive cycles can be used to define five reproductive classes: regressed, early maturation, mid maturation, late maturation, and regression. It is proposed that gonadal function changes during annual reproductive cycles in male fish. Mitosis is the mode of germ cell division during the regressed class, and the mode by which diploid germ cells, the spermatogonia, repopulate testis lobules. Meiosis never occurs. When reproductive, meiosis is the predominate mode by which germ cells divide, and sperm are produced. Mitotic divisions of spermatogonia may occur. In the ovary of the group-synchronous fish studied, common snook, meiosis occurs throughout the year. Oocytes, arrested in the diplotene stage of meiosis, and follicles are continuously produced by the germinal epithelium. Vitellogenesis occurs only during the reproductive season. In contrast to male fish, changes in the stages of oocytes that are present within the ovarian lamellae, not changes in the germinal epithelium, are used to define reproductive classes in females.

KEY WORDS: Germinal epithelium, spermatogenesis, vitellogenesis

INTRODUCTION

In mammals and birds, there is a fixed number of oocytes present at the time of birth (Tokarz 1978). This is determinate egg production. In contrast, teleosts have indeterminate egg production, i. e., females can produce an unlimited number of eggs during their reproductive lifetimes (Tyler and Sumpter 1996) because they possess an active ovarian germinal epithelium (Grier 2000).

Herein, the concept of a germinal epithelium in male and female teleosts is reviewed, particularly as it can be used to understand indeterminate egg production in females and to define reproductive classes in males. An ovarian germinal epithelium may be present in almost all fish. However, given the reproductive diversity of fish, an exception occurs in the pipefish, *Sygnathus scovelli* (Begovac and Wallace 1987, 1988) and the seahorse, *Hippocampus erectus* (Selman et al.

1991). In both of these sygnathids, germinal ridges, one in the pipefish and two in the seahorse, occur along the ovary length. Oogonia are located in the germinal ridge where meiosis and folliculogenesis commence. The process of folliculogenesis, whether oocytes originate from a germinal ridge or a germinal epithelium, are similar. However, all of the criteria that define an epithelium (see below) do not apply to a germinal ridge.

GERMINAL EPITHELIUM CONCEPT

The ovarian germinal epithelium produces the germ cells in the fish ovary, and the testicular germinal epithelium produces those in the fish testis (Grier 2000, Grier and Lo Nostro 2000). The concept that a germinal epithelium continuously producing oocytes and follicles in the ovaries of fish (indeterminate egg production) has hardly been explored. In males, annual changes in the testicular germinal epithelium have been used to define annual reproductive classes, as in common snook, *Centropomus undecimalis* (Taylor et al. 1998, Grier and Taylor 1998), spotted sea trout, *Cynoscion nebulosus* (Brown-Peterson et al. 2001), and cobia, *Rachycentron canadum* (Brown-Peterson et al. in press). These changes in the germinal epithelium are based on definitive histological criteria.

The definition of the germinal epithelium is based upon histological definitions of an epithelium (Grier 2000, Grier and LoNostro 2000). The morphology and functions of epithelia depend on their location in the body–form and function coincide. Although morphologically diverse, all epithelia share the same characteristics:

i) All epithelia border a body surface, lumen, or duct.
ii) All epithelial cells are joined laterally (desmosomes, tight junctions, gap junctions, etc.).
iii) All epithelia are supported by a basement membrane.
iv) All epithelia are avascular.

If any of these characteristics are absent, then a tissue is not an epithelium. The germinal epithelium is unique among the different kinds of epithelia because it is the only epithelium that produces haploid germ cells that are associated with a somatic cell component (Grier and LoNostro 2000). Both ovarian and testicular germinal epithelia are supported by basement membranes and border a body lumen. In evolutionarily advanced female fish, the lumen is the ovarian lumen into which the ovigerous lamellae project from beneath the outer tunica. In more primitive fish, such as sturgeon and salmonids, the ovarian lamellae are suspended into the body cavity. In males, the body cavity that is bordered by the germinal epithelium is the lumen of the lobule (higher fish) or anastomosing tubule (lower fish) (Grier 1993). As a unifying concept, the definition of a germinal epithelium applies to both males and females and between chordate taxa (Grier and Lo Nostro 2000).

When most, but not all of the criteria that define an epithelium apply to a tissue, then the term "epithelioid" applies (Ross et al. 1995). An epithelioid tissue is the layer of follicle cells surrounding an oocyte. They rest upon a basement membrane, are laterally connected, and are avascular. However, they do not border a free body

space but are associated with the developing or mature oocyte. In cobia (Brown-Peterson et al., in press), solid cords of spermatogonia and Sertoli cells grow from the distal ends of the lobules during the regression and regressed classes that are also epithelioid tissue, until a lumen develops.

Germinal epithelia are composed of two cell types: somatic and germ cells. In the testis, the somatic cells are the Sertoli cells (Figure 1, Grier 1993). In the ovary, the somatic cells are the epithelial cells that give rise to prefollicle cells and eventually become follicle cells (Figure 2, Grier,2000). Within the germinal epithelium, the diploid germ cells are either oogonia (ovary) or spermatogonia (testis). At the initiation of meiosis, an oogonium becomes an oocyte, and a spermatogonium becomes a spermatocyte. These germ cells undergo two successive meiotic divisions; the first one is the reduction division, i. e., the chromosome number is halved. The first meiotic prophase is extended and is subdivided into leptotene, zygotene, pachytene, diplotene, and diakinesis. In pachytene, the paired, homologous chromosomes are condensed and joined by a synaptonemal complex that is distinctive. The presence of synaptonemal complexes, seen by using electron microscopy, in the ovaries of regressed common snook was used to discern and define the ovarian germinal epithelium and document that meiosis and folliculogenesis occur throughout the annual reproductive cycle (Grier 2000).

A major difference exists between meiosis in cells that form sperm and those that form eggs. This is true, not only of fish, but also other vertebrates (Tokarz 1978), including mammals (Pelliniemi et al. 1993). In males, meiosis is a continuous process involving two successive cell divisions resulting in the production of four haploid spermatids. These, in turn, begin a morphological transformation called "spermiogenesis" and become sperm. In contrast, during oogenesis, meiosis becomes arrested during diplotene of the first meiotic division. Fish oocytes remain in diplotene through three growth stages: primary growth; secondary growth (vitellogenesis), and final oocyte maturation, after which the oocyte is preovulatory (Figure 3). Primary growth oocytes are marked by a synthesis of heterogenous RNA and ribosomal RNA, the latter produced by multiple nucleoli within the nucleus or germinal vesicle (Selman and Wallace 1989). Oocyte diameters increase from approximately 8-10 μm to approximately 250 μm. During secondary oocyte growth, vitellogenin is synthesized within the liver. Circulating vitellogenin is sequestered from the circulation and incorporated in protein yolk globules, increasing oocyte diameter to about 450 μm in saltwater fish that lay pelagic eggs. Pelagic eggs contain an oil globule for buoyancy and a clear cytoplasm. The process by which the single oil globule and cleared cytoplasm forms froma mature oocyte is called final oocyte maturation (Wallace and Selman 1981).

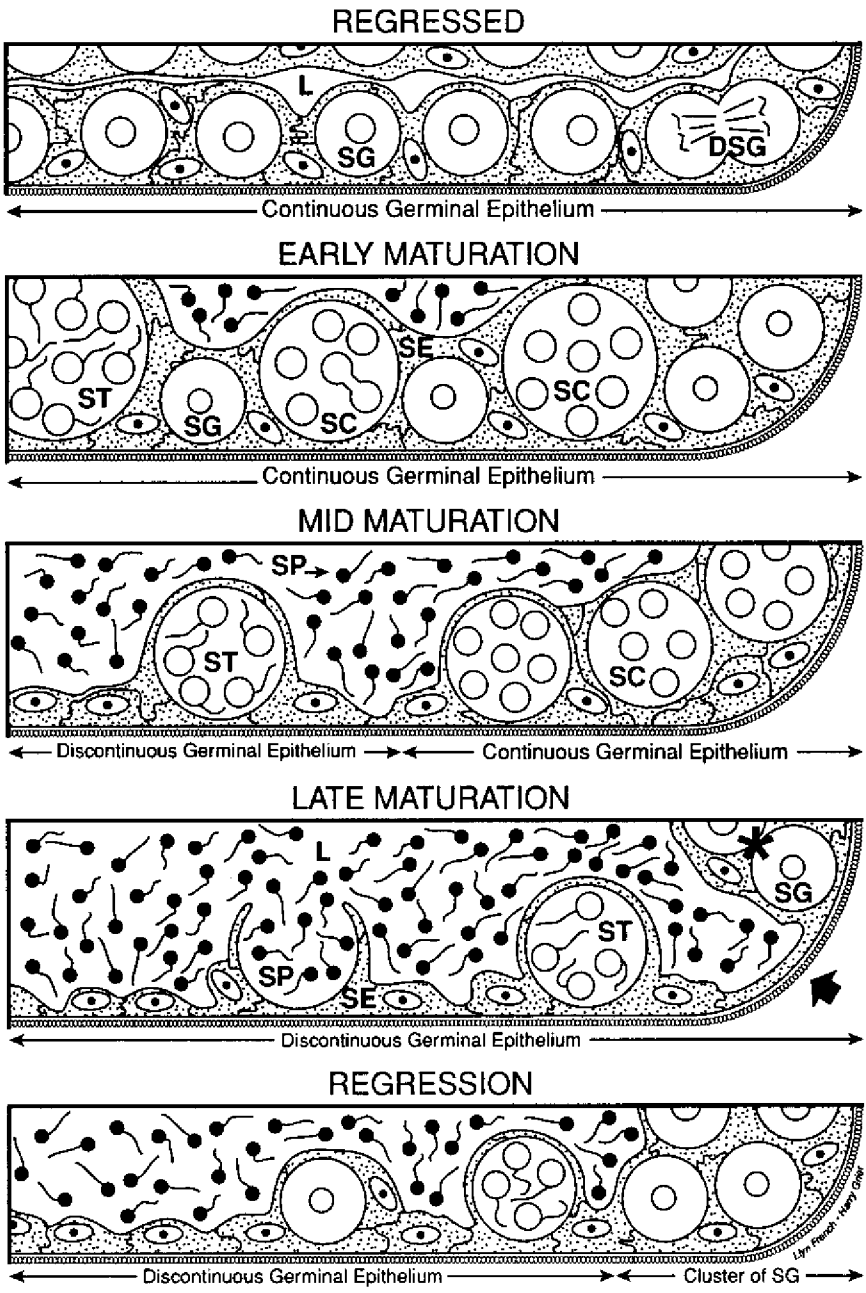


Figure 1. See legend at end of manuscript

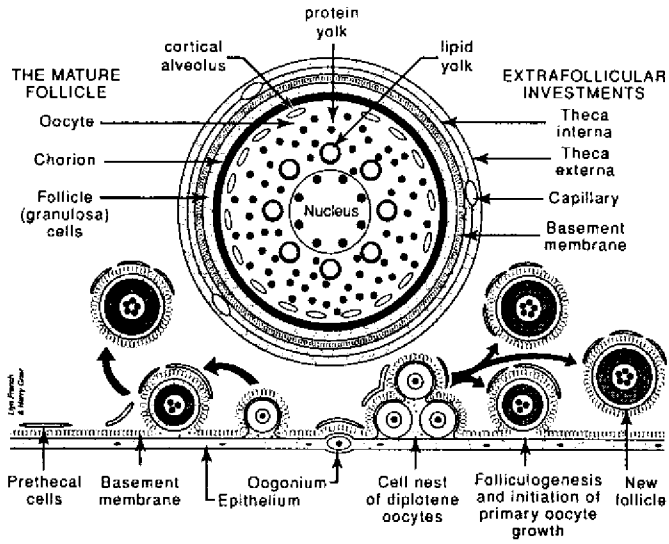


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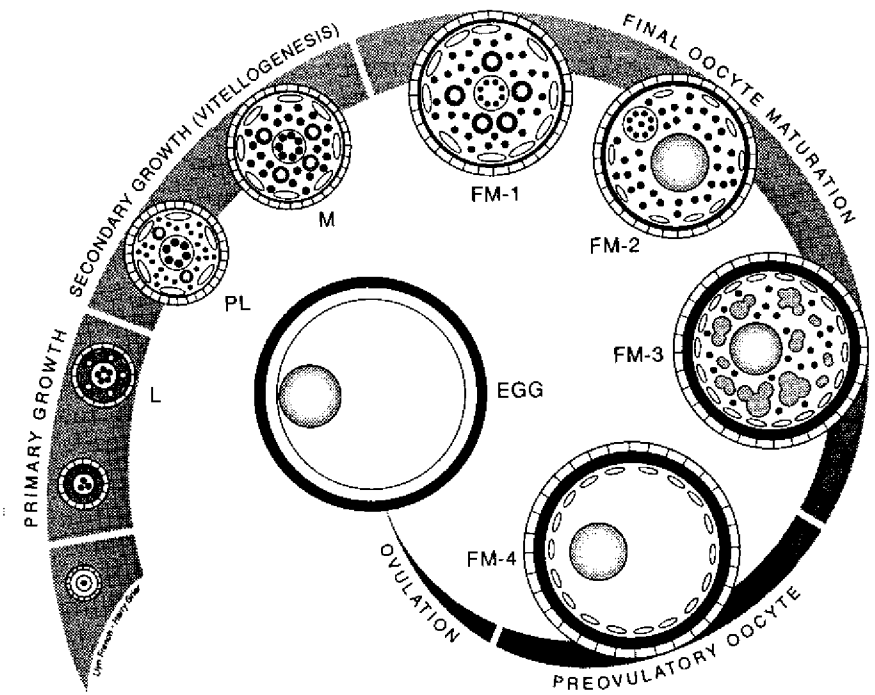


Figure 3. See legend at end of manuscript

At first, diplotene oocytes have a spherical nucleus and a single, prominent nucleolus, which is surrounded by a clear cytoplasm. These diplotene oocytes have frequently been misinterpreted as oogonia (see Grier 2000). Once they enter the primary growth phase of development, increase in diameter, and their cytoplasm becomes basophilic due to the accumulation of ribonucleic acid, there is no mistaking the correct staging of these cells as meiotic oocytes. Oocytes remain in arrested meiosis until the four phases of final oocyte maturation (Figure 3, Neidig et al. 2000) are completed, and they are preovulatory (Wallace and Selman, 1981; Selman and Wallace 1989). At the end of final oocyte maturation, the nucleus has migrated to the periphery of the oocyte, the nuclear membrane has dissociated, and the chromosomes have become free in the nucleoplasm. The first meiotic division is completed and the first polar body is extruded. The remaining chromosomes then proceed to the second meiotic metaphase and again arrest in division (Selman and Wallace 1989).

DETERMINATION OF REPRODUCTIVE CLASSES IN MALES

In the annual reproductive cycle of male fish, descriptive classes can be recognized because of distinct changes in the germinal epithelium (Figure 1). These changes are easily perceived histologically. They are based on whether there is a continuous or a discontinuous germinal epithelium and the germ cell stages that are present (Grier and Taylor 1998). In a continuous germinal epithelium, a continuous population of germ cells and Sertoli cells exists along the lobule basement membrane. The germ cells may be spermatogonia, meiotic spermatocytes, maturing spermatids during spermiogenesis, or sperm. These germ cells develop synchronously within spermatocysts whose borders are formed by Sertoli cells. In a discontinuous germinal epithelium, sperm mature and undergo spermiation (release into the lumen of the lobule). Because the germ cells are not replaced as the spermatogonia all transform into meiotic cells, there is a gradual loss of the germ cell component from the germinal epithelium. Spermatocysts, and generally some spermatogonia, become widely spaced, and an epithelium results that eventually is almost entirely composed of a monocellular layer of Sertoli cells along the lobule basement membrane. The alternation of continuous and discontinuous germinal epithelia, and the stages of the germ cells that are associated with Sertoli cells in the germinal epithelium, are the criteria that are used to determine reproductive classes in male fish (Figure 1).

The regressed class — is defined by the presence of only spermatogonia in the testis (Figure 1). A continuous germinal epithelium extends from the ducts to the distal termini of the lobules. It is significant that the spermatogonia, and their associated Sertoli cells, divide mitotically (Lo Nostro et al. in review) during the regressed class. It is not generally recognized that this is a period when the population of spermatogonia is renewed within the germinal compartments and important testicular growth processes occur. In regressed red drum, mitotic divisions of

spermatogonia produce lobule elongation, which is represented by epithelioid outgrowths, called cords, containing spermatogonia and Sertoli cells just prior to the breeding season (Grier et al. 1987). Cords of spermatogonia and Sertoli cells are particularly evident in cobia (Brown-Peterson et al. in press) during the regression and regressed classes. However, even before the initiation of spermatogenesis, a lumen begins to develop within the epithelioid cords; they then fulfill the criteria for an epithelium and are a germinal epithelium.

The early maturation class — is also defined by the existence of a continuous germinal epithelium between the ducts and the termini of the lobules, but in this class spermatogenesis has been initiated (Figure 1). Because spermatogenesis involves the formation of spermatocysts, that contain a clone of synchronously developing germ cells, the width of lobules increases, and the lobular lumen is generally partially restricted or closed because opposing sides of the lobules press against each other. It becomes continuous when sperm are voided from the spermatocysts (spermiation). There is considerable elongation of the lobules, and the entire testis becomes larger. Early maturation marks the switch from a mitosis-dominated to meiosis-dominated cell division among germ cells (Figure 4).

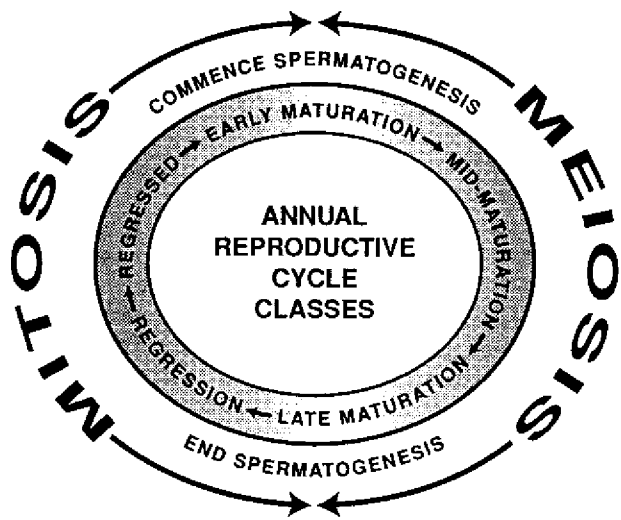


Figure 4. See legend at end of manuscript

The mid maturation class — is characterized by the presence of a discontinuous germinal epithelium in the region of the testis ducts and a continuous germinal epithelium at the lobule termini (Figure 1). As maturation progresses, the lobules can grow in length so long as there are distal spermatogonia and Sertoli cells at their termini. Upon spermiation, or sperm release into the ducts, the germ cell component of the germinal epithelium is lost. Spermatogonia and spermatocysts containing germ cells become scattered along the lobule basement membrane and are separated by Sertoli cells, producing a discontinuous germinal epithelium (Grier 1993).

The late maturation class — commences when at least one lobule within a histological section is observed to possess a discontinuous germinal epithelium at its distal terminus (Figure 1, arrow). In common snook, clusters of spermatogonia (Figure 1, asterisk) also become reestablished in late maturation (Grier and Taylor et al. 1998), but this does not happen until the regression class in cobia (Brown-Peterson et al., in press). At first, only a single lobule within a histological section may have a discontinuous germinal epithelium at its terminus. As maturation progresses, additional lobules lose a continuous germinal epithelium at their termini (Grier and Taylor 1998, Brown-Peterson et al. in press).

Spermiation, or release of sperm from the spermatocyst, is illustrated during the late maturation class of Figure 1. Spermiation, coupled with exhaustion of primary spermatogonia, is the basis for changes in the germinal epithelium through an annual reproductive cycle. At a time when the testis is producing sperm for reproduction, parts of it are ceasing to produce sperm and are becoming involved in sperm storage. The testis undergoes transformation from sperm production to sperm storage, beginning in the duct area of the testis. Most fish must produce large volumes of sperm during a spawning event, particularly if they are group-synchronous spawners and broadcast gametes into the environment. Lacking separate sperm-storage organs, the testis serves this purpose.

As maturation progresses, the process of germ cell exhaustion within the lobules extends towards the testis periphery. However, upon close histological examination, there are generally a few inactive spermatogonia along the lobule lengths. Therefore, the germinal epithelium becomes truly "discontinuous," where there is only a Sertoli cell presence along the lobule walls and very few scattered spermatogonia or spermatocysts. Recognition of these two states of the germinal epithelium, continuous and discontinuous, and the observation that germ cells persist within lobules throughout annual reproductive cycles, led to the conclusion that the lowest taxon in which a permanent germinal epithelium evolved is the fishes (Grier 1993, Grier and Lo Nostro 2000).

The regression class — is characterized by widely scattered spermatocysts along lobule walls, generally lobules and ducts are filled with sperm, spermatogonia are few in number (Figure 1), and there is a decreasing gonadosomatic index. Sperm may be phagocytized by Sertoli cells, as has been observed in snook, or possibly voided from the testis at the cloaca (Grier and Taylor et al. 1998), or they may

remain accumulated in the lobules and ducts as in cobia (Brown-Peterson et al. in press). Species differences regarding the accumulation of sperm within the testis lobules, both during the regression and regressed classes, underscore the reason for not including sperm in the assignment or reproductive classes (Brown-Peterson et al. in press).

COMPARISONS BETWEEN SPECIES (MALES)

The five reproductive classes (regressed, early maturation, mid maturation, late maturation, regression), that are based upon changes in the male germinal epithelium and the types of germ cells that are present, have been applied to other teleosts. Annual changes in the testicular germinal epithelia of common snook, *Centropomus undecimalis* (Grier and Taylor 1998), spotted seatrout, *Cynosion nebulosus* (Brown-Peterson and Warren 2001), cobia, *Rachycentron canadum* (Brown-Peterson, et al. in press), and the synbranchid eel, *Synbranchus marmoratus* (Lo Nostro et al. in review) all cycle by a similar mechanism. The latter species is in the order Synbranchiformes while the former three species are in different families in the order Perciformes. Comparative information on annual changes in the male germinal epithelium is species-limited at present as there are only a few studies. However, the potential application of germinal epithelium criteria for the determination of annual reproductive classes in fish may become common as more fisheries biologists interpret reproductive cycles in light of these new criteria.

The testicular annual reproductive cycle can also be divided into two periods, dominated by either meiosis or mitosis (Figure 4). Sperm production is dominated by meiosis (early maturation, mid maturation, and late maturation classes). The sperm production phase is followed by mitotis-dominated renewal of stem germ cells, the spermatogonia. Meiosis does not occur. The discontinuous germinal epithelium observed in late maturation and regression is replaced by a continuous germinal epithelium, but the only germ cells present are spermatogonia. Reestablishment of a spermatogonial population in the testis may begin as early as late maturation, as in common snook (Taylor et al. 1998), and it continues into the regression and regressed classes. These two phases in male fish, dominated by either meiosis or mitosis, are obviously under distinctively different physiological controls. When fish are in the regressed class, the primary activity is mitotic division of spermatogonia and their associated Sertoli cells to restore a stem germ cell population within the germinal compartment. Herein, it is recognized that there is continual germ cell activity within the testis throughout an annual reproductive cycle, the periods of activity are either mitosis or meiosis dominated. Learning how these mechanisms– mitosis, meiosis, and lobule elongation--temporally interact and differ in fish species with different reproductive strategies, is an arena for future fish research.

THE GERMINAL EPITHELIUM IN FEMALE FISH

The first description of the ovarian germinal epithelium, in the common snook, *Centropomus undecimalis*, which is a group-synchronous spawning species (Grier 2000), established the origin of oocytes in the fish ovary and that meiosis and folliculogenesis occur throughout the annual reproductive cycle. Meiotic oocytes were observed in the ovarian germinal epithelium at the nadir of the annual reproductive cycle, during the regressed class. Unlike the testis maturation stages in male common snook, which occur once through the course of the annual reproductive cycle, there is a cycling between mid maturation and late maturation in common snook ovaries with every spawning event (Taylor et al. 1998).

It is not possible to define reproductive classes, via changes in the germinal epithelium, in the fish ovary. This is due to the marked differences in gamete development between the sexes in fish and the prolonged diplotene stage of the first meiotic division in oocytes. The paper that introduced the germinal epithelium as a potential new interpretative tool for fisheries biologists (Taylor et al. 1998) subtly makes this developmental difference clear. Reproductive classes in male snook were defined based upon distinctive, annual changes in the testicular germinal epithelium that are easily discerned histologically (Figure 1). Reproductive classes in female common snook were defined based upon changes in oocyte developmental stages and oocyte cycling through individual reproductive events in common snook (Figure 3). A single, hormone-induced spawn averaged 280,000 eggs (Neidig et al. 2000), and the natural, estimated time between spawns is 1.6 days (Taylor et al. 1998). In order to support continuous egg production in fish, there needs to be indeterminate egg production: folliculogenesis, or formation of follicles (Figure 2), needs to be continuous. Within the germinal epithelium, diploid oogonia must continuously enter into meiosis, and oocytes may be continuously recruited from the ovarian germinal epithelium into the ovarian lamellae where maturation (primary oocyte growth, vitellogenesis, and final oocyte maturation prior to ovulation, Figure 2).

In order to define folliculogenesis in the fish ovary, it was first necessary to define what a follicle is, because the fish literature has been inconsistent in its definition (Grier 2000). The fish ovarian follicle, by the definition taken from the mammalian literature (Grier 2000, Grier and Lo Nostro, 2000), is composed of the oocyte and its encompassing layer of follicle (granulosa) cells (Figure 2). This definition also reflects on the origin of the follicle from oogonia and epithelial cells (which become the follicle cells (Grier 2000) that are originally in the germinal epithelium (Figure 3). As oocyte maturation progresses, the follicle adds an intercellular layer, the chorion. The follicle is encompassed by an acellular basement membrane and the cellular theca interna and externa (Figure 3). Together, the follicle and its encompassing extrafollicular investments are termed the follicle complex (Grier 2000, Grier and Lo Nostro 2000). In mammals, the formation of an antrum in the developing follicle signifies the secondary stage in development (Fawcett and Jensh 1997). An antrum never forms in teleost ovarian follicles, and the term "secondary follicle" is inappropriate as a means of comparison between taxa.

The ovarian germinal epithelium is the thin epithelium that forms the surface of an ovarian lamella and borders the ovarian lumen (Figure 2); it is composed of two cell types: somatic epithelial cells and germ cells that may be either oogonia or meiotic oocytes. The epithelial cells are attached via desmosomes and tight junctions and rest upon a basement membrane (Grier 2000). They are avascular. Scattered among the epithelial cells are oogonia that may divide mitotically to maintain their population or enter into meiosis to produce single oocytes. The ovarian germinal epithelium is always a discontinuous germinal epithelium by the definition developed for determining male reproductive classes. After repeated mitotic divisions, oogonia may produce a cell nest composed of multiple oogonia and then, at the initiation of meiosis, multiple oocytes become arrested in the diplotene stage of the first meiotic prophase. Observations made on common snook indicate that diplotene oocytes in a cell nest are, at some point, still attached to and part of the germinal epithelium as there is no separating basement membrane (Grier, 2000). Primary oocyte growth begins when oocytes are still attached to the germinal epithelium (Figure 2, Grier 2000).

Within the germinal epithelium, oocyte meiosis proceeds through leptotene, zygotene, pachytene (when synaptonemal complexes are visible), and into diplotene of the first meiotic prophase. During diplotene, lampbrush chromosomes appear (Selman and Wallace 1989); primary oocyte growth, denoted by the accumulation of RNA within the cytoplasm, commences shortly thereafter.

As meiosis advances, epithelial cells become associated with oocytes, these complexes of epithelial cells and oocytes "sink" below the surface of the germinal epithelium and epithelial cells become prefollicle cells. During folliculogenesis, a basement membrane is synthesized around the forming follicle (Figure 3). The follicle is completely separated from the germinal epithelium by the basement membrane (Figure 3). Undifferentiated cells within the ovarian stroma, actually within the extravascular space (Grier 2000), become associated with the follicle as it is forming. These cells differentiate to form the theca interna and externa.

Prior to the completion of folliculogenesis, cortical granule formation, occurrence of lipid yolk, and advancement of the oocyte to the perinucleolar stage of development have not been observed, at least not in common snook (Grier 2000). Presumably, these events in oocyte maturation occur after folliculogenesis is completed, possibly in all fishes. The oocyte within a mature follicle (Figure 3) possesses cytoplasmic lipid and protein yolk globules and peripheral cortical granules. A chorion is not initially present in a newly formed follicle, but it develops during primary oocyte growth.

The events leading to ovulation begin and end with the diplotene oocyte. All of the processes of maturation, until the oocyte is preovulatory (final oocyte maturation stage FM-4, Figure 3), when the nuclear membrane disassociates and chromosomes become free in the cytoplasm and the first meiotic division, occur in the arrested diplotene stage of the first meiotic prophase. When first formed, diplotene oocytes do not possess a basophilic cytoplasm but are large cells with a distinct nucleolus. Primary oocyte growth is initiated within the germinal epithelium

with accumulation of basophilic, cytoplasmic RNA.

Simple techniques, developed for hatchery application (Neidig et. al. 2000), divided final oocyte maturation of common snook into four distinct stages (Figure 3) that can be used, if ovarian biopsies can be taken, to track maturation until broodstock are preovulatory. These stages probably apply to a number of other perciform fish and have been applied to red drum production (unreported). During stage 1 of final oocyte maturation (FM-1), lipids begin to coalesce and are much more distinctive than is nuclear migration to define both FM-1 and FM-2. During FM-1, using a wet mount technique called the coverslip method, it is possible to view the fusion of lipid globules within the oocyte cytoplasm until FM-2 is reached. At FM-2, there is but a single lipid globule, but protein yolk dissolution is not observed. Frequently, protein yolk globules begin to "clear" or become fluid before there is a single oil droplet. The oocyte can proceed from FM-1 directly to FM-3, the stage characterized by oocyte clearing. In the last final oocyte maturation stage, the oocyte possesses a completely clear cytoplasm, a single oil globule, and is preovulatory. At ovulation, the oocyte becomes an egg, voided into the ovarian lumen, and loses its encompassing layer of follicle and thecal cells that become a post-ovulatory follicle.

DISCUSSION

The changes that take place in the regressed testes and ovaries are subtle. Until recently, it has been rare to witness cell divisions or derive growth processes. The regressed testis appears to contain only spermatogonia and Sertoli cells while the ovary has numerous primary growth oocytes. In the ovary of the wahoo, *Acanthocybium solandri* (Scombridae), Brown-Peterson et al. (2000) recognized that multiple spawning species (group synchronous) have "continual oocyte recruitment." However, the underlying cellular basis for this recruitment became known only when the ovarian germinal epithelium and process of folliculogenesis were described (Grier 2000).

New criteria for the determination of reproductive classes in male fish are based upon naturally occurring changes that take place in the germinal epithelium. The reproductive classes--regressed, early maturation, mid maturation, late maturation, and regression--have been applied to male and female common snook (Grier and Taylor 1998, Taylor et al. 1998). Researchers are finding that these classes may be used to describe the reproductive classes in other fishes such as male sea trout, *Cynoscion nebulosus* (Brown-Peterson and Warren 2001), cobia, *Rachycentron canadum* (Brown-Peterson et al. in review), and swamp eels, *Synbranchus marmoratus* (Lo Nostro et al. in review). Nine gonadal reproductive stages were initially described in sea trout, including an immature stage (Brown-Peterson et al. 1988). By using changes in the germinal epithelium to describe the annual reproductive cycle, eight of the reproductive stages were replaced by five classes (Brown-Peterson and Warren 2001). The immature stage should become an immature class following the definitions of stage and class (Taylor et al. 1998).

"Stage" refers to a stage in germ cell development. "Class" refers to changes in gonad development.

The ability of fish to produce continuous numbers of eggs throughout their reproductive lifetime is because of an active ovarian germinal epithelium in adults. The ovarian germinal epithelium has only recently been described (Grier 2000), but its activity undoubtedly underlies fish egg production. The germinal epithelium is active at the nadir of the annual reproductive cycle in common snook, in both males and females. Testicular germinal epithelia produce spermatogonial renewal during the regressed class in cobia and swamp eels. I propose that male fish cycle between gamete production and the coincident exhaustion of diploid spermatogonia (meiosis-dominated part of the annual reproductive cycle) and renewal of the spermatogonia population in the testis (mitosis-dominated part of the annual reproductive cycle). These two processes are temporally separated on an annual basis and occur within respective reproductive classes (Figure 4). The implication is not made that during the meiosis-dominated part of the reproductive cycle there are no mitotic divisions of spermatogonia, only that one type of cell division is predominate. However, meiosis does not occur during the regressed class when only spermatogonia are present within the testis.

There is a basic difference between male and female fish regarding meiosis. In males, only mitosis and division of spermatogonia occur during the regressed class. In females, however, meiosis also occurs during the regressed class, at least in common snook as of this writing (Grier 2000), and follicles are produced in which oocytes enter the primary growth phase. However, they do not become vitellogenic until the early maturation class during the annual reproductive cycle.

FIGURE LEGENDS

Figure 1. Reproduction classes through the year as interpreted by histological changes in the germinal epithelium. Dividing Spermatogonium (DSG); Lumen (L); Sperm (SP); Spermatocyte (SC); Spermatogonia (SG); Spermatid (ST); Sertoli cell (SE).

Regressed class: only spermatogonia are present which are associated with Sertoli cells. The lobule lumen is frequently discontinuous, and spermatogonia may divide mitotically.

Early maturation class: There is a continuous germinal epithelium extending the entire length of the lobule, but spermatogenesis has been initiated.

Mid maturation class: a discontinuous germinal epithelium is present proximally, near the testis ducts. A continuous germinal epithelium is observed at the lobule periphery.

Late maturation class: a discontinuous germinal epithelium is observed at the termini of at least one lobule in a histological section (arrow) and increasingly more lobules as maturation progresses. Spermiation, the release of sperm from a spermatocyst, is depicted.

Regression Class: Spermatogonia begin to reestablish their population along the basement membrane of the lobule in association with Sertoli cells. Spermatogonia are also present at the distal termini of lobules, sometimes being organized as epithelioid cords of cells. There may be a few spermatocysts present, but the

germinal epithelium is primarily made up of Sertoli cell epithelium; the GSI is declining and the testis is becoming smaller.

Figure 2. The ovarian germinal epithelium is composed of oogonia and epithelial cells that rest upon a basement membrane. At the initiation of meiosis the oogonium becomes an oocyte, extending into the ovarian lamella. If oogonia divide mitotically prior to entering meiosis, a cell nest is produced that is attached to the basement membrane. All oocytes within a cell nest eventually become follicles composed of the oocyte and encompassing layer of follicle cells that are derived from the original epithelial cells of the germinal epithelium. As the oocyte matures, an acellular chorion forms between the oocyte and the follicle cells. Primary oocytes possess a RNA-rich cytoplasm (gray area), whereas mature oocyte cytoplasm has cortical alveoli, lipid yolk, and protein yolk. The follicle is surrounded by the basement membrane, derived from that supporting the germinal epithelium, and a vascularized theca that is divided into a theca interna and theca externa. Undifferentiated cells within the extravascular space, the prethecal cells, form the theca interna and externa.

Figure 3. The process of oocyte maturation begins with a diplotene oocyte that enters the primary growth stage. The cytoplasm becomes basophilic due to the accumulation of RNA. Nucleoli become oriented around the periphery of the nucleus (perinucleolar stage), lipid yolk (L Stage), and cortical alveoli form during primary growth. During secondary growth or vitellogenesis, lipid yolk and protein globules (PL Stage) accumulate in the oocyte cytoplasm until the oocyte is mature (M Stage) and will respond to a gonadotropin surge from the pituitary gland, whereupon final oocyte maturation commences. Based upon easily discernable characteristics, revealed by using the coverslip method, final oocyte maturation has been subdivided into four substages (Neidig et al., 2000). These are: (1) Final Maturation-1 (FM-1), where lipids fuse into larger, distinct globules; Final Maturation-2 (FM-2), where there is a single oil globule, but no apparent "clearing" of the oocyte cytoplasm; Final Maturation-3 (FM-3), where protein yolk begins to liquify and the cytoplasm becomes clear; and Final Maturation-4 (FM-4), where the cytoplasm is completely clear and the oocyte is preovulatory. Prior to ovulation, the first meiotic division is completed; the oocyte progresses to metaphase of the second meiotic division and again rests in development. The oocyte ovulates and becomes an egg, losing its encompassing layer of follicle cells in the process. These remain in the ovarian lamellae as a post-ovulatory follicle.

Figure 4. Diagramatic representation of annual testis cycling in fish. The testis cycles between mitosis-dominated (late maturation, regression and regressed classes) or meiosis-dominated (early maturation, mid maturation, late maturation classes) cell division. Mitosis-domination represents renewal of diploid spermatogonia, whereas meiosis domination cell division represents spermatogenesis and haploid sperm production.

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LITERATURE CITED

Begovac, P.C. and R.A. Wallace. 1987. Ovary of the pipefish, *Syngathus scovelli*. *Journal of Morphology* **193**:117-133.

Begovac, P.C. and R.A. Wallace. 1988. Stages of oocyte development in the pipefsh, Sygnathus scovelli. *Journal of Morphology* **197**:353-369.

Brown-Peterson, N.J., J.S. Franks, and A.M. Burke. 2000. Preliminary observations on the reproductive biology of wahoo, Acanthocybium solandri, from the northern Gulf of Mexico and Bimini, Bahamas. *Proceedings of the Gulf and Caribbean Fisheries Institute* **51**:414-427.

Brown-Peterson, N.J., H.J. Grier, and R.M. Overstreet. [In press]. Annual changes in the germinal epithelium determine male reproductive classes of cobia, *Rachycentron canadum*. *Journal of Fish Biology*.

Brown-Peterson, N.J., P. Thomas, and C.R. Arnold. 1988. Reproductive biology of the spotted seatrout, *Cynoscion nebulosus*, in south Texas. *Fisheries Bulletin* **86**:373-388.

Brown-Peterson, N.J. and J.W. Warren. 2001. The reproductive biology of spotted seatrout, *Cynoscion nebulosus*, along the Mississippi gulf coast. *Gulf of Mexico Science* **2001**:61-73.

Grier, H.J. 1993. Comparative organization of Sertoli cells including the Sertoli cell barrier. Pages 704-730 in: Russell, L. D. and M.D. Griswold (eds.) *The Sertoli Cell*. Cache River Press, Florida.

Grier, H.J. 2000. Ovarian germinal epithelium and folliculogenesis in the common snook, *Centropomus undecimalis* (Teleostei: Centropomidae). *Journal of Morphology* **243**:265-281.

Grier, H.J. and F. Lo Nostro. 2000. The teleost germinal epithelium: a unifying concept. Pages 233 – 236 in: B. Norberg, O.S. Kjesbu, G.L. Taranger, E. Andersson, S.O. Stefansson, (eds.) *Proc. 6th International Symposium on the Reproductive Physiology of Fish*. Institute of Marine Research and University of Bergen, Bergen, Norway. July 1999.

Grier, H.J. and R.G. Taylor. 1998. Testicular maturation and regression in the common snook. *Journal of Fish Biology*. 53:512-542.

Grier, H.J., R.G. Taylor, and R.O. Reese. 1987. The mechanism of tubule elongation during testicular recrudescence in the redfish, Sciaenops ocellatus (Perciformes). Pages 285-291 in: S.O. Kullander and B. Fernholm (eds.) *Proceedings of the V Congress of European Ichthyologists*. Swedish Museum

of Natural History, Stockholm, Sweden. 1985.

Lo Nostro, F., Grier, H.J., L. Andreone, and G.A. Guerrero. [In review]. Role of the gonadal germinal epithelium during both sex reversal and seasonal testicular changes in the protogynous swamp eel, Synbranchus marmoratus Bloch, 1795 (Teleostei, Synbranchidae).*Journal of Morphology*.

Neidig, C.L., D.P. Skapura, and H.J. Grier. 2000. Techniques for spawning common snook: broodstock handling, oocyte staging, and egg quality. *North American Journal of Aquaculture* **62**:103-113.

Pelliniemi, L.K.J., K. Frojdman, and J. Paranko. 1993. Embryological and prenatal development and function of Sertoli cells. Pages 87 – 113 in: L.D. Russell and M.D. Griswold (eds.) *The Sertoli Cell*. Cache River Press. Florida.

Ross, M.H., L.J., Romrell, and G.I. Kaye. 1995. *Histology, a Text and Atlas, 3rd ed.* Williams and Wilkins. Baltimore, Maryland USA. 58pp.

Selman, K. and R.A. Wallace. 1989. Cellular aspects of oocyte growth in teleosts. *Zoological Science* **6**: 211-231.

Selman, K., R.A. Wallace, and D. Player 1991. Ovary of the seahorse, Hippocampus erectus. *Journal of Morphology* **209**:285-304.

Taylor, R.G., H.J. Grier, and J.A. Whittington. 1998. Spawning rhythms of common snook in Florida. *Journal of Fish Biology* **53**: 502-520.

Tokarz, R.R. 1978. Oogonial proliferation, oogenesis and folliculogenesis in nonmammalian vertebrates. Pages 145-179 in: R.E. Jones (ed.) *The Vertebrate Ovary*. Plenum Press New York, New York USA.

Tyler, C.R. and J.P. Sumpter 1996. Oocyte growth and development in teleosts. *Reviews in Fisheries Biology* **6**:287-318.

Wallace, R.A., and K. Selman. 1981. Cellular and dynamic aspects of oocyte growth in teleosts. *American Zoologist* **21**:325-343.

A Review of Age, Growth, and Reproduction of Cobia, *Rachycentron canadum*, from U.S. Waters of the Gulf of Mexico and Atlantic Ocean

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ABSTRACT

A review of available scientific information on the age, growth, and reproduction of cobia, *Rachycentron canadum*, from United States waters of the Gulf of Mexico and Atlantic Ocean is provided. Periodicity of annulus formation on sectioned sagittae has been partially validated by marginal-increment analysis, and age in years is estimated as the number of observed opaque bands. Growth in length for both sexes is rapid through age 2. Females grow faster and live longer than males and dominate all age groups. Gulf males reached age 9 and 1,390 mm FL; females reached age 11and 1,651 mm FL. Atlantic males reached age 14 and 1,360 mm FL; females reached age13 and 1,420 mm FL. Estimates of the von Bertalanffy growth parameters (L_∞, K, and t_0) within studies showed significant differences in L_∞ and K for the sexes, whereas estimates for t_0 were not always significantly different. Ages 2 - 5 dominated the age structure of Gulf and Atlantic samples. Cobia were fully recruited to the northeastern Gulf recreational fishery at age 4, and the instantaneous rate of total mortality (Z) estimated for fully recruited cobia ages 4 - 8 was 0.75. Cobia have an extended spawning season throughout their range in United States waters, averaging five months (mid-April-August) in the Atlantic Ocean and six months (April-September) in the Gulf of Mexico. Some Gulf females appear to cease spawning by July. Female cobia can obtain sexual maturity as small as 700 mm FL. Histological analysis shows cobia are a multiple spawning species; females are estimated to spawn once every five days throughout most of the U.S. region. Batch fecundity increases significantly with FL and ovary-free body weight (OFBW); mean relative batch fecundity is 53.1 ± 9.4 eggs/g OFBW. While the testis of males contain sperm year-round, spermatogenesis only takes place from February - August, and spermatogonial proliferation is observed during non-spawning months.

KEY WORDS: *Rachycentron canadum*, age, growth, reproduction

INTRODUCTION

Cobia, *Rachycentron canadum*, are large, coastal pelagic fish of the monotypic family Rachycentridae and are distributed worldwide in tropical and subtropical seas, except for the eastern Pacific (Shaffer and Nakamura 1989). In the western Atlantic Ocean, cobia occur from Massachusetts and Bermuda to Argentina (Briggs 1960) but are most common along the United States (U. S.) Atlantic coast and in the northern Gulf of Mexico (Shaffer and Nakamura, 1989). In the Gulf of Mexico, cobia range from Key West, Florida and along the entire coast to Campeche, Mexico (Dawson 1971). In this paper, reference will be made to the U.S. Gulf of Mexico and Atlantic Ocean as Gulf and Atlantic, respectively.

Cobia are migratory fish, and in the eastern Gulf cobia typically migrate from their wintering grounds off south Florida into northeastern Gulf waters during early spring. Cobia occur off northwest Florida, Alabama, Mississippi and southeast Louisiana from late-March through October and return to the wintering grounds in the fall (Franks et al. 1999, Biesiot et al. 1994). However, Howse et al. (1992) reported that some cobia over-winter in the northern Gulf at depths of 100 - 125 m. Cobia move along the U.S. east coast as far north as the Chesapeake Bay during summer, then presumably migrate to south Florida, although it is unclear where cobia from the U.S. Atlantic overwinter (Smith 1995). Timing of the migrations appears related to spawning and possibly to the availability of important prey species.

Cobia is a highly-prized recreational species in the Gulf and Atlantic and is caught incidentally in several commercial fisheries (Shaffer and Nakamura 1989). Recreational and commercial regulations for cobia in U. S. waters consist of a minimum size of 838 mm fork length (33 inches) and daily bag and possession limits of 2 fish per person (GM&SAFM, 1990). The cobia catch (commercial and recreational) from the Gulf and Atlantic, combined, averaged 1 million kg per year during a recent 14 - year period (1984-97, Scott and Phares, 1999). The recreational catch averaged ~90 % of the total harvest for the 14-year period, and the majority (~70%) of that catch came from the Gulf with an average of 0.63 million kg per year (Scott and Phares 1999).

At the present time, there are not enough data to determine the status of the cobia fishery. The Gulf of Mexico Fishery Management Council is in the process of conducting an assessment of the cobia stock in the Gulf waters. An MSY of 2.2 million pounds (1 million kg; Gulf and Atlantic, combined) currently is substituted in the preliminary assessments in place of unavailable information on the spawning potential ratio (SPR, Scott and Phares 1999). More information on harvest levels, SPR, bycatch, and recruitment are needed to better assess the stocks.

The purpose of this paper is to provide a review of current information on age, growth, and reproductive biology of cobia from waters of the United States. We intend that our present contribution build upon and supplement the FAO cobia synopsis published by Shaffer and Nakamura (1989). All references for this review reported on cobia sampled primarily from the recreational fishery. Readers are advised to consult the primary sources for information on methods and detailed

descriptions of each study.

SIZE, AGE, AND GROWTH OF COBIA

Size Composition

Even though most specimens were sampled from the recreational fishery, most authors believed their samples were not biased towards larger fish, since samples typically consisted of a large number of fish representing a broad size range.

Table 1 summarizes the weight and length ranges reported by the various studies. Cobia from the Gulf tended to be larger than those from the Atlantic, although the minimum size of males and females were similar in most studies.

Table 1. Size range and mean size of cobia, *Rachycentron canadum*, sampled in U.S. Gulf of Mexico and south Atlantic studies.

			Length (FL, mm)		Weight (TW, kg)		
Area	Sex	*n*	Range	Mean	Range	Mean	Reference
Virginia	M	155	- -1194	–	- -19.0	–	Richards
	F	98	- -1377	–	- -34.0	–	(1967)[2]
North	M	174	390 -1360	–	0.5-32.0	–	Smith
Carolina	F	182	440 -1420	–	0.7-32.2	–	(1995)[1]
Carolinas	M	28	801 -1,130	950.7	5.9 - 9.8	11.40	Burns et al.
	F	45	941 -1,380	1,155.7	10.0-34.9	20.47	(1998)[1]
FL Atlantic	M	28	830 -1,130	960.0	5.8-20.9	11.53	"
	F	55	830 -1,290	1,000.8	6.8-25.9	12.79	
FL Keys	M	20	701 -1,000	86.2	3.9 - 8.2	6.67	"
	F	28	700 -1,060	86.0	3.2-19.5	7.98	
FL Gulf	M	41	361 -1,220	760.6	0.2-26.3	6.72	"
	F	75	351 -1,270	820.3	0.8-25.4	9.16	
Northeastern	M	66	380 -1,390	970.3	0.3- 4.4	10.01	"
Gulf	F	216	370 -1,631	1,050.4	0.3- 8.4	15.45	
Northeastern	M	275	345 -1,450	952.0	0.3-29.0	10.5	Franks et al.
Gulf	F	730	335 -1,651	1,050.0	0.3-62.2	16.6	(1999)
Western	M	464	528 -1,432	–	1.5-30.8	–	Thompson
Louisiana	F	218	358 -1,445	–	1.0-45.6	–	et al. (1992)
Texas	M	20	310 -1,050	950.8	–	–	Burns et al.
	F	61	311 -1,280	950.8			(1998)[1]

[1] FL lengths originally reported in centimeters, converted to millimeters
[2] FL reported in inches (converted to mm), TW reported in pounds (converted to kg)
- = not reported

Size Relationships

Regressions to predict FL from TL and TL from FL are shown in Table 2. Relationships were calculated using the linear regression models: FL = a + bTL and TL = a + bFL. The slopes of the regressions did not differ significantly between males and females for any study, and all reported $r^2 \geq 0.95$.

Length-weight relationships between males and females did not differ significantly for any of the studies, although females were typically larger than males. Length-weight regressions, using log-transformed (base 10) data, were calculated to predict TW from FL (Table 2). While all regressions were statistically significant, the strength of the relationship varied from $r^2 = 0.51$ for female cobia in the Carolinas (Burns et al., 1998) to $r^2 = 0.98$ for sexes combined in North Carolina (Smith, 1995).

Annulus Formation

Richards (1967) used scales to age cobia, whereas Thompson et al. (1992), Smith (1995), Burns et al. (1998), and Franks et al. (1999) aged cobia based on analysis of transverse-sectioned sagittal otoliths. Based on marginal increment analysis, cobia appear to form a single annulus on sagittae each year during spring - summer (Thompson et al. 1992, Smith 1995, Burns et al. 1998, Franks et al. 1999). Thus, age in years for cobia is presumed equal to the number of opaque bands observed in sectioned sagittae. Although the periodicity of annulus formation on otoliths coincides with the cobia spawning season in the northern Gulf (Burns, et al. 1998, Brown-Peterson et al. 2001) and off the U.S. east coast (Smith 1995), annulus deposition may be more related to cobia migrations, at least in the northern Gulf in spring (Franks et al. 1999). Franks et al. (1999) reported that sagittae of several sexually mature cobia sampled in March and April (early part of the spawning season) already showed distinctive opaque bands, as did sexually immature fish in spring. Thus reproduction may not be the sole determining factor related to annulus formation; environmental and physiological factors should not be discounted.

Estimated Age

Some studies provided age-length keys for both sexes to provide estimates of the age structure of cobia from the respective U.S. regions. Richards (1967) developed age-length keys from back-calculated size-at-age data, while Burns et al. (1998) and Franks et al. (1999) used observed ages at lengths to derive age-length keys.

Typically there was a wide range of lengths within most age groups for both sexes of cobia, e.g., Franks et al. (1999) found that males within a 1,000- 1,050 mm size group ranged from ages 2 to 7 and within a 1,200 - 1,250 mm FL group ranged from ages 4 to 9. Females within a 1,350 - 1,400 mm FL group ranged from ages

5 to 9. This variation in size makes it difficult to precisely estimate the age of cobia from length alone. Franks et al. (1999) reported the largest cobia by weight in their sample weighed 62.2 kg, which was slightly greater than the all-tackle world record weight for cobia (61.5 kg) reported by the International Game Fish Association (1997). However, at a FL of 1,610 mm and age 8, this specimen was neither the longest nor the oldest in their sample. A prolonged spawning season and multiple spawns characteristic of cobia (Lotz et al., 1996; Brown-Peterson et al., 2001) probably account for the wide variation in size of young-of-the-year cobia and, in part, for other age groups as well.

Table 2. Length-length, length-weight, and otolith weight-age regressions for cobia, *Rachycentron canadum*, from U.S. waters. FL = fork length (mm), TL = total length (mm), WT = total weight (kg), OTWT = otolith weight (g), and AGE = age in years. Values in parentheses are standard errors. M = male, F = female.

			Y = a + bX			
Area	**Y**	**X**	**a**	**b**	**r^2**	**Reference**
Virginia	log_{10}WT	log_{10}FL	-3.51	3.08		Richards (1967)[1]
No. Carolina	TL	FL	-0.9	1.10	0.99	Smith (1995)[1]
No. Carolina	log_{10}WT	log_{10}FL	-13.0	3.40	0.98	"
Carolinas	"	"	(M) 0.10	2.86	0.86	Burns et al. (1998)[1]
			(F) 0.24	2.55	0.51	
Florida Atlantic	"	"	(M) 0.0001	2.89	0.79	"
			(F) 0.021	3.55	0.82	
Florida Gulf	"	"	(M) 0.006	3.42	0.90	"
			(F) 0.002	3.15	0.90	
Northeastern Gulf	"	"	(M) 0.37	3.07	0.89	"
			(F) 0.001	2.22	0.77	
Northeastern Gulf	FL	TL	9.9494	0.8916	0.98	Franks et al. (1999)
			(3.5691)	(0.0032)		
	TL	FL	1.8861	1.1088	0.98	
			(3.9964)	(0.0040)		
Northeastern Gulf	log_{10}WT	log_{10}FL	-9.2445	3.4287	0.97	"
			(0.6474)	(0.0215)		
Northeastern Gulf	Age	OTWT	(M) 0.0081	0.0072	0.78	"
			(0.0012)	(0.0003)		
			(F) 0.0006	0.0110	0.84	
			(0.0010)	(0.0003)		
Western Louisiana	FL	TL	0.87	0.94	0.98	Thompson et al. (1992)
	TL	FL	1.13	0.57	0.98	
Western Louisiana	log_{10}WT	log_{10}FL	3.80	3.24	0.97	"
Western Louisiana	Age	OTWT	(M)0.09	0.31	0.82	"
			(F) 0.08	0.36	0.81	

[1] Lengths originally reported in centimeters, converted to millimeters

Table 3 shows the mean observed length-at-age for male and female cobia reported by studies conducted in the U.S. Atlantic (2, Carolinas) and the Gulf of Mexico (2, NEGOM). These studies provide for a comparison of mean FL-at-age within and between the two regions and were selected because samples from the studies contained the greatest number of specimens used for age estimations among all available cobia studies. Burns et al. (1998) and Franks (1999) reported similar mean length-at-age for their respective samples of male and female cobia from the NEGOM as well as for cobia of both sexes from the Carolinas that were age 4 or less (Burns et al. 1998). However, mean length-at-age reported by Smith (1995) for male and female cobia was, with few exceptions, less than that reported by Burns et al. (1998) and Franks et al. (1999) for every comparable age class. The studies indicate that Gulf cobia reach a greater length than cobia of comparable age from the U.S. Atlantic but that Atlantic cobia live longer.

Maximum ages of cobia from Louisiana (Thompson et al. 1992; males, 10; females, 10) and Virginia (Richards 1967, 1977; males, 10; females, 9) were similar to the findings of Franks et al. (1999) (males, age 9; females, age 11) for the northeastern Gulf of Mexico (NEGOM). However, Burns et al. (1998) reported the oldest male and female cobia in their NEGOM sample as 8 and 6 years, respectively. Smith (1995) reported a maximum age of 14 for male and age 13 for female cobia from North Carolina and commented that erosion on scale edges may have caused Richards (1967) to underestimated the ages of Virginia cobia. Burns et al. (1998) reported three age-11, one age-12, and one age-13 fish from the Carolinas. Additionally, there was a slightly higher percentage of females greater than six years old from the Carolinas than for other Gulf and Atlantic regions (Burns 1998). In general, cobia off the U.S east coast appear to live longer than their Gulf counterparts. Interestingly, the results of cobia tagging programs have shown that there is a mixing of cobia between the Gulf and Atlantic (Franks et al. 2000), and yet no fish older than age 11 have been sampled in the Gulf.

All studies reported that mean observed lengths at age for females were larger than those for males for age classes 1 and greater. Additionally, longevity of male and female cobia appears to differ. Richards (1967, 1977), Thompson et al. (1992), and Franks et al. (1999) found that males older than age 7 and females older than 8 were rare. Smith (1995) sampled few males and females greater than age 10, and Burns et al. (1998) reported a general trend among all regions (Gulf and U.S. Atlantic) they sampled which showed, with the slight exception of the Carolinas, few males and females older than age 7.

Predicted age

Thompson et al. (1992) and Franks et al. (1999) reported otolith weight was significantly related to cobia age (Table 2). Franks et al. (1999) found the slopes of the otolith weight-age regressions to be significantly different for males and females ($P < 0.0001$).

Table 3. Mean observed fork length (mm) for male and female cobia, *Rachycentron canadum*, from the U.S. Gulf of Mexico and south Atlantic Ocean. M = Male, F = Female. Numbers in parentheses are ± 1SE.

Age	North Carolina[1]				Carolinas[2]				NEGOM[3]				NEGOM[4]			
(yr)	*n*	M	*n*	F	*n*	M	*n*	F	*n*	M	*n*	F	*n*	M	*n*	F
0									1	380	3	487	5	439 (30)	28	409 (8)
1	6	500 (4)	3	550 (4)	3	850			2	656	3	883	14	705 (26)	28	720 (22)
2	22	740 (2)	18	810 (3)	7	924	2	948	10	919	61	981	47	885 (9)	103	956 (8)
3	41	820 (1)	50	890 (1)			1	1130	31	984	67	1075	47	971 (10)	116	1056 (7)
4	32	880 (1)	23	1020 (2)			3	1037	10	1020	32	1166	35	1034 (14)	64	1140 (10)
5	20	920 (1)	13	1060 (1)	2	1010	6	1003	2	1065	16	1221	16	1070 (17)	31	1248 (18)
6	7	950 (2)	20	1110 (2)	6	1028	6	1119	5	1156	12	1313	1	1140	7	1346 (38)
7	6	1000 (2)	11	1170 (2)	2	1032	5	1230	1	1100			3	1198 (87)	5	1385 (44)
8	8	990 (2)	8	1230 (2)	1	985	6	1263	1	1025					8	1553 (27)
9	6	1070 (6)	7	1250 (2)	1	1050	6	1199					2	1250 (10)	3	1507 (70)
10	5	1050 (1)	3	1270 (5)											1	1613
11	6	1050 (2)					3	1357							1	1566
12			3	1270 (2)												
13	1	1130	2	1380 (4)			1	1320								
14	1	1060														

[1]Smith (1995)
[2]Burns et al. (1998)
[3]Northeastern Gulf, Burns et al. (1998)
[4]Northeastern Gulf, Franks et al. (1999)

The von Bertalanffy growth equation $FL_t = L_\infty(1\text{-}\exp[-K(t\text{-}t_0)])$ described the relationship between observed FL and age. Parameter estimates for this growth model are provided in Table 4. A significant difference in the overall von Bertalanffy growth models for males and females was reported by all studies and indicated that females achieved a greater theoretical asymptotic length and grew at a faster rate than males. Franks et al. (1999) reported that likelihood-ratio tests also showed that estimates of L_∞ and K were significantly different between sexes, although t_o was not significantly different.

Theoretical growth coefficients (L_∞ and t_o) reported by Thompson et al. (1992) for cobia from Louisiana were smaller than estimates reported by Franks et al. (1999) and Burns et al. (1999) for the NEGOM (Table 4). However, the estimates of K were larger in Louisiana (Thompson, 1992) than those reported by Franks et al. (1999) for both sexes and by Burns et al. (1998) for females in the NEGOM.

Asymptotic lengths for males and females taken off Virginia (Richards, 1977) were considerably larger than L_∞ values reported by Smith (1995), Thompson et al. (1995), Franks et al. (1999), and Burns et al. (1998), with the exception of male cobia from the Florida Keys and female cobia from Texas. Asymptotic length reported by Franks et al. (1999) for NEGOM males was similar to that reported for NEGOM males by Burns et al (1998), although Franks et al. (1999) reported somewhat larger lengths for females.

Overall, cobia from the Gulf appear to grow faster than those from Atlantic waters, however cobia off the Atlantic exhibit greater longevity than Gulf cobia. The differences in estimates of growth coefficients for cobia throughout their range in U.S. waters may be due to differences in geographical coverage (Franks et al. 1999) or methodological differences, e.g. sectioned otoliths verses scales. Franks et al. (1999) concluded that growth parameter estimates from their NEGOM study were appropriate for use in stock assessment studies of cobia from the NEGOM. Predicted lengths-at-age derived by the von Bertalanffy equations generally were in close agreement with observed lengths for all ages, and predicted lengths of females were greater than those of males for all ages (Thompson 1992, Smith 1995, Burns 1998, Franks 1999). All studies showed that growth in length for both sexes was relatively fast through age 2, after which growth slowed gradually.

Age Structure, Catch Curve Analysis, and Mortality

Ages 2-5 dominated the age structure of Gulf and Atlantic collections of cobia, with the exception of that of Smith (1995) who reported that 6 year-old fish also comprised a substantial portion of his sample. Franks et al. (1999) used age-length keys (male/female) to develop an estimate of the age structure of the NEGOM cobia recreational fishery (only fish greater than regulation size, ≥838 mm FL) from 1987 - 1995 and reported that ages 2 - 4 represented 85% of the catch (age 3 = 37%) and ages 5-11 represented 15%. Burns et al. (1998) found ages 3 - 5 dominated their NEGOM collections, and Thompson et al. (1992) reported that the western Louisiana sample was dominated by 2 - 4 year old cobia (75% of the sample). Thompson et al. (1992) and Franks et al. (1999) believed their sample represented

the cobia recreational fishery in their respective areas at the time their studies were conducted.

Richards (1977) reported the total mortality for cobia off Virginia during the late 1960's might be excessive and suggested that a catch limit might be desirable. While there is no current estimates of fishing mortality for Virginia cobia (Mills, 2000), monitoring of the cobia fishery in Chesapeake Bay could provide data needed for effective future management of the fishery in that area.

Instantaneous total mortality estimated for NEGOM cobia using catch curve analysis of fish fully recruited into the fishery (Franks et al. 1999) showed that the age at full recruitment to the fishery was age 4. The instantaneous rate of total mortality (Z) estimated by catch curve analysis for ages 4 - 8 was 0.75 (Franks et al. 1999). Although Franks et al. (1999) believed their estimate of Z was reliable, several authors (Rounsefell and Everhart 1953, Johnson et al. 1983, Manooch et al. 1987) caution against using catch curves to predict mortality for migratory pelagic species. A fairly broad age structure and low value for Z suggest that the NEGOM population of cobia is reasonably healthy (Franks et al. 1999).

REPRODUCTIVE BIOLOGY

Sex ratio

In general, most studies found a higher percentage of females than males in their samples. The exception is Smith (1995) who found a 1:1ratio in North Carolina. Along the Gulf of Mexico, Thompson et al. (1992) reported an overall sex ratio of 1:2.1 that was skewed towards males, whereas, Franks et al. (1999) reported a predominance of females (2.7:1). Since both studies were conducted concurrently in the northern Gulf, it is difficult to explain the discrepancy, except to suggest differential segregation or a higher mortality for males east of the Mississippi River delta. Burns et al. (1998) reported an overall ratio (all areas sampled) of 2.2:1 (female:male), but noted an overwhelming number of females in the NEGOM sample (3.3:1).

Size and age at sexual maturity

Historically, few small and immature cobia of either sex have been captured due to a minimum retention size in state territorial waters and the EEZ. Thus, accurate estimates of length or age at 50% maturity cannot be made. However, reports of the smallest sexually mature male cobia observed vary from 365 mm FL and age 0 in the eastern Gulf of Mexico (Brown-Peterson et al. 2001) to 640 mm FL and age 1 in the north central Gulf of Mexico (Lotz et al. 1996). Age estimates of mature male cobia from Louisiana (Thompson et al. 1992), North Carolina (Smith 1995) and Virginia (Richards 1967) show that most males have reached sexual maturity by age 2. In contrast, females appear to reach sexual maturity at a larger size and older age. The smallest reported sexually mature female cobia range from 700 mm FL and age 1 in the eastern Gulf of Mexico (Brown-Peterson et al. 2001) to 834 mm FL and age 2 in the north central Gulf of Mexico (Lotz et al. 1996).

Table 4. Parameter estimates for the von Bertalanffy growth model for cobia Rachycentron canadum from U.S. waters. Values shown in parentheses are standard errors.

Area	Sex	n	L_∞ (mm)	K	t_0	r^2	Structure	Reference
Virginia	M	–	1,210	0.28	-0.06	–	scales	Richards (1967)[1]
	F	–	1,640	0.23	-0.08			
North Carolina	M	116	1,050	0.37	-1.08	–	otoliths	Smith (1995)[1]
			(185)	(0.04)	(0.29)			
	F	92	1,350	0.24	-1.53	–		
			(3.82)	(0.03)	(0.39)			
Carolinas	M	22	1,046	0.536	-1.085	–	"	Burns et al. (1998)[1]
	F	39	1,622	0.085	-8.596			
FL Atlantic	M	24	1,138	0.195	-5.681	–	"	"
	F	46	1,651	0.075	-7.674			
FL Keys	M	17	1,170	0.230	-3.846	–	"	"
	F	21	1,333	0.182	-4.664			
FL Gulf	M	37	1,225	0.294	1.347	–	"	"
	F	72	1,302	0.245	1.551			
Northeastern Gulf	M	63	1,132	0.550	-0.759	–	"	"
	F	194	1,302	0.461	-0.968			
Northeastern Gulf	M	170	1,170	0.432	-1.150	0.78	"	Franks et al. (1999)
			(28.08)	(0.046)	(0.173)			
	F	395	1,555	0.272	-1.254	0.87		
			(35.14)	(0.017)	(0.092)			
Western Louisiana	M	–	1,132	0.49	-0.49	–	"	Thompson et al. (1992)
	F	–	1,294	0.56	0.11			
Texas	M	29	929	1.43	-0.395	–	"	Burns et al. (1998)[1]
	F	41	1,830	0.125	-3.621			

[1] L_∞ estimates originally reported in centimeters, converted to millimeters;
- = not reported by author(s).

Female cobia appear to reach sexual maturity during their second year in Louisiana (Thompson et al. 1992) and North Carolina (Smith 1995) but not until age 3 in Virginia (Richards 1967). The differences in reported first size and age at maturity could be related to actual geographical differences or to differences in ageing techniques. Overall, it appears that males > 650 mm FL and females > 800 mm FL probably have reached sexual maturity.

Spawning Season and Gonadal Maturation

Cobia have an extended spawning season throughout their range. The spawning season has been documented using various methods, including the gonadosomatic index (GSI), observations of ovarian histology, and collection of eggs or young larvae. Table 5 summarizes the reported information on the duration of the spawning season. In general, cobia spawn during the spring and summer throughout their range. Increases in GSI values and histological observations of vitellogenic oocytes suggest that cobia are in spawning condition by April in the northern Gulf of Mexico (Thompson et al. 1992, Biesiot et al. 1994, Lotz et al. 1996, Brown-Peterson et al. 2001).

Table 5. Summary of cobia spawning seasons in United States waters.

Region	Spawning Season	Method	Reference
Virginia	June - August	GSI, histology	Joseph et al, 1964; Richards, 1967
Virginia	June - August	egg, larval collections	Joseph et al, 1964; Mills, 2000
North Carolina	May - July	GSI	Smith, 1995
North Carolina	May - August	egg, larval collections	Hassler and Rainville, 1975; Smith, 1995
South Carolina	May - August	egg, larval collections	Shaffer and Nakamura, 1989
North central Gulf of Mexico	April - September	GSI, histology	Biesiot et al., 1994; Lotz et al., 1996; Brown-Peterson et al., 2001
North central Gulf of Mexico	May - September	egg, larval collections	Ditty and Shaw, 1971
Louisiana	April - August	GSI, histology	Thompson et al., 1992
Texas	May - September	egg, larval collections	Baughman, 1950; Finucane et al. 1978

The peak spawning time was variously reported as April (Biesiot et al. 1994), May (Lotz, et al. 1996), June (Thompson et al. 1992) and May through July (Brown-Peterson et al. 2001). While the spawning season appears to extend for six months in the northern Gulf of Mexico, the percentage of females in reproductive condition by September is greatly reduced (Brown-Peterson et al. 2001). However, collection of cobia eggs and young larvae from May through September throughout the northern Gulf of Mexico (Ditty and Shaw 1971, Finucane et al. 1978) confirm the six month spawning season in the region.

Cobia along the Atlantic coast of the southeastern United States have a shortened reproductive season relative to Gulf of Mexico fish (Table 5). Smith (1995) reported a May through July spawning season in North Carolina, with a peak in June, based on GSI values. Egg and larval collections from North and South Carolina (Hassler and Rainville 1975, Smith 1995, Shaffer and Nakamura 1989) confirm a four month, May through August, spawning season. However, Brown-Peterson et al. (2001) reported that cobia from Morehead City, North Carolina to Cape Canaveral, Florida were in reproductive condition by April based on histological observations. Cobia in the Chesapeake Bay, Virginia region appear to have a June through August reproductive season, based on GSI values (Joseph et al. 1964), ovarian observations (Richards, 1967) and collections of eggs and larvae (Joseph et al. 1964, Mills, 2000).

Some female cobia in the northern Gulf of Mexico do not appear capable of spawning during the entire six month reproductive season. Female cobia with ovaries in the spent and regressed classes were observed in July and August during the course of several studies (Thompson et al. 1992, Biesiot et al. 1994, Lotz et al. 1996, Brown-Peterson et al. 2001). Similarly, some cobia were not in spawning condition until May or June (Brown-Peterson et al. 2001). This phenomena has not been reported along the Atlantic coast of the southeastern United States, which may be a result of the shorter reproductive season in that area.

Histological observations of male cobia suggest that spermatogonial proliferation and spermatogenesis is a year-round process (Brown-Peterson et al. in review). Spermatogonial proliferation takes place from the end of the reproductive season in September until the beginning of the next season in April while spermatogenesis occurs from February through August. Although male cobia always contained sperm in the testis (Brown-Peterson et al. 2001; in review), and may be capable of year-round spawning, females were only found in the late developing ovarian class from April through September.

Cobia are capable of spawning several times during the reproductive season. While multiple spawning was first proposed by Richards (1967), Brown-Peterson et al. (2001) were the first to provide definitive evidence of multiple spawning in the form of post ovulatory follicles (POF) in the ovaries of fish with fully mature, vitellogenic oocytes. Additional evidence of multiple spawning is ovaries containing oocytes undergoing final oocyte maturation (FOM) concurrent with fully mature, vitellogenic oocytes (Lotz et al. 1996, Brown-Peterson et al. 2001).

Spawning Location

Definitive information on the location of cobia spawning is lacking. In the northern Gulf of Mexico, no cobia with hydrated oocytes have been captured (Thompson et al. 1992, Lotz et al. 1996, Brown-Peterson et al. 2001), suggesting that sampling does not occur around spawning locations. Several cobia with hydrated oocytes have been captured from the Chesapeake Bay, Virginia area (J. Olney, VIMS, pers. comm.). The location of these captures corresponds with collections of eggs and larvae, suggesting that cobia in Chesapeake Bay spawn at the mouth of the Bay and immediately offshore of the Virginia Capes (Joseph et al. 1964, Mills, 2000). Egg and larval collections from North Carolina suggests spawning near inlets (Smith 1995) as well as 25 to 50 km offshore (Hassler and Rainville 1975). Offshore spawning was also indicated in South Carolina (Shaffer and Nakamura 1989) as well as throughout the northern Gulf of Mexico (Baughman 1950, Dawson 1971, Finucane et al. 1978, Ditty and Shaw 1982). However, collections of newly spawned eggs and recently hatched larvae in Crystal Bay, Florida (Ditty and Shaw 1982) suggest cobia may also spawn inshore in 6 m of water in the northern Gulf of Mexico. Overall, few eggs or larvae have been obtained in any collections, leading to further confusion regarding the exact location of cobia spawning.

Batch Fecundity and Spawning Frequency

Early reports of cobia fecundity were inaccurate, as they attempted to estimate the fecundity of a multiple spawning fish by counting all vitellogenic oocytes rather than just hydrated oocytes (Richards 1967, Lotz et al., 1996). The lack of cobia containing hydrated oocytes resulted in Brown-Peterson et al. (2001) using cobia with oocytes undergoing FOM for estimates of batch fecundity. Fecundity was determined by counting all oocytes > 700 μm using the volumetric method and by counting the number of oocytes undergoing FOM in histological sections. Batch fecundity was significantly, positively related to both fork length and ovary-free body weight (OFBW). Mean batch fecundity estimates were not significantly different among methods and varied from 377,000 ± 64,500 to 1,980,500 ± 1,598,500 eggs (Brown-Peterson et al. 2001). Relative batch fecundity was not significantly different among months during the spawning season and averaged 29.1 ± 4.8 eggs/g OFBW for the histological method and 53.1 ± 9.4 eggs/g OFBW for the volumetric method (Brown-Peterson et al. 2001). These relative batch fecundity values compare favorably with those of other pelagic species such as wahoo (*Acanthocybium solandri*, Brown-Peterson et al. 2000), tripletail (*Lobotes surinamensis*, Brown-Peterson and Franks, in press), southern bluefin tuna (*Thunnus maccoyii*, Farley and Davis 1998) and yellowfin tuna (*T. albacares*, Schaefer 1996).

While the multiple spawning nature of cobia has been acknowledged for many years, actual estimates of the spawning frequency of cobia have only recently been reported. Brown-Peterson et al. (2001) examined the percentage of cobia with fully mature ovaries containing either POF or FOM and determined that cobia from the north-central Gulf of Mexico and from the Atlantic Coast of the southeastern United

States spawn once every five days. Cobia from Texas were estimated to spawn once every 9 to 12 days, although this spawning frequency was not significantly different from other areas within the Gulf of Mexico (Brown-Peterson et al. 2001). However, these estimates suggest that cobia spawn less frequently than other pelagic species such as southern bluefin tuna (Farley and Davis 1998), yellowfin tuna (Schaefer 1996), wahoo (Brown-Peterson et al. 2000) and narrow barred Spanish mackerel (*Scomberomorus commerson*, McPherson 1993).

Potential annual fecundity of cobia can be estimated by combining the batch fecundity and spawning frequency estimates. Thus, a 20 kg cobia from the north-central Gulf of Mexico may potentially spawn 20,952,000 to 38,232,000 eggs between April and September. The shorter reproductive season along the southeastern United States would result in a potential annual fecundity for the same size female of 14,200,800 to 25,912,800 eggs from mid-April through mid-August. Finally, the lower spawning frequency of cobia in Texas would result in a potential annual fecundity of the same 20 kg female of 8,730,000 to 21,240,000 eggs from April through September.

Areas of Future Research

While much has been learned about the biology of cobia during the past 20 years, there is a lack of information in several critical areas. The population age structure, growth parameters, and harvest levels of cobia warrant continued monitoring and assessment throughout its U.S. range. Accurate estimates of the size and age of sexual maturity for both male and female cobia are necessary, particularly with the increase in recreational exploitation of cobia and the development of region-wide fishery management plans. While the knowledge of spawning seasonality and gonadal maturation of cobia appears adequate, the lack of accurate information on spawning locations needs to be addressed. Additional information on batch fecundity, particularly by region, will give a better understanding of spawning stock dynamics of cobia. The fecundity values provided by Brown-Peterson et al. (2001) are a good first approximation, but are based on a relatively small sample size (N = 39) of combined samples from the Atlantic Coast of the southeastern United States (North Carolina to Florida) and the northern Gulf of Mexico (Florida to Louisiana). The striking differences in spawning frequency within the Gulf of Mexico needs to be researched further, with additional samples from all areas of the Gulf. Future biological studies of cobia in U.S. waters also should include a genetic assessment of the cobia population(s) in Gulf and U.S. Atlantic waters.

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LITERATURE CITED

Baughman, J.L. 1950. Random notes on Texas fishes, Part 11. *Texas Journal of Science* 2:242-263.

Biesiot, P.M., R M. Caylor, and J.S. Franks. 1994. Biochemical and histological changes during ovarian development of cobia, *Rachycentron canadum*, from the northern Gulf of Mexico. *Fisheries Bulletin, U. S.* **92**:686-696.

Briggs, J.C. 1960. Fishes of worldwide (circumtropical) distribution. *Copeia* 1960(3):171-180.

Brown-Peterson, N.J. and J.S. Franks. 2001. Aspects of the reproductive biology of tripletail, *Lobotes surinamensis*, in the northern Gulf of Mexico. *Proceedings of the Gulf and Caribbean Fisheries Institute* **52**:586-597

Brown-Peterson, N.J., J.S. Franks and A.M. Burke. 2000. Preliminary observations on the reproductive biology of wahoo, *Acanthocybium solandri*, from the northern Gulf of Mexico and Bimini, Bahamas. *Proceedings of the Gulf and Caribbean Fisheries Institute* **51**:414-427.

Brown-Peterson, N.J., R. M. Overstreet, J. M. Lotz, J. S. Franks, and K. M. Burns. 2001. Reproductive biology of cobia, *Rachycentron canadum*, from coastal waters of the southern United States. *Fisheries Bulletin, U.S.* **99**, in press.

Brown-Peterson, N.J., H.J. Grier and R.M. Overstreet. [In review]. Annual changes in the germinal epithelium determine reproductive classes in male cobia, *Rachycentron canadum*. *J. Fish Biol.*

Burns, K.M., C. Neidig, J.M. Lotz, and R.M. Overstreet. [1998]. Cobia *(Rachycentron canadum)* stock assessment study in the Gulf of Mexico and the South Atlantic. Final Rep.to U. S. Dep. Commer., NOAA, NMFS, Award No. NA57FF0294, Marine Fisheries Initiative (MARFIN) Prog., Mote Marine Laboratory, Sarasota, FL, var. pag.

Dawson, C.E. 1971. Occurrence and description of prejuvenile and early juvenile Gulf of Mexico cobia, *Rachycentron canadum*. *Copeia* 1960(3):171-180.

Ditty, J.G., and R.F. Shaw. 1992. Larval development, distribution, and ecology of cobia, *Rachycentron canadum* (Family:Rachycentridae), in the northern Gulf of Mexico. *Fisheries Bulletin, U. S.* **90**:668-677.

Farley, J.H. and T.L.O. Davis. 1998. Reproductive dynamics of southern bluefin tuna, *Thunnus maccoyii*. *Fisheries Buletin., U.S.* **96**:223-236.

Finucane, J.H., L.A. Collins and L.E. Barger. 1978. Ichthyoplankton/mackerel eggs and larvae. Environmental studies of the south Texas outer continental shelf. 1977. Final Rep. to Bur. Land Manage. by Natl. Mar. Fihs. Serv., NOAA, Galveston, Texas 77550 USA.

Franks, J.S., J.R. Warren, and M. Buchanan. 1999. Age and growth of cobia, *Rachycentron canadum*, from the northeastern Gulf of Mexico. *Fisheries Bulletin*, U.S. **97**:459-471.

Franks, J.S., J. Read Hendon, N.J. Brown-Peterson, and B.H. Comyns. 2000. Mississippi marine sport fish studies. Seasonal movements and migratory patterns of cobia, *Rachycentron canadum*. Project No. F-120. Annual report to the U.S. Fish and Wildlife Service, Atlanta, GA and the Mississippi

Department of Marine Resources, Biloxi, MS. (var. pag.).

Gulf of Mexico & South Atlantic Fishery Management Councils (GM&SAFMC). 1990. Amendment No. 5, fishery management plan for the coastal migratory pelagic resources (mackerels); environmental assessment and supplemental regulatory impact review. Gulf Mex. Fish. Manage. Counc., Tampa, FL and South Atlan. Fish. Manage. Counc., Charleston, South Carolina USA..

Hassler, W. W., and R. P. Rainville. 1975. Techniques for hatching and rearing cobia, *Rachycentron canadum*, through larval and juvenile stages. Univ. N.C. Sea Grant Coll. Prog., UNC-SG-75-30, Raleigh, North Carolina USA. 26 pp.

Howse, H.D., R M. Overstreet, W.E. Hawkins, and J.S. Franks. 1992. Ubiquitous perivenous smooth muscle cords in viscera of the teleost *Rachycentron canadum*, with special emphasis on liver. *Journal of Morphology* **212**:175-189.

International Game Fish Association. 1997. *World Record Game Fishes.* International Game Fish Association, Pompano Beach, Florida USA. 352 pp.

Johnson, A.G., W.A. Fable, M.L. Williams, and L.E. Barger. 1983. Age, growth, and mortality of king mackerel, *Scomberomorus cavalla*, from the southeastern United States. *Fisheries Bulletin, U.S.* **81**:97-106.

Joseph, E. B., J. J. Norcross, and W. H. Massmann. 1964. Spawning of the cobia, *Rachycentron canadum*, in the Chesapeake Bay area, with observations of juvenile specimens. *Chesapeake Science* **5**:67-71.

Lotz, J.M., R.M. Overstreet, and J.S. Franks. 1996. Gonadal maturation in the cobia, *Rachycentron canadum*, from the northcentral Gulf of Mexico. *Gulf Research Reports* **9**:147-159.

Manooch, C.S., S.P. Naughton, C.B. Grimes, and L. Trent. 1987. Age and growth of king mackerel, *Scomberomorus cavalla*, from the U. S. Gulf of Mexico. *Marine Fisheries Review* **49**(2):102-108.

Mills, S. 2000. A cobia by any other name. *Virginia Marine Resources Bulletin* **32**:1-10.

McPherson, G.R. 1993. Reproductive biology of the narrow barred Spanish mackerel (*Scomberomorus commerson* Lacepede, 1800) in Queensland waters. *Asian Fisheries Science* **6**:169-182.

Richards, C.E. 1967. Age, growth and fecundity of the cobia, *Rachycentron canadum*, from the Chesapeake Bay and adjacent Mid-Atlantic waters. *Transactions of the American Fisheries Society* **96**:343-350.

Richards, C.E. 1977. Cobia (*Rachycentron canadum*) tagging within Chesapeake Bay and updating of growth equations. *Chesapeake Science* **18**:310-311.

Rounsefell, G.A., and W.H. Everhart. 1953. *Fishery Science: its Methods and Applications*. John Wiley and Sons, Inc., New York, New York USA. 444 p.p

Schaefer, K.M. 1996. Spawning time, frequency, and batch fecundity of yellowfin tuna, *Thunnus albacares*, near Clipperton Atoll in the eastern Pacific Ocean. *Fisheries Bulletin, U.S.* **94**:66-76.

Scott, G.P. and P.L. Phares. 1999. Cobia fishery information update. Sustainable Fish. Div. Cont. SFD-98/99-51. NOAA/NMFS, SEFSC, Miami, Florida USA.

Shaffer, R.V., and E.L. Nakamura. 1989. Synopsis of biological data on the cobia

Rachycentron canadum (Pisces:Rachycentridae). FAO Fisheries Synop. 153 (NMFS/S 153). U. S. Dep. Commer., NOAA Tech. Rep. NMFS 82, 21 pp.

Smith, J.W. 1995. Life history of cobia, *Rachycentron canadum* (Osteichthyes: Rachycentridae), in North Carolina waters. *Brimleyana* **23**:1-23.

Thompson, B.A., C.A. Wilson, J.H. Render, and M. Beasley. 1992. Age, growth and reproductive biology of greater amberjack and cobia from Louisiana waters. Year 1. Rep. to U. S. Dep. Commer., NOAA, NMFS, Coop. Agreement NA90AA-H-MF089, Marine Fisheries Initiative (MARFIN) Prog., Coastal Fish. Inst., Louisiana State University, Baton Rouge, Louisiana USA. 55 pp.

Characterization of the Mitochondrial DNA Control Region of Cobia, *Rachycentron canadum*, from Mississippi Coastal Waters

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ABSTRACT

Limited research has been conducted on the biology and life history of the cobia, *Rachycentron canadum*, and no information on cobia molecular genetics has been published. This migratory, pelagic species is nearly circumglobally distributed. These fish are sought by offshore recreational anglers and are the basis of important commercial fisheries. Our preliminary research consisted of a characterization of the mtDNA control region and flanking tRNA genes. Whole DNA isolates were obtained from muscle tissue samples collected from cobia caught in Mississippi coastal waters. Universal primers were used in PCR amplifications to generate fragments of approximately 2,000 base pairs (bp). Subsequent direct sequencing produced sequences containing portions of cytochrome b and 12S rRNA, the entire tRNAs for proline (pro), threonine (thr), and phenylalanine (phe) and portions of the control region. Using these sequences, species specific primers were constructed in the tRNAs pro and phe flanking the control region and used in subsequent amplifications. The sequence of the entire control region of six cobia was obtained and found to range in size from 1067 to 1068 bp. One termination associated sequence (TAS-I) and four conserved sequence blocks (CSB D, I, II, III) were identified and compared with other fish species. Sequence variability of the control region was low; only three transversions and seven indels were found between the six cobia. Additional sequence data is needed from geographically isolated regions to determine if sufficient sequence variability exists in the control region for it to serve as a useful molecular marker in population and stock enhancement studies.

KEY WORDS: *Rachycentron canadum*, genetics, mitochondrial DNA

INTRODUCTION

The cobia, *Rachycentron canadum*, is a pelagic species found worldwide in tropical and subtropical coastal waters, except off the eastern Pacific (Briggs 1960, Shaffer and Nakamura 1989). In the early spring off the southeastern U.S., cobia typically migrate from their wintering grounds off south Florida into the northeastern Gulf of Mexico, and from late March through October, they occur off northwest Florida, Alabama, Mississippi, and southeast Louisiana (Franks et al. 1991, Biesiot et al. 1994). This migration pattern has led scientists to speculate that cobia exist

as a single population within the eastern Gulf of Mexico and perhaps over their entire range in U.S. waters. Tagging data from a study being conducted on northern Gulf cobia tends to support this hypothesis (Franks et al. 2000). Based on RFLP mitochondrial DNA (mtDNA) analyses of 90 fish collected off the Gulf states and Virginia, Biesiot et al. (1993) suggested cobia should be managed as a single unit. They found 86 haplotypes, but could not distinguish separate spawning stocks.

Increased fishing in the U.S. has put additional pressure on this species. For example, annual cobia commercial landings from the western central Atlantic, including the Gulf of Mexico, have increased from 58 metric tons in 1980 to 148 metric tons in 1998. The commercial catch peaked at 193 metric tons in 1996 (National Marine Fisheries Service 2000). Also, the price of cobia increased from approximately $0.38 per pound in 1980 to approximately $1.87 per pound in 1998 (National Marine Fisheries Service 2000). For reasons such as these, the U.S. Gulf of Mexico Marine Stock Enhancement Program listed cobia as a secondary species for the potential development of enhancement procedures.

The purpose of this study was to characterize the cobia mtDNA control region and preliminarily evaluate its suitability to assess cobia population structure. The mtDNA control region is typically a rapidly evolving portion of an already rapidly evolving genome (Brown et al. 1982, Vawter and Brown 1986), and can accumulate mutations two to five times faster than the rest of the mitochondrial genome (Meyer, 1993). The control region also contains conserved motifs and the sites of initiation of both heavy-strand replication, and heavy- and light-strand transcription (Chang and Clayton 1987 Clayton 1991a, 1991b, Digby et al. 1992). Because of its potentially high mutation rate, sequence data from the control region has been useful in assessing population structure of various species of marine fish (e.g. Garber 1999, Seyoum et al. 1999, Reeb et al. 2000).

In this initial study we obtained the sequence of the cobia mtDNA control region and its flanking tRNAs threonine (thr), proline (pro), and phenylalanine (phe). We then utilized this information to design species specific primers in the tRNAs pro and phe for direct sequencing and subsequent characterization of the control region.

MATERIALS AND METHODS

Cobia were collected off the coast of Mississippi, USA. White muscle tissue was excised and fixed in SED buffer (250 mM EDTA, pH 7.5, 20% DMSO, 3.42 M NaCl). Total genomic DNA was extracted from each sample using a procedure modified from Taggart et al. (1992), quantified using fluorescence spectrophotometry (Gallagher 1994), and adjusted to 100 ng/µL with 1 mM Tris, pH 8.5.

Two primer sets were initially employed in PCR (Fig.1): CB3R (5' CACAT TCAAC CAGAA TGATA TTT 3'; Palumbi, 1996) and 12SA-H1067, referred to in this work as 12SAR, (5' ATAAT AGGGT ATCTA ATCCT AGTT 3'; Martin et al. 1992), and CB3R and MUL12S (5'-CACGA GATTT ACCGG CCCTA TTAG-3'; Garber 1999). Appropriate PCR products were gel-purified

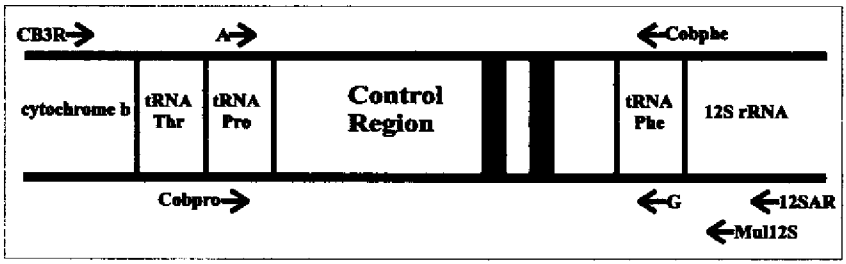
using the QIAquick™ Gel Extraction Kit (Qiagen, Inc.), quantified as above, and direct sequenced at the University of Maine DNA Sequencing Facility on an ABI Model 373A Sequencer. One set of sequences from one cobia was produced from each primer pair. Species specific primers in pro (CobPro, 5' ACCTG TACCT CTGGC TCCCA A 3') and phe (CobPhe, 5' CCGGG TTAGT GGCCA TCTTA A 3') were then designed from the resulting sequence information and used to amplify the entire control region from the previously sequenced sample and five additional samples (Figure 1). Appropriate PCR products were gel-purified, quantified, and sequenced as above.

A nested PCR using control region primers from a previously published study ("A" 5' TTCCA CCTCT AACTC CCAAA GCTAG 3' and "G" 5' CGTCG GATCC CATCT TCAGT GTTAT GCTT 3'; Lee et al. 1995; Figure 1) was conducted to verify we had sequenced mtDNA and not a nuclear pseudogene. In this procedure, the gel-purified product from the CB3R/12SAR amplification was used as template in a second reaction with the aforementioned primers.

All PCR amplifications were conducted in replicate 50 µL reactions containing 200 ng template, 1.5 mM $MgCl_2$, 200 µM each dNTP (Promega, Inc.), 0.4 µM of each primer, and 3.5 units of *Taq* DNA polymerase with 10X PCR buffer supplied by the manufacturer (Amersham Pharmacia & Biotech). PCR conditions were 94 °C for 3 min, followed by 35 cycles of 94 °C for 45 sec, 55 °C for 1 min (universal and mullet primers)/58 °C for 30 sec (cobia primers)/52 °C for 1 min (nested primers), 72 °C for 2 min, and a final elongation of 72 °C for 7 min.

DNA sequences were imported into OMIGA, ver. 1.1 (Oxford Molecular Ltd., Oxford, England), a multiple sequence editor, aligned using CLUSTALW (Higgins and Sharp, 1988) with the default settings, and adjusted by eye. Transfer RNA secondary structures were elucidated using Sean Eddy's Lab tRNAscan-SE Search Server (Lowe and Eddy 1997). Sequences were compared with those deposited at the National Center for Biotechnology Information (NCBI) using NCBI's BLAST WWWServer (Basic Local Alignment Tool; Altschul et al. 1990).

Figure 1. The control region and flanking areas of the piscine mitochondrial genome. Arrows indicate the relative position of primers employed to amplify the control region of the cobia, *Rachycentron canadum*.



RESULTS

The primer pair CB3R/12SAR produced a ,2000 base pair (bp) fragment, and the primer pair CB3R/MUL12S produced a 1,900 bp fragment (Figure 2a). Sequencing produced approximately 550 bp at both the 5' and 3' ends. When compared with sequences deposited at the NCBI, the 5' end was identified as a portion of cytochrome b and the complete tRNAs thr and pro (Figure 3a, 3b). A 27 bp noncoding region between thr and pro was also identified (Figure 4). The 3' end was identified as the complete tRNA phe (Fig. 3c) and a portion of 12S rRNA. The sequence fragments were aligned and deposited in Genbank (accession number AF311947).

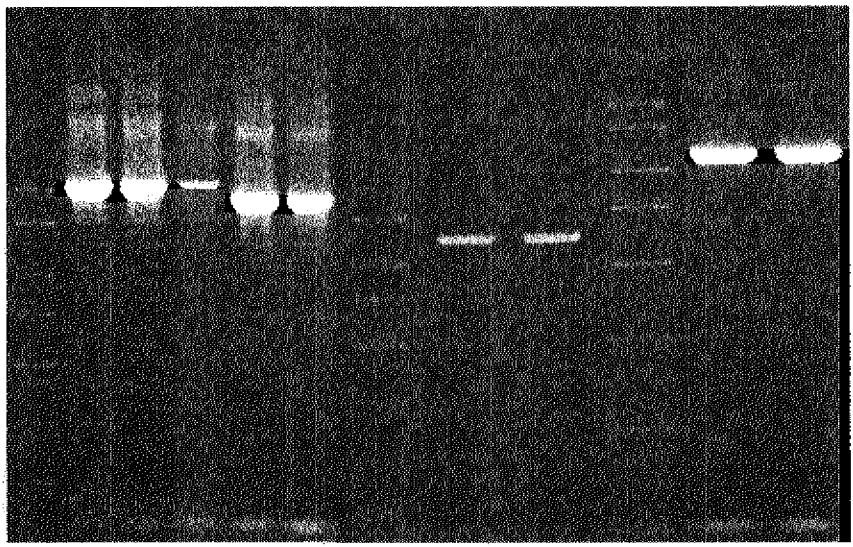
The sequence information obtained was utilized to design species specific primers located in pro (CobPro) and phe (CobPhe). These primers produced a DNA fragment of approximately 1100 bp from six fish (Fig. 2b). NCBI searches indicated these sequences were the mtDNA control region. The sequences were deposited in Genbank (accession numbers AF311945-950). Nested PCR of the gel-purified CB3R/12SAR product with the primers A and G produced a DNA fragment of approximately 1100 bp (Fig. 2c), as anticipated.

The control region of six fish ranged from 1067-1068 bp with a consensus length of 1069 bp (Figure 4). The consensus sequence contained three transversions, seven indels (insertions/deletions), and one unresolvable sequence ambiguity (N) in a single individual. One termination associated sequence (TAS) was identified: TAS-I located in the tRNA pro. Four conserved sequence blocks (CSB), CSB-D, CSB-I, CSB-II, and CSB-III, were also identified. A pyrimidine block of 21 bp, containing one purine, was identified between CSB-D and CSB-I (Fig. 4).

DISCUSSION

The primer pairs, CB3R/12SAR and CB3R/MUL12S, produced fragments that had significant similarity to the mtDNA cytochrome b and 12S rRNA genes, and flanking tRNAs of numerous fish. A 27 bp noncoding region, located between thr and pro, was also identified in these fragments (Figure 4). Although this region is not common in other fish species, Johansen *et al.* (1990) identified a 74 bp gap in the Atlantic cod. Species specific primers developed in the flanking tRNAs, pro and phe, produced an 1100 bp fragment showing significant similarity to both the corresponding sequence of the original fragment and the mtDNA control region. The fact that this product was the predicted length was a direct indication the primers were amplifying the desired portion of the mtDNA and not a nuclear pseudogene (Palumbi 1996). Nuclear pseudogenes have been observed in other species of marine organisms such as sea urchins, crabs, and corals (Jacobs et al. 1983, Palumbi 1996). An additional precaution was undertaken to exclude this possibility. Following the concept of "long PCR" (Cheng et al. 1994a, 1994b), the PCR product produced with the universal primers CB3R/12SAR was used as template in a nested PCR with previously published fish mtDNA primers located in

pro and phe (Lee et al. 1995). The resulting PCR product was the expected size, thus confirming the mtDNA control region was amplified.



A. B. C.

Figure 2. Agarose gels of the mitochondrial DNA control region of the cobia, *Rachycentron canadum*, amplified with the following primer pairs: (A) Lanes 2-4: CB3R/12SAR, Lanes 5-6: CB3R/MUL12S (lanes are numbered left to right), (B) CobPro/CobPhe, and (C) A/G (see text for details). Agarose Gel Ladder sizes (top to bottom): 2000, 1500, 1000, 750, 500, 300, 150, and 50 base pairs (Amresco, Inc.).

The cobia control region ranged in length from 1,067 to 1,068 bp which is comparable to the control region length in other fish species. Lee et al. (1995) reported that the control region length of 27 species of fish ranged from 856 to 1,500 bp. Cichlids and gadids contained the shortest control regions and pleuronectids contained the longest. The nucleotide sequences and locations of the TAS and the CSBs, elements that are highly conserved in vertebrate control regions, were similar to those of other fish species (Table 1). We identified a TAS-I, as well as, a CSB-D, a CSB-I, a CSB-II, and a CSB-III (Fig. 4). TAS-I was located in pro as in the white sturgeon (Buroker et al. 1990), rainbow trout (Digby et al. 1992), and wahoo (Garber et al. in press). We also identified a pyrimidine block of 21 bp, that contained one purine, between CSB-D and CSB-I (Figure 4). A 17 bp pyrimidine block was identified in the Atlantic cod (Johansen et al. 1990) and a 26 bp block in the rainbow trout (Digby et al. 1992). This site may provide a point of interaction with mtDNA single-strand-binding protein (Digby et al. 1992).

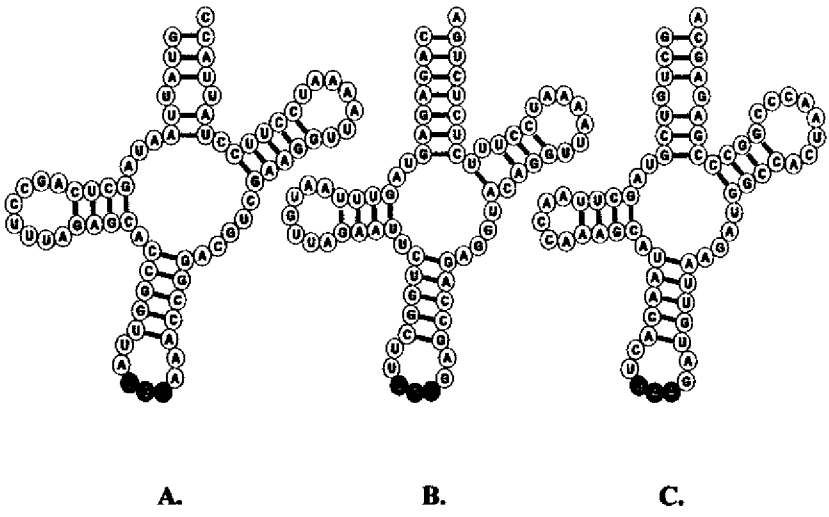


Figure 3. Sequence and structure of the mitochondrial tRNAs (A) threonine, (B) proline, and (C) phenylalanine from the cobia, *Rachycentron canadum*. Black circles represent the anticodons.

Pairwise comparisons revealed that each set of cobia sequences shared 99% sequence similarity. Only three transversions, one unresolvable ambiguity, and seven indels were observed (Figure 4). Seven of the 10 mutations and the unresolvable ambiguity were located near the ends of the samples and could possibly have resulted from direct sequencing artifacts. Regardless of their origin, variability was low and a central conserved region, flanked by more variable segments, could not be identified as in other fish species (Buroker et al. 1990, Johansen et al. 1990, Digby et al. 1992, Lee et al. 1995).

Mitochondrial DNA control region sequences have proven useful in population genetic studies and fisheries management. Although, their value has been contingent on the presence of a substantial amount of variability. Rosel and Block (1996) found there was enough variation in a 300 bp segment of the control region to indicate swordfish populations were structured on a global scale, but the variation was too high to detect subdivision within ocean basins. Therefore, by sequencing a 629 bp portion of the control region and increasing sample size, Reeb et al. (2000) was able to identify population structuring of swordfish in the Pacific. Seyoum et al. (1999) also found sufficient variability in a 369 bp portion of the red drum control region to suggest fisheries in the Atlantic and Gulf continue to be managed separately. To assess whether or not the cobia control region generally lacks variation or if this lack of variation is related to its migratory patterns and its possible utility as a molecular marker, it would be necessary to sequence more individuals from different localities.

```
|Threonine
GTATTAATAG CTCAGCCTTT AGAGCACCGG TTATGTAAAC     40
                                  |Nonooding Region
CGGACGTCGA AGGTTAAAAT CCTTCCTATT ACCAAACTTT     80
                    |Proline
TTAACCAAGC TCTGCCACAC TCAGAGAGAA AGGATTTTAA    120
                                  TAS-I
CCTGTACCTC TGGCTCCCAA AGCCAGAATT CTAACATTAA    160
            |Control Region
ACTACTCTCT GGTATAACAC ATGTACTCCA AGTATAGTAC    200
ATATNTGTAT ATACCCCATA CATCTATATG TACGCATTCA    240
TGTAGTCTTC TAGGACATAA TTTATTATTC ACCTAACTTT    280
CCTTTCAACC ATAAAATCGA GGACAACCTT CCGACATAGG    320
TATAACATAT CAATGAATAT TCAATTTCAC ATGATAACGC    360
TTTTTAGACA TTTAWGTAAA ACTTCTAGTT TCACCATACT    400
ATTAAAATCC AAAGATATAC CAGGACTCAA CAATCTATTA    440
TCTCTAAACA GTTTAATGTA GTAAGAGCCC ACCATCAGTT    480
GATTCCTTTA CGCTAACGGT TCTTGATGGT CAAGGACAGT    520
                                  CSB-D
AACCGTGGGG GTCACATAAC TTGAATTATT CCTGGCATTT    560
GGTTCCTACC TCAGGGTCAC TAATCGCGTT ACTCCCCTCA    600
CTTTCATTGA CGCTCGCATA AGTTAATGCT TTTTATACAT    640
ACTCCTCGTT ACCCAGCATG CCGAGCGTTC TCTCCACAGG    680
                Pyrimidine Block
GGCCAGGGGT ATTTTTTTAT TTTTTCCTTT TCACTCGCAT    720
TTCACAGTGC AGAGCTAAGA CAGTTGAGCC AAGGTGGAGC    760
ATTTTCTTGC TTACACGTAC TACCGTTTAA TTATGAAGGA    800
                CSB-I
CATTTACTGA TAAGTTACAT AACTGATATC AAGAGCATAA    840
TGCATGTAAT ATCCCCCTGG GATCTCTAAG AACCTTAATT    880
TCTCAGAACT TCCAGGATTA AACTAAAGGT AGGTGGGCGA    920
      CSB-II
TAAACCCCCC TACCCCCCTA AACTCCTAAG ATCAATGTGA    960
          CSB-III
CTCCTGCAAA CCCCCCGGAA ACAGGAAAAT CTTAGGGTTA   1000
GAATCAAACT AAACGTCCCA AAATTAAATG CTAAGAGACA   1040
AACAAGGCCC TGACACACCC CCCCCCTTTT TTAGCATACG   1080
CAAAACACGC CCTCTTGTAC TATAGTGCCC CTAAAATCAA   1120
AATATTGAGG CATCATAAAA ATTTATATTA TCATATTATT   1160
TTTTATAATA ATATTTTAAT TTTATACAGG GTAACCAAAW   1200
                                  |Phenylalanine
TCWCGTAACA ATACTATTTG AATTTTATGT AACATCACCG   1240
CTGTCGTAGC TTAACCGAAG CATATCACTG AAGATGTTAA   1280
GATGGCCACT AACCCGGCCC GAGAGCA                1320
```

Figure 4. Consensus sequence of the mtDNA control region and flanking tRNAs of the cobia, *Rachycentron canadum*. The termination associated sequence (TAS-I), conserved sequence blocks (CSB-D, CSB-I, CSB-II, CSB-III), and pyrimidine block are underlined. The transversions (W) and unresolved sequence ambiguity (N) are in bold text and double underlined.

Due to rising importance in commercial and recreational fisheries, increased pressure has been placed on the cobia. Therefore, information on the biology, life history, and genetics of the cobia is fundamental to preventing a decrease in stocks beyond a sustainable level and the associated loss of genetic diversity. This study provides initial molecular genetic data that will prove useful in future research.

Table 1. Comparative alignment of termination associated sequence (TAS) and conserved sequence blocks (CSB) identified in the cobia, *Rachycentron canadum*, and other fish species.

TAS-I		
	Cobia	ACATTAAACTACT
	Wahoo[1]	AAATTAAACTATT
	Trout[2]	AAATTAAACTACC
	Sturgeon[3]	ACATTAAACTATT
CSB-D		
	Cobia	GG-CATTTGG-TTCCTACCT-CAGGGTCACT
	Wahoo	GGGCATTkGGGTTCCTAATTTCAGG-TCCAT
	Swordfish[4]	GG-CATTTGG-TTCCTACTT-CAGGG-CCAT
	Sturgeon	GG-CATCTGG-TTCCTA-TTTCAGG-TCCAT
CSB-I		
	Cobia	ACATA
	Wahoo	ACATA
	Trout	ACATA
	Snook[5]	ACATA
CSB-II		
	Cobia	TAAACCCCCCTACCCCC
	Wahoo	TAAACCCCCCTACCCCC
	Trout	TAAACCCCCCTACCCCC
	Sturgeon	-AAACCCCC-TACCCCC
CSB-III		
	Cobia	TGCAAA-CCCCCCGGAA-C-A
	Wahoo	TG-AAAACCCCCCGTAAAC-A
	Trout	TGTTAAA-CCCC—TAAACCA
	Swordfish	TG-AAAA-CCCCC

[1]Garber et al. in press; [2]Digby et al. 1992; [3]Buroker et al. 1990; [4]Rosel and Block 1996; [5]Wilson et al. 1997

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LITERATURE CITED

Altschul, S.F., W. Gish, W. Miller, E.W. Myers and D.J. Lipman. 1990. Basic local alignment search tool. *Journal of Molecular Biology* **215**:403-410.

Biesiot, P.M., R.M. Caylor and J.S. Franks. 1994. Biochemical and histological changes during ovarian development of cobia, *Rachycentron canadum*, form the northern Gulf of Mexico. *Fisheries Bulletin, U.S.* **92**:686-696.

Biesiot, P.M., A.W. Hrincevich and J.S. Franks. 1993. Mitochondrial DNA analysis of cobia, *Rachycentron canadum*, from the northern Gulf of Mexico. Final report for Sea Grant #R/LR-26, Mississippi/Alabama Sea Grant Consortium, Ocean Springs, Mississippi USA.

Briggs, J.C. 1960. Fishes of worldwide (circumtropical) distribution. *Copeia* **1960(3)**:171-180.

Brown, W.M., E.M. Prager, A. Wang and A.C. Wilson. 1982. Mitochondrial DNA sequences of primates: Tempo and mode of evolution. *Journal of Molecular Evolution* **18**:225-239.

Buroker, N.E., J.R. Brown, T.A. Gilbert, P.J. O'Hara, A.T. Beckenbach, W.K. Thomas and M.J. Smith. 1990. Length heteroplasmy of sturgeon mitochondrial DNA: an illegitimate elongation model. *Genetics* **124**:157-163.

Chang, D.D. and D.A. Clayton. 1987. A novel endonuclease cleaves at a priming site of mouse mitochondrial DNA replication. *EMBO Journal* **6**:409-417.

Cheng, S., C. Fockler, W.M. Barnes and R. Higuchi. 1994a. Effective amplification of long targets from clone inserts and human genomic DNA. *Proceedings of the National Academy of Science USA* **91**:5695-5699.

Cheng, S., R. Higuchi and M. Stoneking. 1994b. Complete mitochondrial genome amplification. *Natural Genetics* 7:350-351.

Clayton, D.A. 1991a. Nuclear gadgets in mitochondrial DNA replication and transcription. *Trends in Biocheical Science* **16**:107-14.

Clayton, D.A. 1991b. Replication and transcription of vertebrate mitochondrial DNA. *Annu. Rev. Cell Biol.* 7:453-478.

Digby, T.J., M.W. Gray and C.B. Lazier. 1992. Rainbow trout mitochondrial DNA: sequence and structural characteristics of the non-coding control region and flanking tRNA genes. *Gene* **113**:197-204.

Franks, J.S., J. Read Hendon, N.J. Brown-Peterson and B.H. Comyns. 2000. Mississippi marine sport fish studies. Seasonal movements and migratory patterns of cobia, *Rachycentron canadum*. Project No. F-120. Annual report to the U.S. Fish and Wildlife Service, Atlanta, GA and the Mississippi Department of Marine Resources, Biloxi, Mississippi USA. (var. pag.).

Franks, J.S., M.H. Zuber and T.D. McIlwain. 1991. Trends in seasonal movements of cobia, *Rachycentron canadum*, tagged and released in the northern Gulf of Mexico. *Journal of the Mississippi Academy of Science* **36**(1):55.

Gallagher, S.R. 1994. Commonly used biochemical techniques, Appendix 3. Pages A.3.10-A.3.11 in: K. Janssen, (series ed.) *Current Protocols in Molecular Biology*. John Wiley and Sons, Inc. New York, New York USA.

Garber, A.F., K.C. Stuck, J.S. Franks, N.M. Garber and D.R. Geter. 2001. Characterization of the mitochondrial DNA control region of the wahoo, *Acanthocybium solandri*, from the northcentral Gulf of Mexico and Bimini, Bahamas. *Proceedings of the Gulf and Caribbean Fisheries Institute* **52**:610-621.

Garber, N.M. 1999. Application of the mitochondrial DNA control region in population structure studies of *Mugil cephalus* (striped mullet) in North America. M.S. Thesis. The University of Southern Mississippi, Hattiesburg, Mississippi USA. 86 pp.

Higgins, D.G. and P. Sharp. 1988. Clustal: a package for performing multiple sequence alignment on a microcomputer. *Gene* **73**:237-244.

Jacobs, H.T., J.W. Posakony, J.W. Grula, J.W. Roberts, J.H. Xin, R.J. Britten and E.H. Davidson. 1983. Mitochondrial DNA sequences in the nuclear genome of *Strongylocentrotus purpuratus*. *Journal of Molecular Biology* **165**:609-632.

Johansen, S., P.H. Guddal and T. Johansen. 1990. Organization of the mitochondrial genome of Atlantic cod, *Gadus morhua*. *Nucleic Acids Research* **18**:411-419.

Lee, W., J. Conroy, W.H. Howell and T.D. Kocher. 1995. Structure and evolution of teleost mitochondrial control regions. *Journal of Molecular Evolution.* **41**:58-66.

Lowe, T. and S.R. Eddy. 1997. tRNAscan-SE: a program for improved detection of transfer RNA genes in genomic sequences. *Nucleic Acids Research* **25**:955-964.

Martin, A.P., R. Humphreys and S.R. Palumbi. 1992. Population genetic structure of the armorhead, *Pseudopentaceros wheeleri*, in the North Pacific ocean: application of the polymerase chain reaction to fisheries problems. *Canadian Journal of Fisheries and Aquatic Science* **49**:2386-2391.

Meyer, A. 1993. Evolution of mitochondrial DNA in fishes. Pages 1-38 in: P.W. Hochachka and T.P. Mommsen, (eds.) *Biochemistry and Molecular Biology of Fishes, Molecular Biology Frontiers, Vol. 2.* Elsevier Science Publishers, Amsterdam, The Netherlands.

National Marine Fisheries Service. 2000. Commercial fisheries landings statistics, 1974-1998; Atlantic and Gulf. NOAA, Sustainable Fisheries Division, Miami, Florida USA.

Palumbi, S.R. 1996. Nucleic acids II: the polymerase chain reaction. Pages 205-247 in: D.M. Hillis, C. Moritz and B.K. Mable, (eds.) *Molecular Systematics, 2nd ed.* Sinauer Associates, Inc., Sunderland, Massachusetts USA.

Reeb, C.A., L. Arcangeli and B.A. Block. 2000. Structure and migration corridors in Pacific populations of the Swordfish, *Xiphius gladius*, as inferred through analyses of mitochondrial DNA. *Marine Biology* **136**:1123-1131.

Rosel, P.E. and B.A. Block. 1996. Mitochondrial control region variability and global population structure in the swordfish, *Xiphias gladius*. *Marine Biology* **125**:11-22.

Seyoum, S., M.D. Tringali, T.M. Bert, D. McElroy and R. Stokes. 1999. An

analysis of genetic population structure in red drum, *Sciaenops ocellatus*, based on mtDNA control region sequences. *Fisheries Bulletin* **98**:127-138.

Shaffer, R.V. and E.L. Nakamura. 1989. Synopsis of biological data on the cobia *Rachycentron canadum* (Pisces: Rachycentridae). FAO Fisheries Synop. 153 (NMFS/S 153). U.S. Dept. Commer., NOAA Tech. Rep. NMFS 82. 21 pp.

Taggart, J.B., R.A. Hynes, P.A. Prodohl and A. Ferguson. 1992. A simplified protocol for routine total DNA isolation from salmonid fishes. *Journal of Fisheries Biology* **40**:963-965.

Vawter, L. and W.M. Brown. 1986. Nuclear and mitochondrial DNA comparisons reveal extreme rate variation in the molecular clock. *Science* **234**:194-196.

Wilson, R.R., Jr., K.A. Donaldson, M.E. Frischer and T.B. Young. 1997. Mitochondrial DNA control region of common snook and its prospect for use as a genetic tag. *Transactions of the American Fisheries Society* **126**:594-606.

A Versatile and Inexpensive Method for Training and Testing Observers Conducting Underwater Visual Censuses Requiring Size Estimates

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ABSTRACT

Underwater visual-based population monitoring programs that include the collection of size-structure information of the organisms surveyed require that observers collecting this data are able to accurately estimate the recorded size parameter. Training and testing of observers conducting size estimates during underwater visual surveys have traditionally employed very simple linear artificial targets of known dimensions or more complex and costly life-sized models of the organisms surveyed. As part of its efforts to monitor reef fish populations in the Florida Keys, the Florida Marine Research Institute has developed a new visual target type that is inexpensive to build, easy to maintain and deploy in-situ, and allows for almost infinite variability in target image size as well as accurate representation of species-specific visual aspects. These new targets are created by placing images of organisms photocopied onto waterproof paper between two sheets of Plexiglas. A large variety of sizes can be generated from the same original image by using the photocopier to reduce or enlarge copy size. Teflon bolts and wingnuts are used to hold the two Plexiglas sheets together around the inserted images. Targets are deployed in the field using an anchor and float arrangement. New observers can be trained and tested with the images before collecting program data, and experienced observers retested on a regular basis. This new target system, which should overcome the estimation biases associated with the use of simple linear target systems without incurring the high expenses of constructing solid, lifelike models of the organisms surveyed, should be tested and evaluated more thoroughly for its applicability as a training tool.

KEY WORDS: visual surveys, underwater size estimation, visual census training and testing

INTRODUCTION

Underwater visual censuses are an efficient, nondestructive way to observe and assess populations of aquatic organisms, and are now widely accepted and used by fish biologists in particular (Jones and Thompson 1978, Bohnsack and Bannerot 1986, Clarke 1986, Bortone et al. 1989, Russ 1989, Smith 1989). Many fisheries managers use visual censuses as a tool to estimate species length-frequency distributions and abundance in monitoring programs (Thresher and Gunn 1986, Alcala and Russ 1990, Kulbicki and Wantiez 1990, Roberts 1995, Dixon 1997, Wantiez et al. 1997). When implementing visual-based population monitoring programs in which size structure data is collected, it is crucial that the observers collecting these data (usually SCUBA divers) are trained to accurately estimate the size parameter of individuals (often total length) which is recorded. *In situ* testing of size estimation skills underwater can serve to improve the ability of observers to accurately conduct visual surveys by identifying individual size estimation biases that can then be eliminated with practice. Studies have shown that by training and testing underwater observers with known-size visual targets, size estimation accuracy for most taxa increases in a relatively short amount of time (Bell et al. 1985, Mille and Van Tassell 1994, Thompson and Mapstone 1997).

Traditionally, the known-size artificial targets used to train and test divers in size estimations have been either lengths of simple rods or tubes (Bell et al. 1985) or specially constructed life-sized models of target organisms (Rooker and Recksieck 1988, Mille and Van Tassell 1994). Simple elongate targets, while inexpensive, will not assist observers in recognizing (and correcting for) errors and biases associated with estimating sizes of complex-shaped organisms. Bell et al. (1985) found that divers trained to accurately estimate lengths of PVC pipe experienced difficulties transferring this skill to fish length estimation. Species-specific, two-dimensional or three-dimensional models are more realistic and can provide more useful training and testing aids, but constructing a large number of them can be cumbersome and expensive. Large numbers of visual targets are desirable because observers are less likely to memorize model sizes when they are trained and tested on a repeated basis using the same set of targets.

In view of the problems with the previously used underwater visual survey methods for developing and testing observer size estimation skills, the Fisheries-Independent Monitoring program at the Florida Marine Research Institute has developed a new visual target system to be used in the training and evaluation of our divers. Our visual target system is inexpensive and simple to build, easy to maintain and deploy in the field, and allows for almost infinite variability in target size and provides species-specific targets for each organism that is being monitored. Herein we describe the construction of this visual target system and illustrate it's use in our sampling program, and discuss it's economy, simplicity, and applicability. Although we developed this system in order to train and test SCUBA divers conducting length estimations of reef fish species, it is applicable with little or no modification to most underwater visual sampling programs which require observer estimations of size parameters of aquatic organisms.

MATERIALS AND METHODS

Our new underwater visual targets are created by placing drawings or photographs of organisms (in our case, fishes) photocopied onto waterproof paper between two sheets of Plexiglas (Figure 1), and rigging these sheets with a weight and float arrangement that allows them to be deployed in the field (Figure 2).

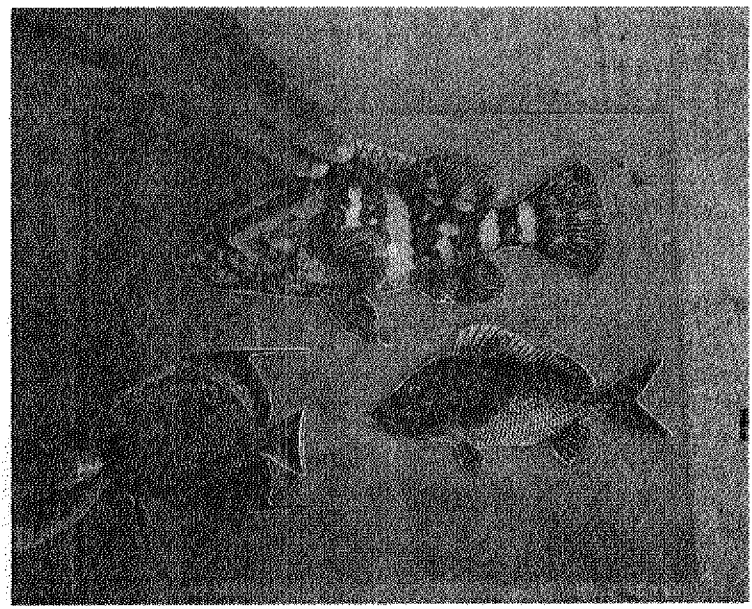


Figure 1. Target images are placed between Plexiglas sheets.

Construction of the targets is relatively simple and requires a minimal amount of materials and labor and few tools (Table 1). The specific materials listed are those available in our area, but substitutions can be made to adapt to most local markets.

To construct each target, we use a table saw fitted with a Plexiglas blade to cut two equal sized pieces of Plexiglas from a 121.9 cm x 248.9 cm (48" x 98") sheet of Palsun 0.32 cm (1/8") Plexiglas. Plexiglass frames of various sizes are used to prevent observers from using the frame size as an aid to estimate target image size. Holes are drilled a few centimeters from each corner of the two pieces of matching Plexiglas in order to fasten the pieces together with nylon nuts and bolts. One or two additional securing bolts placed near the center of the Plexiglas pieces are required when building a target larger than about 45 cm x 60 cm.

Our file of target images was created by photocopying drawings or pictures of local reef fish species from various sources onto waterproof paper. A variety of target image sizes are created for each species by are enlarging or reducing the image during the copying process. Excess paper is trimmed from around each image so that it will appear realistic underwater and allow an unobstructed view of the

background around the target. To assemble the target arrays, the fish images are placed between a pair of matching Plexiglas pieces of appropriate size before bolting them securely together (Figure 1). To prevent paper images from slipping, a spacer made from a small piece of felt is added under the reverse side of the image. Multiple images can be placed within a single Plexiglas frame.

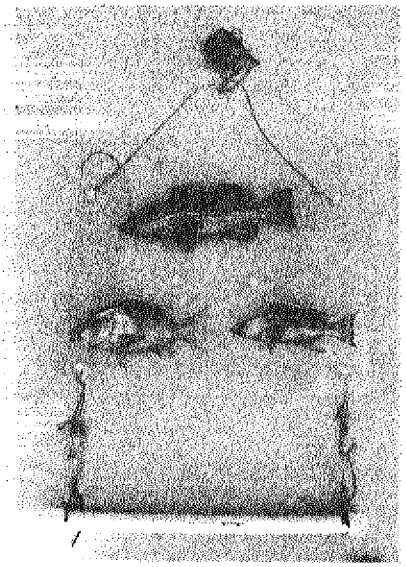


Figure 2. Visual target array with component parts labeled.

Our target arrays are deployed underwater in the field by suspending the Plexiglas frame above the bottom using a weight and float arrangement. Our weights are constructed by cutting pieces of polyvinylchloride (PVC) pipe into the lengths appropriate for the target arrays, filling with sand, and sealing on both ends with PVC slip caps glued in place with PVC cement. A piece of nylon twine is tied to each end of the filled PVC pipe and also to a stainless steel longline clip. The longline clips are attached to loops of nylon twine tied securely to each of the bottom corner bolts of the Plexiglas pieces (Figure 2). The pipe weight should be rigged so that the target array will float in a natural position when suspended in the water. PVC sponge net floats of appropriate size to suspend the target array perpendicular to the bottom are attached to the top of the target by using additional nylon twine and longline clips. Our completed target arrays are designed to be negatively buoyant with the target images suspended in the water column near the bottom, but positively buoyant float and weight combinations could be used to suspend arrays beneath surface buoys, or arrays could be attached to fixed structures attached to the bottom or in the water column.

We have used our target arrays for both generalized diver training and formal testing under simulated visual survey conditions. During training, the arrays are

(marked with a surveyor's tape) and record estimated total lengths and species identification of each target image in each array, and also record their estimate of the distance from the transect line to each array. This simulates the transect surveys that we normally employ during regular censuses. Additional targets are also set around a nearby stake, to which the diver proceeds and then conducts a simulated stationary point count (Figure 3), recording the same estimates and species identifications as during the simulated transect survey. We test new divers' length estimation skills before any training or practice, and retest after approximately six weeks of training. Training includes practice with measuring sticks, paired-count comparisons with experienced divers, and estimating the lengths of live fish that are then captured and measured. Tests are given to experienced divers semi-annually to maintain the reliability of our visual length data and to help observers identify and correct biases that they may have developed.

RESULTS AND DISCUSSION

The underwater visual target system we have developed is inexpensive and easy to construct, very durable, and much more versatile than previously reported target systems. In addition, since the target arrays are easy to deploy in the field and very flexible as to target images and deployment mechanics, this system could be adapted to a variety of projects which require underwater visual species identifications and size estimations. While our primary intent in developing the system was to assure accurate estimation of total fish lengths during underwater visual population surveys, we found the system also functioned well to verify species identifications and the ability of divers to accurately estimate distances.

The availability and afford ability of materials for constructing sophisticated underwater visual target systems may be a constraint in some isolated field-based laboratories or developing countries, so we designed our targets to be constructed from easily obtained, relatively inexpensive, durable materials. The estimated cost of our largest target array (45 cm x 60 cm frame) is $21.57 (Table 1), but target frames can be smaller and therefore less expensive. Plexiglas and waterproof paper represent the majority of each target array's cost ($15.40 of the total cost of $21.57 for one 45 cm x 60 cm target array), but because these and all of the other materials used were chosen specifically for their resistance to damage by water, corrosion, and ultraviolet light, a long useful life may be expected. Other examples of durable products used include non-corrosive nylon bolts, stainless steel longline clips, and PVC weights and floats. These visual target systems can sustain high use in rugged conditions and last indefinitely with minimal care, thereby obviating construction costs for replacements.

Table 1. List of materials and approximate costs for constructing seven large (45 cm x 60 cm) target arrays for underwater visual size estimation training. Prices are quoted from local vendors in the Florida Keys during 1999.

	Price per Unit	Number of Units Required	Price per Target	Price for 7 Targets
Weights				
PVC Pipe Schedule 40 (1")	$ 2.22/ 10 ft.	1.5 ft. per target	$ 0.32	$ 2.22
PVC Slip Cap (1")	$ 0.30 each	2 per target	$ 0.60	$ 4.20
PVC Cement (8 oz.)	$ 2.55/ bottle		$ 0.10	$ 2.55
Sand (50 lb. Bag)	$ 2.96/ bag	1.5 lbs. per target	$ 0.08	$ 0.56
Target				
Plexiglas	$94.88/ sheet	7 targets per sheet	$13.55	$ 94.88
($^1/_8$" x 48" x 96")	$ 0.28 each	(assorted sizes)		
Nylon Bolt (¼" x 1½")	$0.40/ pair	5 per target	$ 1.40	$ 9.80
Nylon Wingnut (¼")	$36.89/ box	5 per target	$ 1.00	$ 5.20
Waterproof Paper		5 sheets per target	$ 1.85	$12.95
(100 sheets/box)				
Buoyancy				
Assorted PVC sponge floats	$ 0.75/ float	1 or 2 per target	$ 1.25	$ 8.75
Spool of Twine (325 ft.)	$ 2.30/ spool	avg. 6 ft. per target	$ 0.04	$ 0.28
Longline Clips (10 per bag)	$ 4.60/ bag	3 per target	$ 1.38	$ 9.66
		Total estimated cost:	$21.57	$151.05

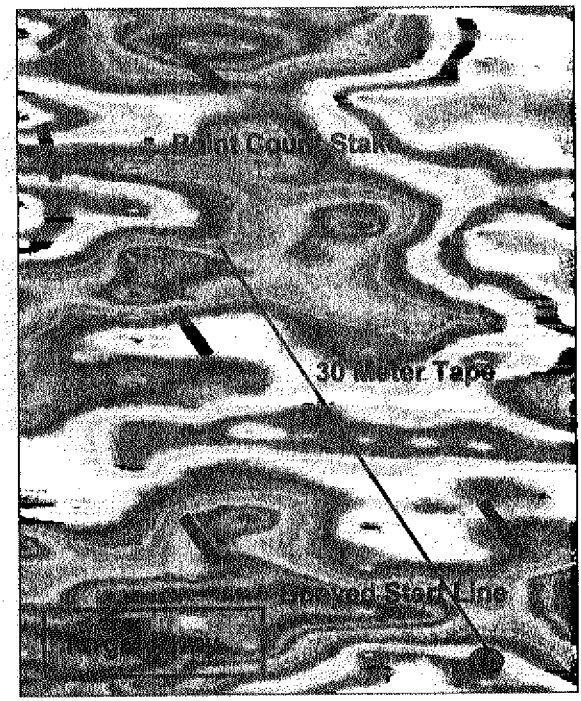


Figure 3. Layout target arrays over bottom to simulate transect and point count underwater visual surveys.

Despite an almost negligible cost per individual target image, the use of species-specific graphic representations allows divers to train and test with images that have all of the same distinct body shapes and markings characteristic of the individual species included in actual surveys. Suspended over the substrate, the photocopies can in fact appear very lifelike to approaching divers. The capability to produce numerous photocopies with a large range of sizes from the same image eliminates the possibility of observers becoming familiar with individual targets through repeated exposure. We minimize the potential for the divers becoming familiar with the dimensions of the Plexiglas frames used in the target arrays by varying both their size and shape and constantly changing the fish images used in each array. In addition, the floats, clips, PVC pipe, nuts and bolts used to construct the arrays can be purchased in various sizes, and can be varied on individual frames between uses to reduce chances of these items providing cues to dimensions.

Carefully controlled comparison studies would be required to thoroughly evaluate the effectiveness of our target system to eliminate or minimize the reported biases associated with underwater visual training and testing methods using simple elongate visual targets, or to establish the relative effectiveness of the use of the two-dimensional silhouette images used in our system as opposed to three-dimensional models. While these studies are beyond our current resources, we

believe that based on practical considerations alone, our system offers an excellent compromise between accepting the biases introduced by shape differences between simple linear objects and living organisms (as well as shape differences between different species of organisms) and the costs of constructing solid, lifelike, two- or three-dimensional models. Our system has proven to be highly effective in the application for which we developed it, i.e. testing and training SCUBA divers making total length estimations of reef fish populations. A very significant improvement in length estimation of target images has been documented for our new observers after only a short training period utilizing both our model system and estimations of the sizes of real fish. Figure 4 illustrates the results of a typical new observer who was tested with models before any practice or experience and then retested after about a dozen training dives over a six-week period. Accuracy in assigning targets to correct size classes improved from 40% to 89% after training. In conclusion, we believe our new underwater visual target system is a practical and versatile tool for the training and periodic testing of observers required to make size estimations of aquatic organisms in their natural environment, especially for multi-species, visual survey-based population monitoring programs such as ours. The system is inexpensive, easy to use and maintain, and yet provides the ability to employ a large variety of realistic target images and sizes without incurring the high labor costs required to generate solid models of target organisms. Its potential as a training and testing tool for conducting underwater visual censuses warrants further testing and evaluation.

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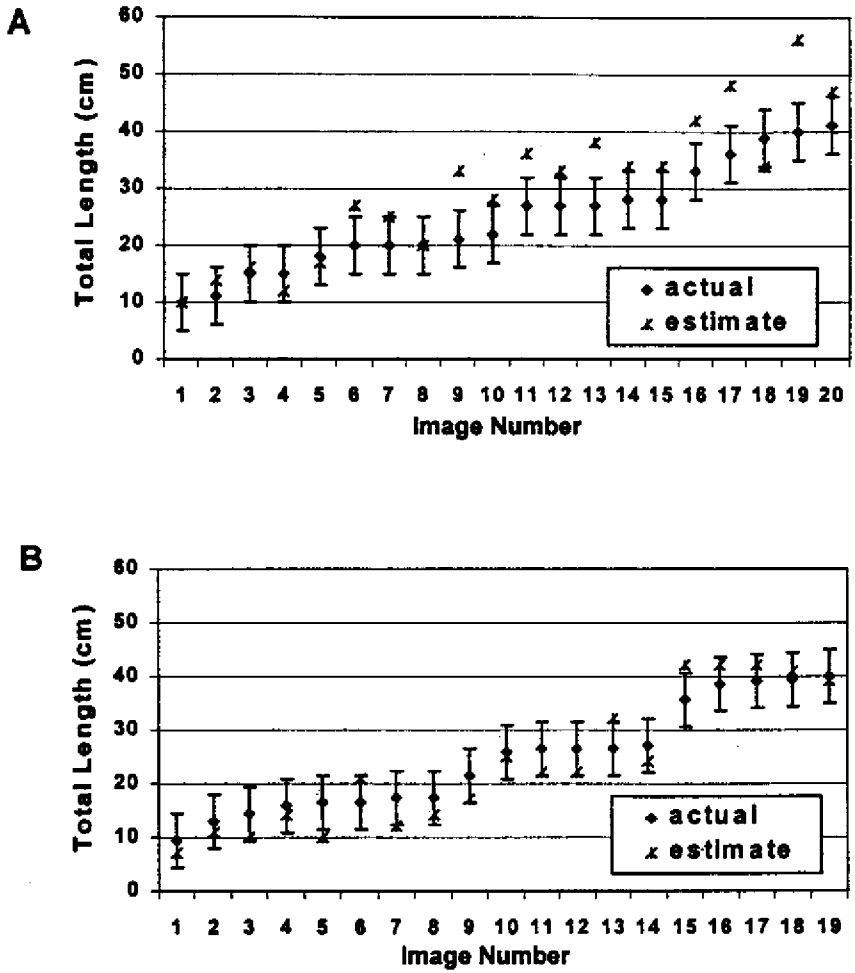


Figure 4. A diver's estimate of lengths plotted with the actual image sizes (A) prior to and (B) following training. Error bars represent +/- 5 cm from the actual size, designated as the acceptable range for our visual census program. Forty percent of the diver's size estimates in the initial test were within the acceptable range. Following a short training period, the diver's estimation accuracy increased to 89%.

LITERATURE CITED

Alcala, A. C. and G. R. Russ. 1990. A direct test of the effects of protective management on abundance and yield of tropical marine resources. *J. Cons. Int. Explor. Mer* 47:40-47.

Bell, J. D., G.J.S. Craik, D.A. Pollard and B.C. Russell. 1985. Estimating length frequency distributions of large reef fish underwater. *Corals Reefs* 4:41-44.

Bohnsack, J.A. and S. P. Bonnerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Tech. Rep. NMFS 41, July 1986, 15 pp.

Bortone, S.A., J.J. Kimmel and C.M. Bundrick. 1989. A comparison of three methods for visually assessing reef fish communities: time and area compensated. *Northeast Gulf Science* **10**(2):85-96.

Clarke, D.G. 1986. Visual censuses of fish populations at the Florida Middle Ground. *Northeast Gulf. Science* **8**(1):65-81.

Dixon, M. 1997. The use of SCUBA and punctuated transects to count a temperate reef fish. Pages 47-54 in: Seventeenth Annual Scientific Diving Symposium, American Academy of Underwater. Science.

Jones, R.S. and M. J. Thompson. 1978. Comparison of Florida reef fish assemblages using a rapid visual technique. *Bulletin of Marine Science* **28**:159-172.

Kulbicki, M. and L. Wantiez. 1990. Comparison between fish bycatch from shrimp trawlnet and visual censuses in St. Vincent Bay, New Caledonia. *Fisheries Bulletin* **88**:667-675.

Mille, K.J. and J.L.Van Tassell. 1994. Diver accuracy in estimating lengths of models of the parrotfish, *Sparisoma cretense*, in situ. *Northeast Gulf Science* **13**(2):149-155.

Roberts, C.M. 1995. Rapid build-up of fish biomass in a Caribbean marine reserve. *Conservation Biology* **9**(4):815-826.

Rooker, J. and C. Recksieck. 1988. The effects of training with fish models in estimating lengths of fish underwater. *Proceedings of the Gulf and Caribbean Fisheries Institute* **41**:321-331.

Russ, G.R. 1989. Distribution and abundance of coral reef fishes in the Sumilon Island Reserve, Central Philippines, after nine years of protection from fishing. *Asian Marine Biology* **6**:59-71.

Smith, M.P.L. 1989. Improving multispecies rocky reef fish censuses by counting different groups of species using different procedures. *Environmental Biology of Fishes* **26**:29-37.

Thompson, A.A. and B.D. Mapstone. 1997. Observer effects and training in underwater visual surveys of reef fishes. *Marine Ecol.ogy Progress Series* **154**:53-63.

Thresher, R.E. and J.S. Gunn. 1986. Comparative analysis of visual census techniques for highly mobile, reef associated piscivores (Carangidae). *Environmental Biology of Fishes* **26**:29-37.

Wantiez, L., P. Thollot and M. Kulbicki. 1997. Effects of marine reserves on coral reef fish communities from five islands in New Caledonia. *Coral Reefs* **16**:215-224.

The Reef Fish Assemblage of Bonaire Marine Park: An Analysis of REEF Fish Survey Data

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ABSTRACT

The REEF/TNC Fish Survey Project is a volunteer fish monitoring program developed by the Reef Environmental Education Foundation (REEF) with support from The Nature Conservancy (TNC). REEF volunteers collect fish distribution and log scale abundance data for the project using a standardized visual method. These data are housed in a publicly accessible database on REEF's Website (http://www.reef.org). To date, the REEF database contains over 19,000 surveys from approximately 1,800 sites in the tropical western Atlantic region. The standardized census method provides a consistency in data collection applied over a wide geographic range. Such a database represents a valuable tool for marine resource managers. REEF data are currently being used by a number of marine parks and resource agencies for assessment and long-term monitoring, including the Bonaire Marine Park (BMP; Bonaire, Netherlands Antilles). Between December 1993 and July 1999, approximately 2,000 fish surveys have been completed by REEF volunteers on the reefs of Bonaire and Klein Bonaire. From these data, a total of 362 species were reported from 77 sites surveyed, making Bonaire one of the most species rich locations in REEF's database. Similarity and ordination analysis on a sub-set of sites indicated that fish assemblages on Klein Bonaire were distinct from those on Bonaire. Sites within the two Bonaire research reserves appeared distinct from other Bonaire sites. This paper provides the most comprehensive species list to date for the BMP. In addition, this established database will act as a baseline against which future change can be assessed.

KEY WORDS: Bonaire, reef fish, volunteer monitoring

INTRODUCTION

Effective conservation and management of resources in a marine protected area require assessment for site characterization and monitoring to detect changes in the natural community. Unfortunately, the costs associated with *in situ* activities, coupled with the unreliable nature of marine conditions, make the consistent acquisition of sufficient data difficult. In addition, the available scientific manpower is often insufficient to generate the amount and diversity of information needed for research or monitoring (Pattengill-Semmens and Semmens 1998). As a result, resource managers have recently begun to utilize volunteer groups. The advantages of such programs include:

i) The costs of assessing the resource are often born by the volunteers, and

ii) Sampling effort greatly exceeds the effort scientists and resource agencies would be able to contribute to field research.

Furthermore, the spatial coverage of the volunteer sampling effort is often greater than that of scientists. Volunteer or "citizen" science allows all those who are interested in the resource to contribute to its understanding. Beyond providing valuable data, the increased stewardship that comes from participation is vital to the protection of a resource.

The Reef Environmental Education Foundation (REEF) is a nonprofit organization that educates the public about marine resources and enables divers to participate in long-term monitoring. REEF accomplishes this through its Fish Survey Project, which was developed by REEF with support from The Nature Conservancy (TNC) and guidance by the National Marine Fisheries Service Southeast Fisheries Science Center. The REEF/TNC Fish Survey Project allows volunteer divers and snorkelers to collect and report information on marine fish populations in the tropical western Atlantic and the west coast of the United States and Canada. Volunteers conduct fish surveys during their regular diving and snorkeling activities, and then submit their data to REEF on specially designed computer scantron data sheets. These data sheets are then scanned, and the information is subsequently entered into a database managed by REEF. This database is publicly-accessible via REEF's Website (<http://www.reef.org>), and as of October 1999, contains over 19,000 surveys. A variety of summary reports can be generated from the database over the Internet. REEF also provides datafiles to researchers and agencies upon request.

The REEF/TNC Fish Survey Project and its database are an important source of information for many resource agencies and marine parks, including the Bonaire Marine Park (BMP). Since 1993, the BMP has been the focus of seven REEF field surveys and individual survey effort there has been large. These surveys provide a useful reef fish species inventory, as well as a baseline of information that the BMP can use to enhance park management. In addition, site-specific data provide a tool to evaluate relationships between sites with different physical characteristics and levels of use.

Bonaire, the second largest island of the Netherlands Antilles, is located 100km off the coast of Venezuela. The island is approximately 56km long and 11km wide, and boasts a semi-arid climate. Klein Bonaire is a small, uninhabited island off the leeward (western) coast of Bonaire. The entire coasts of both Bonaire and Klein Bonaire are lined by narrow fringing coral reefs, and a double reef complex is present in most of the southern sites on Bonaire's leeward side (Van Veghel 1997). A sand/coral rubble shelf is present from shore out to the reef crest. Besides salt production and oil storage, tourism related to SCUBA diving is the third largest industry on Bonarie (Dixon et al. 1993). In response to increased use, the BMP was created in the early 1980s to protect the waters surrounding Bonaire and Klein Bonaire from the high water mark to the 200 foot contour. Collecting of any kind while on SCUBA or snorkel is prohibited. Approximately seventy mooring buoys have been installed to minimize anchor damage and an admission use fee for diving

was implemented in 1992. Two marine reserve areas, one adjacent to the Karpata Ecological Centre and one south of Washington Slagbaai National Park, were established as research only sites.

The fishes of Bonaire have not been systematically studied, but J.M. van Rooij and others have conducted a prolific amount of research on parrotfishes (Scaridae). Other reef fish research conducted on Bonaire includes Velde et al. (1990), Nemtzov et al. (1993), Nemtzov (1997), and Wicksten (1998).

This paper presents a description of the fish assemblage of the BMP with preliminary analyses to examine relationships among sites on Bonaire and Klein Bonaire. The utility of REEF as a community-based monitoring program to enhance the management of the BMP is also discussed.

METHODS

Volunteers conduct REEF surveys during organized field surveys or on their own. REEF surveys are conducted using the Roving Diver Technique (RDT) (Schmitt and Sullivan, 1996), a visual survey method developed specifically for volunteer data collection. During RDT surveys, divers swim freely throughout a dive site and record every observed species using waterproof slates and underwater checklists. At the conclusion of each survey, divers assign each recorded species one of four $\log_{10}$ abundance categories [single (1); few (2-10); many (11-100); and abundant (> 100)]. The species data along with survey time, depth, temperature, and other environmental information are then transferred to a REEF scansheet. These sheets are returned to REEF and optically scanned into the database.

The RDT survey data provide species lists, frequency of occurrence, and relative abundance data. Percent sighting frequency (%SF) for each species is the percentage of all dives in which the species was recorded. An estimate of abundance is calculated as:

$$\text{Abundance Score} = D \times \%SF$$

where the density score (D) for each species is a weighted average index based on the frequency of observations in different abundance categories. Density score is calculated as:

$$D = ((n_S x1)+(n_F x2)+(n_M x3)+(n_A x4)) / (n_S + n_F + n_M + n_A),$$

where n_S, n_F, n_M, and n_A represent the number of times each abundance category was assigned for a given species. Data are categorized as expert or novice according to the surveyor's survey experience and performance on a series of identification exams.

A cumulative species list for the BMP was compiled using the expert survey data. However, to capitalize on the power of the large dataset, the %SF and D for each species was calculated using all surveys (expert and novice). Expert sightings

were used to reduce mis-identifications. To compare sites and areas (Bonaire and Klein Bonaire), a two-dimensional MDS ordination plot was produced using Pearson's similarity index. The similarity analysis dataset included sites with more than 20 RDT surveys (37 sites, Figure 1) and was calculated using the log of abundance score for species seen in at least 5% of all surveys (135 species). The species cutoff was used in order to minimize the effect of including rare species in a similarity analysis (Grossman et al. 1982). Analyses were completed with SYSTAT 7.01.

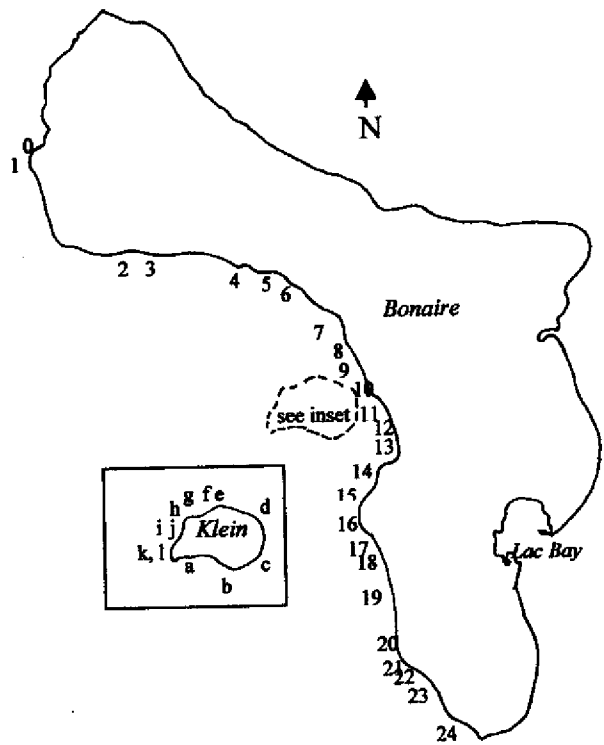


Figure 1. Map of Bonaire with sites used in the similarity analysis shown. 0- Twin Rocks; 1- North Reserve; 2- Karpata Reserve; 3- Karpata Non-Reserve; 4- Ol' Blue; 5- 1000 Steps; 6- Weber's Joy; 7- Small Wall; 8- Cliff; 9- La Machaca; 10- Bari Reef; 11- Something Special; 12- Town Pier; 13- Calabas Reef; 14- 18th Palm; 15- Bachelor's Beach; 16- The Lake; 17- Angel City; 18- Alice in Wonderland; 19- Salt Pier; 20- Invisibles; 21- Tori's Reef; 22- Pink Beach; 23- Margate Bay; 24- Red Slave; a- Forest; b- Bonaventure; c- Just a Nice Dive; d- No Name; e- Sampler; f- Knife; g- Ebo's Special; h- Carl's Hill; i- Carl's Hill Annex; j- Sharon's Serenity; k- Southwest Corner; l- Munk's Haven.

RESULTS

Between December 1993 and July 1999, REEF volunteers conducted 1,557 novice and 457 expert RDT surveys on the reefs of Bonaire and Klein Bonaire, representing 1,937 hours of survey time at 58 sites. A total of 362 species were reported, with 286 of those species reported by REEF experts (Appendix). Volunteers reported 270 species on Bari Reef, the highest species richness of all sites in the REEF database, locally and Caribbean-wide.

The composition of the fish assemblage on Bonaire reefs was similar to that found throughout the southern Caribbean. The five most frequent species sighted were blue tang (*Acanthurus coeruleus*), bicolor damsel (*Stegastes partitus*), stoplight parrotfish (*Sparisoma viride*), brown chromis (*Chromis multilineata*), and bluehead wrasse (*Thalassoma bifasciatum*). The diversity of grunts (Haemulidae) was lower than other Caribbean areas.

According to the MDS plot (Figure 2), the fish assemblages of Bonaire sites were relatively distinct from those on Klein. One notable exception was the grouping of the Karpata Reserve site with the Klein Bonaire sites and the two northern reserve sites as outliers. The Town Pier and La Machaca wreck were also outliers.

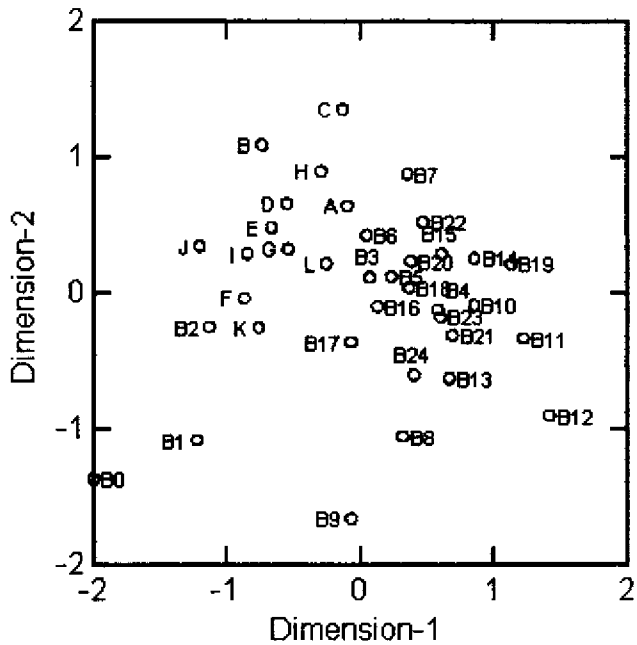


Figure 2. MDS Ordination Plot. Site labels given in Figure 1. Two distinct clusters were revealed, with Klein sites (A-K) in one and most of the Bonaire sites in the other. The Karpata Reserve site (B2) grouped with the Klein cluster. The two northern reserve sites (B0 and B1), La Machaca Wreck (B9) and Town Pier (B12) were outliers.

The overall species composition between Bonaire sites and Klein sites was the same. Species that were the most different by abundance score between Klein and Bonaire included bluestriped grunt (*Haemulon sciurus*), smallmouth grunt (*Haemulon chrysargyreum*), spotted goatfish (*Pseudupeneus maculatus*), and yellowfin mojarra (*Gerres cinereus*), with lower abundance for all species on Klein sites. The reserve sites were characterized by similarly low abundance of these species and slightly higher abundance of the planktivores blue chromis (*Chromis cyanea*), brown chromis (*Chromis multilineata*), and creole wrasse (*Clepticus parrae*). The slippery dick wrasse (*Halichoeres bivittatus*), a species commonly encountered on other Bonaire sites, was rarely seen at the reserve sites.

DISCUSSION

The reefs of Bonaire and Klein Bonaire support a rich fish assemblage, with a diverse array of species. The wide sand shelf, reef ledge, wall, and occasional rocky structures such as jetties and breakwaters provide a wide variety of habitats for reef fish species. Submerged vegetated habitat such as grassbeds and mangroves are only found within Lac Bay. The Bay is an important nursery area, and helps maintain the park's reef fish diversity (Velde et al. 1990). The lack of grassbeds adjacent to the reefs, however, has led to a lower diversity and abundance of grunts (Haemulidae) in the BMP as compared with other Caribbean reefs, and this is due to the use of grassbeds by grunts during nocturnal feeding.

Results of the ordination analysis suggest that the composition of fish assemblages of Bonaire and Klein Bonaire are distinct from each other. It is clear that the overall fish assemblage composition is similar, and that certain components of the assemblage are driving the ordination pattern. The low average abundance of bluestriped grunt and smallmouth grunt on Klein sites is most likely an important factor. It is assumed that this is also responsible for the separation of the reserve sites from other Bonaire sites. Another distinction between Klein and reserve sites from Bonaire sites is their lack of a wide sand shelf, and this was reflected in the low abundance of spotted goat, yellowfin mojarra, and slippery dick, all species that primarily utilize the sand habitat. The reserve sites are further distinguished by high wave action and currents, leading to large schools of planktivores.

The two outliers, Town Pier and La Machaca wreck, are both artificial structures and the pier is mostly surveyed during dusk. Given these factors, their distinction from the main groupings is obvious.

The MDS analysis is a useful tool to graphically examine the overall similarity among sites and identify major groups. However, to compare sites within the groups, further analysis is needed to generate sufficient resolution. It is expected that differences between sites in each group is the result of a variety of factors. The double reef system present at many of the sites on the southern end of Bonaire most likely influences the local fish assemblage. The distance of B17 (Angel City), which has a double reef, from the main Bonaire grouping (Figure 2) suggests that this is the case. A site's location in reference to prevailing current and wind regimes

should also affect the resident fishes. The level of use a site gets and its proximity to resorts and other development should be considered. For example, fish feeding by divers is illegal within the BMP, but many seaside restaurants discard leftovers in the water. Additional factors that may drive differences between sites include the width of the sand shelf and the presence and density of octocorals in the shallow area of a reef. The factors listed above can be used in concert with REEF data in a multivariate analysis to further investigate site-specific differences in fish assemblage composition.

The large survey effort by volunteers on the reefs of the BMP is undeniably a valuable resource to park management. The question is how to use this information. As illustrated here, a large number of volunteer surveys can produce a relatively complete taxonomic list for an area. Survey data collected in a consistent manor at a number of sites can also provide a means for site characterization. Beyond similarity analyses, trophic patterns and fish-habitat interactions can also be investigated (Jeffrey and Pattengill-Semmens, in prep.). The continual nature of volunteer data can also provide a valuable dataset to document change over time. In addition to long-term monitoring, REEF data can be used in management decisions, such as in siting algorithms for marine reserves (Schmitt et al. in press) or to assess the impact of disturbance events or management strategies such as harvest restrictions (Pattengill-Semmens and Semmens 1999).

One issue of particular concern for the BMP is the level of use by divers and how that use affects the overall condition of the reef. The reserves, which restrict recreational SCUBA diving, can be a way to look at this. The dissimilarity of the Bonaire reserve sites from other areas on Bonaire suggests that either the sites are different or that the level of use at other Bonaire sites has influenced their structure. The location of both reserves on the northern portion of the leeward side, an area subject to greater wind and waves, could be one factor driving this difference. Further analysis and research, along with historical data, will be needed to more fully understand the differences.

The use of volunteer-generated data requires that consideration be given to the wide variety of surveyor skill levels. It has been shown that for a given number of surveys, experts generate more precise data (Pattengill-Semmens and Semmens 1998). However, it is also important to note that the power of non-expert data often exceeds expert data at survey sites, because of differences in sampling effort. The statistical power to detect change increases as sample size increases, and the power of non-expert data has been shown to be comparable to or better than that generated by a smaller group of experts for most species (Pattengill-Semmens and Semmens 1998). Confidence in data used from the REEF database can be increased by selecting a sighting frequency cut-off (i.e. only using information for species seen in more than a given percentage of surveys) or by selectively using data from REEF members with more experience and skill.

The use of REEF Fish Survey Project data to describe the fish assemblages of the BMP is a significant step toward better understanding the park's resources. The species list generated here is the most complete set of information to date at the fish

assemblage level. Further analyses on the data should be initiated to investigate site-specific differences. Additionally, the dataset can complement scientific research and other park monitoring efforts. Volunteer-generated data such as those in the REEF program are a valuable element to resource managers, and can enhance the management and protection of a marine resource.

LITERATURE CITED

Dixon, J., L.F. Scura, and T. van't Hof. 1993. Meeting ecological and economic goals: marine parks in the Caribbean. *Ambio* **22** (2-3): 117-125.

Grossman, G.D., P.B. Moyle, and J.O. Whitaker. 1982. Stochasticity in structural and functional characteristics of an Indiana stream fish assemblage: a test of community theory. *American Naturalist* **120** (4):423-454.

Jeffrey, C.F.G. and C.V. Pattengill-Semmens. [In Prep]. Quantifying habitat heterogeneity and regional differences in reef fish assemblages within the Florida Keys Marine Scanctuary – A preliminary analysis.

Nemtzov, S.C. 1997. Intraspecific variation in home range exclusivity by female green razorfish, *Xyrichtys splandens* (family Labridae), in different habitats. *Environmental Biology of Fishes* **50**(4):371-381.

Nemtzov, S.C., S M. Kajiura, and C A. Lompart. 1993. Diel color phase changes in the coney *Epinephelus fulvus* (Teleostei, Serranidae). *Copeia* **3**:883-885.

Pattengill-Semmens, C.V. and B.X. Semmens. 1999. Assessment and monitoring applications of a community-based monitoring program: The Reef Environmental Education Foundation. Poster Presentation. *International Conference on Scientific Aspects of Coral Reef Assessment, Monitoring, and Restoration.* April 14-16, 1999. NCRI. Ft. Lauderdale, Florida USA.

Pattengill-Semmens, C.V. and B.X. Semmens. 1998. An analysis of fish survey data generated by nonexpert volunteers in the Flower Garden Banks National Marine Sanctuary. *Journal of Gulf of Mexico Science* **2**:196-207.

Schmitt, E.F., T.D. Sluka, and K M. Sullivan-Sealy.[In press]. Evaluating the use of roving diver and transect surveys to assess the coral reef assemblages off southeastern Hispaniola. *Coral Reefs.*

Schmitt, E.F. and K.M. Sullivan. 1996. Analysis of a volunteer method for collecting fish presence and abundance data in the Florida Keys. *Bulletin of Marine Science* **59**(2) 404-416.

Van Veghel, M.L J. 1997. A field guide to the reefs of Curacao and Bonaire. *8th International Coral Reef Symposium* 1:223-234.

Velde, G.V.D., M.W. Gorissen, C.D. Hartog, T.V.T.. Hoff, and G.J. Meijer. 1992. Importance of the Lac-lagoon (Bonaire, Netherlands Antilles) for a selected number of reef fish species. *The Ecology of Mangroves and Related Systems, Mombasa (Kenya)* **247** (1-3):139-140.

Wicksten, M.K. 1998. Behaviour of cleaners and their client fishes at Bonaire, Netherlands Antilles. *Environmental Biology of Fishes* **47** (1):81-91.

Appendix. Species list for REEF surveys from Bonaire and Klein Bonaire. Species reported by experts were used to compile the list, but values given are based on all REEF surveys (novice and expert). Data given are sighting frequency (%SF) and density score (den).

Common Name	Species	%SF	Den
Angelfishes	*Pomacanthidae*		
Cherubfish	*Centropyge argi*	7%	1.6
Flameback Angelfish	*Centropyge aurantonotus*	0%	1.7
Blue Angelfish	*Holacanthus bermudensis*	1%	1.8
Queen Angelfish	*Holacanthus ciliaris*	42%	1.5
Rock Beauty	*Holacanthus tricolor*	86%	2.1
Gray Angelfish	*Pomacanthus arcuatus*	3%	1.4
French Angelfish	*Pomacanthus paru*	57%	1.6
Barracudas	*Sphyraenidae*		
Great Barracuda	*Sphyraena barracuda*	21%	1.4
Southern Sennet	*Sphyraena picudilla*	1%	1.9
Bigeyes	*Priacanthidae*		
Bigeye	*Priacanthus arenatus*	1%	1.5
Glasseye Snapper	*Priacanthus cruentatus*	10%	1.3
Blennies (Clinids)	*Clinidae*		
Roughhead Blenny	*Acanthemblemaria aspera*	1%	1.8
Secretary Blenny	*Acanthemblemaria maria*	29%	2.2
Spinyhead Blenny	*Acanthemblemaria spinosa*	10%	1.9
Yellowface Pikeblenny	*Chaenopsis limbaughi*	1%	1.3
Blackhead Blenny	*Coralliozetus bahamensis*	7%	1.5
Sailfin Blenny	*Emblemaria pandionis*	6%	1.5
Lofty Triplefin	*Enneanectes altivelis*	3%	1.3
Blackedge Triplefin	*Enneanectes atrorus*	0%	1
Mimic Triplefin	*Enneanectes jordani*	0%	2
Redeye Triplefin	*Enneanectes pectoralis*	1%	1.4
Puffcheek Blenny	*Labrisomus bucciferus*	0%	1
Downy Blenny	*Labrisomus kalisherae*	0%	1
Hairy Blenny	*Labrisomus nuchipinnis*	3%	1.2
Goldline Blenny	*Malacoctenus aurolineatus*	1%	1.6
Dusky Blenny	*Malacoctenus gilli*	1%	1.2
Rosy Blenny	*Malacoctenus macropus*	1%	1.8
Saddled Blenny	*Malacoctenus triangulatus*	13%	1.8
Ringed Blenny	*Starksia hassi*	0%	1.1
Dwarf Blenny	*Starksia nanodes*	3%	1.2
Blennies (Combtooth)	*Blenniidae*		
Barred Blenny	*Hypleurochilus bermudensis*	1%	1.6
Tesselated Blenny	*Hypsoblennius invemar*	0%	1
Redlip Blenny	*Ophioblennius atlanticus*	41%	2.2
Seaweed Blenny	*Parablennius marmoreus*	3%	1.8
Molly Miller	*Scartella cristata*	1%	1.8
Bonefish	*Albulidae*		
Bonefish	*Albula vulpes*	12%	2.2
Bonnetmouths	*Inermiidae*		
Boga	*Inermia vittata*	18%	3.5
Bonnetmouth	*Emmelichthyops atlanticus*	2%	3
Boxfishes	*Ostraciontidae*		
Spotted Trunkfish	*Lactophrys bicaudalis*	47%	1.6
Honeycomb Cowfish	*Lactophrys polygonia*	47%	1.4

Appendix. Continued.

Common Name	Species	%SF (%)	Den
Scrawled Cowfish	Lactophrys quadricornis	4%	1.3
Trunkfish	Lactophrys trigonus	1%	2
Smooth Trunkfish	Lactophrys triqueter	80%	2
Brotula	Bythitidae		
Black Brotula	Stygnobrotula latebricola	0%	1
Butterflyfishes	Chaetondontidae		
Longsnout Butterflyfish	Chaetodon aculeatus	27%	1.4
Foureye Butterflyfish	Chaetodon capistratus	91%	2.3
Spotfin Butterflyfish	Chaetodon ocellatus	10%	1.9
Reef Butterflyfish	Chaetodon sedentarius	2%	1.7
Banded Butterflyfish	Chaetodon striatus	66%	2
Cardinalfishes	Apogonidae		
Bigtooth Cardinalfish	Apogon affinis	0%	2.3
Barred Cardinalfish	Apogon binotatus	18%	2.1
Whitestar Cardinalfish	Apogon lachneri	16%	1.9
Flamefish	Apogon maculatus	12%	1.8
Pale Cardinalfish	Apogon planifrons	2%	1.8
Twospot Cardinalfish	Apogon pseudomaculatus	2%	1.8
Sawcheek Cardinalfish	Apogon quadrisquamatus	0%	1.6
Belted Cardinalfish	Apogon townsendi	25%	2.1
Dusky Cardinalfish	Phaeoptyx pigmentaria	3%	1.9
Sponge Cardinalfish	Phaeoptyx xenus	9%	1.6
Clingfish	Gobiesocidae		
Barred Clingfish	Tomicodon fasciatus	0%	1
Red Clingfish	Arcos rubiginosus	2%	1.6
Cornetfishes	Fistulariidae		
Bluespotted Cornetfish	Fistularia tabacaria	4%	1.2
Chubs	Kyphosidae		
Bermuda/Yellow Chub	Kyphosus sectatrix/incisor	23%	1.9
Damselfishes	Pomacentridae		
Sergeant Major	Abudefduf saxatilis	86%	2.8
Night Sergeant	Abudefduf taurus	5%	1.8
Blue Chromis	Chromis cyanea	91%	3.6
Sunshinefish	Chromis insolata	5%	1.8
Brown Chromis	Chromis multilineata	91%	3.8
Yellowtail Damselfish	Microspathodon chrysurus	83%	2.4
Longfin Damselfish	Stegastes diencaeus	48%	2.5
Dusky Damselfish	Stegastes fuscus	41%	2.3
Beaugregory	Stegastes leucostictus	15%	2
Bicolor Damselfish	Stegastes partitus	93%	3.6
Threespot Damselfish	Stegastes planifrons	77%	3
Cocoa Damselfish	Stegastes variabilis	26%	2.3
Drums	Sciaenidae		
Highhat	Equetus acuminatus	2%	1.2
Jackknife-Fish	Equetus lanceolatus	1%	1.1
Spotted Drum	Equetus punctatus	46%	1.5
Reef Croaker	Odontoscion dentex	0%	2
Eels (Conger)	Congridae		
Brown Garden Eel	Heteroconger halis	6%	3.1
Eels (Moray)	Muranidae		
Chain Moray	Echidna catenata	6%	1.2
Chestnut Moray	Enchelycore carychroa	1%	1

Appendix. Continued.

Common Name	Species	%SF (%)	Den
Viper Moray	*Enchelycore nigricans*	1%	1.1
Green Moray	*Gymnothorax funebris*	5%	1.1
Goldentail Moray	*Gymnothorax miliaris*	22%	1.3
Spotted Moray	*Gymnothorax moringa*	35%	1.4
Purplemouth Moray	*Gymnothorax vicinus*	2%	1.1
Reticulate Moray	*Muraena retifera*	0%	1
Eels (Snake)	*Ophichthidae*		
Spotted Spoon-nose Eel	*Echiophis intertinctus*	0%	1
Sharptail Eel	*Myrichthys breviceps*	16%	1.2
Goldspotted Eel	*Myrichthys ocellatus*	1%	1.3
Spotted Snake Eel	*Ophichthus ophis*	1%	1.1
Frogfishes	*Antennariidae*		
Longlure Frogfish	*Antennarius multiocellatus*	3%	1.2
Goatfishes	*Mullidae*		
Yellow Goatfish	*Mulloidichthys martinicus*	88%	2.9
Spotted Goatfish	*Pseudupeneus maculatus*	37%	2
Gobies	*Gobiidae*		
Colon Goby	*Coryphopterus dicrus*	14%	2
Pallid Goby	*Coryphopterus eidolon*	27%	2.2
Bridled Goby	*Coryphopterus glaucofraenum*	60%	3.1
Peppermint Goby	*Coryphopterus lipernes*	45%	2.4
Masked Goby/Glass Goby	*Coryphopterus personatus/hyalinus*	60%	3.7
Spotted Goby	*Coryphopterus punctipectophorus*	0%	2
Nineline Goby	*Ginsburgellus novemlineatus*	0%	1.5
Goldspot Goby	*Gnatholepis thompsoni*	35%	2.5
Dash Goby	*Gobionellus saepepallens*	2%	1.8
Shortstripe Goby	*Gobiosoma chancei*	8%	1.9
Orangesided Goby	*Gobiosoma dilepsis*	10%	1.4
Sharknose Goby	*Gobiosoma evelynae*	24%	2
Cleaning Goby	*Gobiosoma genie*	5%	2
Yellowline Goby	*Gobiosoma horsti*	20%	2
Spotlight Goby	*Gobiosoma louisae*	7%	1.7
Tiger Goby	*Gobiosoma macrodon*	1%	1.3
Broadstripe Goby	*Gobiosoma prochilos*	1%	1.8
Yellownose Goby	*Gobiosoma randalli*	24%	2
Slaty Goby	*Gobiosoma tenox*	0%	1.2
Yellowprow Goby	*Gobiosoma xanthiprora*	1%	1.7
Hovering Goby	*Ioglossus helenae*	1%	1.8
Island Goby	*Lythrypnus nesiotes*	1%	1.5
Orangespotted Goby	*Nes longus*	0%	2
Rusty Goby	*Priolepis hipoliti*	4%	1.2
Grunts	*Haemulidae*		
Black Margate	*Anisotremus surinamensis*	17%	1.6
Tomtate	*Haemulon aurolineatum*	2%	2.4
Caesar Grunt	*Haemulon carbonarium*	22%	1.6
Smallmouth Grunt	*Haemulon chrysargyreum*	34%	2.7
French Grunt	*Haemulon flavolineatum*	88%	2.4
Spanish Grunt	*Haemulon macrostomum*	5%	1.6
Cottonwick	*Haemulon melanurum*	1%	2.2
Sailors Choice	*Haemulon parra*	6%	1.8
Bluestriped Grunt	*Haemulon sciurus*	53%	1.9

Appendix. Continued.

Common Name	Species	%SF (%)	Den
Striped Grunt	*Haemulon striatum*	2%	2.5
Hawkfishes	*Cirrhitidae*		
Redspotted Hawkfish	*Amblycirrhitus pinos*	32%	1.7
Jacks	*Carangidae*		
Yellow Jack	*Caranx bartholomaei*	2%	2.1
Blue Runner	*Caranx crysos*	0%	2
Crevalle Jack	*Caranx hippos*	2%	1.7
Horse-Eye Jack	*Caranx latus*	25%	2.1
Black Jack	*Caranx lugubris*	1%	1.6
Bar Jack	*Caranx ruber*	80%	2.2
Mackerel Scad	*Decapterus macarellus*	3%	3.3
Round Scad	*Decapterus punctatus*	1%	3.4
Irish Pompano	*Diapterus olisthostomus*	0%	1.6
Rainbow Runner	*Elagatis bipinnulata*	1%	1.8
Spanish Mackerel	*Scomberomorus maculatus*	0%	2
Cero	*Scomberomorus regalis*	2%	1.7
Bigeye Scad	*Selar crumenophthalmus*	0%	3.6
Permit	*Trachinotus falcatus*	2%	1.5
Palometa	*Trachinotus goodei*	6%	2.1
Jawfishes	*Opistognathidae*		
Yellowhead Jawfish	*Opistognathus aurifrons*	11%	1.7
Leatherjackets	*Balistidae*		
Orange Filefish	*Aluterus schoepfi*	2%	1.7
Scrawled Filefish	*Aluterus scriptus*	20%	1.3
Queen Triggerfish	*Balistes vetula*	3%	1.3
Whitespotted Filefish	*Cantherhines macrocerus*	43%	1.5
Orangespotted Filefish	*Cantherhines pullus*	46%	1.6
Ocean Triggerfish	*Canthidermis sufflamen*	2%	1.5
Black Durgon	*Melichthys niger*	37%	2.3
Pygmy Filefish	*Monacanthus setifer*	0%	1.7
Slender Filefish	*Monacanthus tuckeri*	13%	1.4
Lefteye Flounders	*Bothidae*		
Peacock Flounder	*Bothus lunatus*	24%	1.3
Eyed Flounder	*Bothus ocellatus*	4%	1.3
Lizzardfishes	*Synodotidae*		
Sand Diver	*Synodus intermedius*	37%	1.5
Bluestriped Lizardfish	*Synodus saurus*	1%	1.4
Red Lizardfish	*Synodus synodus*	1%	1.3
Snakefish	*Trachinocephalus myops*	0%	1.2
Mojarra	*Gerreidae*		
Spotfin Mojarra	*Eucinostomus argenteus*	0%	1.3
Slender Mojarra	*Eucinostomus jonesi*	2%	2.1
Mottled Mojarra	*Eucinostomus lefroyi*	9%	2.1
Flagfin Mojarra	*Eucinostomus melanopterus*	4%	2
Yellowfin Mojarra	*Gerres cinereus*	45%	2.1
Mullets	*Mugilidae*		
White Mullet	*Mugil curema*	7%	2.2
Needlefishes	*Belonidae*		
Flat Needlefish	*Ablennes hians*	1%	1.8
Keeltail Needlefish	*Platybelone argalus*	3%	2.3
Atlantic Needlefish	*Strongylura marina*	0%	3
Redfin Needlefish	*Strongylura notata*	0%	2.5

Appendix. Continued.

Common Name	Species	%SF (%)	Den
Houndfish	*Tylosurus crocodilus*	4%	2.3
Parrotfishes	*Scaridae*		
Midnight Parrotfish	*Scarus coelestinus*	9%	1.4
Blue Parrotfish	*Scarus coeruleus*	7%	1.5
Striped Parrotfish	*Scarus croicensis*	45%	2.2
Rainbow Parrotfish	*Scarus guacamaia*	13%	1.7
Princess Parrotfish	*Scarus taeniopterus*	82%	2.5
Queen Parrotfish	*Scarus vetula*	77%	2.5
Greenblotch Parrotfish	*Sparisoma atomarium*	2%	1.6
Redband Parrotfish	*Sparisoma aurofrenatum*	72%	2.4
Redtail Parrotfish	*Sparisoma chrysopterum*	28%	1.8
Bucktooth Parrotfish	*Sparisoma radians*	2%	2.2
Redfin Parrotfish	*Sparisoma rubripinne*	28%	1.8
Stoplight Parrotfish	*Sparisoma viride*	93%	2.7
Pipefishes	*Syngnathidae*		
Harlequin Pipefish	*Micrognathus ensenadae*	1%	1
Longsnout Seahorse	*Hippocampus reidi*	3%	1.3
Shortfin Pipefish	*Cosmocampus elucens*	0%	1
Porgies	*Sparidae*		
Jolthead Porgy	*Calamus bajonado*	5%	1.2
Saucereye Porgy	*Calamus calamus*	7%	1.4
Sheepshead Porgy	*Calamus penna*	0%	1
Silver Porgy	*Diplodus argenteus*	2%	1
Puffers	*Tetradontidae*		
Sharpnose Puffer	*Canthigaster rostrata*	76%	2.3
Bridled Burrfish	*Chilomycterus antennatus*	0%	1.9
Web Burrfish	*Chilomycterus antillarum*	1%	1.2
Balloonfish	*Diodon holocanthus*	40%	1.8
Porcupinefish	*Diodon hystrix*	16%	1.2
Bandtail Puffer	*Sphoeroides spengleri*	3%	1.9
Rays (Eagle)	*Myliobatidae*		
Spotted Eagle Ray	*Aetobatus narinari*	1%	1.1
Rays (Stingray)	*Dasyatidae*		
Southern Stingray	*Dasyatis americana*	2%	1.1
Remoras	*Echeneididae*		
Sharksucker	*Echeneis naucrates*	1%	1.3
Sea Basses	*Serranidae*		
Sand Perch	*Diplectrum formosum*	0%	2
Rock Hind	*Epinephelus adscensionis*	22%	1.4
Graysby	*Epinephelus cruentatus*	82%	2.2
Coney	*Epinephelus fulvus*	59%	2
Red Hind	*Epinephelus guttatus*	15%	1.6
Marbled Grouper	*Epinephelus inermis*	0%	4
Red Grouper	*Epinephelus morio*	0%	1.6
Nassau Grouper	*Epinephelus striatus*	2%	1.3
Yellowcheek Basslet	*Gramma linki*	0%	2.5
Fairy Basslet	*Gramma loreto*	83%	3.1
Blackcap Basslet	*Gramma melacara*	2%	2.8
Hybrid Hamlet	*Hypoplectrus (Hybrid)*	6%	1.2
Yellowbelly Hamlet	*Hypoplectrus aberrans*	2%	1.1
Yellowtail Hamlet	*Hypoplectrus chlorurus*	44%	1.7
Blue Hamlet	*Hypoplectrus gemma*	0%	2

Appendix. Continued.

Common Name	Species	%SF (%)	Den
Golden Hamlet	*Hypoplectrus gummigutta*	0%	1.3
Shy Hamlet	*Hypoplectrus guttavarius*	0%	1.2
Black Hamlet	*Hypoplectrus nigricans*	5%	1.3
Barred Hamlet	*Hypoplectrus puella*	45%	1.6
Masked Hamlet	*Hypoplectrus sp.*	0%	1.8
Tan Hamlet	*Hypoplectrus sp.*	1%	1.2
Butter Hamlet	*Hypoplectrus unicolor*	38%	1.5
Threeline Basslet	*Lipogramma trilineatum*	4%	1.4
Candy Bass	*Liopropoma carmabi*	1%	1.1
Cave Bass	*Liopropoma mowbrayi*	0%	1.1
Peppermint Bass	*Liopropoma rubre*	14%	1.5
Black Grouper	*Mycteroperca bonaci*	4%	1.5
Yellowmouth Grouper	*Mycteroperca interstitialis*	6%	1.2
Comb Grouper	*Mycteroperca rubra*	5%	1.2
Tiger Grouper	*Mycteroperca tigris*	55%	1.6
Yellowfin Grouper	*Mycteroperca venenosa*	4%	1.1
Creole-fish	*Paranthias furcifer*	63%	2.8
Lantern Bass	*Serranus baldwini*	10%	1.6
Tobaccofish	*Serranus tabacarius*	16%	1.7
Harlequin Bass	*Serranus tigrinus*	80%	2.3
School Bass	*Shultzea beta*	4%	2.9
Scorpionfishes	*Scorpionidae*		
Reef Scorpionfish	*Scorpaenodes caribbaeus*	3%	1.4
Spotted Scorpionfish	*Scorpaena plumieri*	19%	1.2
Mushroom Scorpionfish	*Scorpaena inermis*	0%	1
Sharks (Requeim)	*Carcharhinidae*		
Reef Shark	*Carcharhinus perezi*	0%	1
Blackfin Snapper	*Lutjanus buccanella*	1%	2.7
Sharks (Nurse)	*Orectolobidae*		
Nurse Shark	*Ginglymostoma cirratum*	1%	1.2
Snappers	*Lutjanidae*		
Mutton Snapper	*Lutjanus analis*	3%	1.6
Schoolmaster	*Lutjanus apodus*	83%	2.3
Cubera Snapper	*Lutjanus cyanopterus*	4%	1.5
Gray Snapper	*Lutjanus griseus*	21%	2.3
Dog Snapper	*Lutjanus jocu*	2%	1.8
Mahogany Snapper	*Lutjanus mahogoni*	69%	2.2
Lane Snapper	*Lutjanus synagris*	1%	2.3
Yellowtail Snapper	*Ocyurus chrysurus*	83%	2.6
Snook	*Centropomidae*		
Common Snook	*Centropomus undecimalis*	4%	1.7
Soapfishes	*Grammistidae*		
Whitespotted Soapfish	*Rypticus maculatus*	0%	1
Greater Soapfish	*Rypticus saponaceus*	31%	1.5
Spotted Soapfish	*Rypticus subbifrenatus*	3%	1.4
Squirrelfishes	*Holocentridae*		
Squirrelfish	*Holocentrus adscensionis*	26%	1.7
Reef Squirrelfish	*Holocentrus coruscum*	5%	1.7
Longjaw Squirrelfish	*Holocentrus marianus*	38%	1.7
Longspine Squirrelfish	*Holocentrus rufus*	34%	1.7
Dusky Squirrelfish	*Holocentrus vexillarius*	14%	1.7
Blackbar Soldierfish	*Myripristis jacobus*	82%	2.5

Appendix. Continued.

Common Name	Species	%SF (%)	Den
Cardinal Soldierfish	*Plectrypops retrospinis*	4%	1.2
Surgonfishes	*Acanthuridae*		
Ocean Surgeonfish	*Acanthurus bahianus*	75%	2.6
Doctorfish	*Acanthurus chirurgus*	45%	2.1
Blue Tang	*Acanthurus coeruleus*	93%	2.9
Sweepers	*Pempheridae*		
Shortfin Sweeper	*Pempheris poeyi*	1%	2.9
Glassy Sweeper	*Pempheris schomburgki*	3%	2.2
Tarpon	*Elopidae*		
Tarpon	*Megalops atlanticus*	8%	1.7
Tilefishes	*Matacanthidae*		
Sand Tilefish	*Malacanthus plumieri*	3%	1.5
Trumpetfishes	*Aulostomidae*		
Trumpetfish	*Aulostomus maculatus*	92%	2.2
Wrassess	*Labridae*		
Spotfin Hogfish	*Bodianus pulchellus*	2%	2
Spanish Hogfish	*Bodianus rufus*	81%	2.2
Creole Wrasse	*Clepticus parrae*	77%	3.4
Slippery Dick	*Halichoeres bivittatus*	51%	2.8
Yellowhead Wrasse	*Halichoeres garnoti*	85%	3
Clown Wrasse	*Halichoeres maculipinna*	40%	2.3
Rainbow Wrasse	*Halichoeres pictus*	29%	2.4
Blackear Wrasse	*Halichoeres poeyi*	1%	2.1
Puddingwife	*Halichoeres radiatus*	40%	1.9
Rosy Razorfish	*Hemipteronotus martinicensis*	6%	2.1
Pearly Razorfish	*Hemipteronotus novacula*	2%	1.8
Green Razorfish	*Hemipteronotus splendens*	7%	1.6
Hogfish	*Lachnolaimus maximus*	5%	1.9
Bluehead	*Thalassoma bifasciatum*	89%	3.2
TOTAL # SPECIES	**284**		

Essential Fish Habitat and Marine Reserves for Groupers in the Turks & Caicos Islands

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ABSTRACT

There has been much interest recently in the use of marine reserves to conserve fish stocks, particularly those species such as groupers, which are long-lived and slow growing and in many cases aggregate to spawn. Marine reserves may benefit fish stocks in several ways, including protection of spawning stock biomass and the maintenance of undisturbed fish habitat. Studies on the habitat preferences of Turks & Caicos grouper indicate that grouper occupy a wide range of habitats. Coney (*Epinephelus fulvus*) and adult Nassau grouper (*E. striatus*) were most abundant on high-relief shelf-edge bank reefs. Studies of the effects of protection on grouper in the Bahamas, Barbados, Belize, Cuba, the Dominican Republic, and the Florida Keys have shown increased density and biomass of groupers in protected areas. However, recent research in the Turks & Caicos Islands shows no effect of marine reserves on grouper abundance or distribution. Fishing pressure on grouper in the Turks & Caicos Islands may be insufficient to cause differences in density or biomass between fished and protected areas. Several species of grouper, such as Nassau grouper and gag (*Mycteroperca microlepis*) undertake seasonal spawning migrations of up to several hundred kilometers. During these migrations, grouper may leave the boundaries of marine reserves and may be subject to fishing mortality. More information is needed on the habitat preferences and migratory habits of groupers in order to design more effective reserves.

KEY WORDS: Essential fish habitat, grouper, marine reserves

INTRODUCTION

Groupers (Serranidae) are important to both commercial and recreational fisheries. They occur worldwide in warm-temperate to tropical waters, generally associated with hard bottom habitats. The larger groupers (those most targeted by fisheries) are slow-growing, long-lived species with delayed reproduction and reduced spawning periods (Chiappone et al. 2000). Many species are protogynous hermaphrodites that aggregate to spawn (Domeier and Colin 1997). These life history traits render groupers particularly susceptible to overexploitation (Huntsman and Schaaf 1994). Groupers are subject to intense fishing pressure, particularly in

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the southeastern United States and Caribbean regions, where catches have declined dramatically over the past few decades (Bannerot et al. 1987, Bohnsack et al. 1994, Sadovy 1994). Conventional regulation of catch and effort has apparently done little to prevent overfishing of grouper stocks (Chiappone et al. 2000). Nassau grouper (*Epinephelus striatus*) and jewfish (*E. itajara*) are considered commercially extinct throughout much of the Caribbean (Sadovy 1994) and are protected in the southern Atlantic waters of the United States (including Puerto Rico and the U.S. Virgin Islands). With the authorization of the Sustainable Fisheries Act in 1996, the emphasis of fisheries management has shifted to include conservation of essential fish habitat and the creation of non-extractive marine reserves (Rosenberg et al. 2000). Recently, a number of studies have investigated the habitat preferences of groupers (Eggleston 1995, Sluka et al. 1996a,b, Sullivan and Sluka 1996, Sluka et al. 1998) and the efficacy of marine reserves in protecting grouper stocks (Sluka et al. 1997, 1998, Chiappone et al. 2000). To date, species-specific patterns of habitat preference remain unclear. Most species appear to prefer moderate to high-relief habitats with abundant holes and crevices, while some prefer isolated patch reefs with surrounding sandy bottom (reviewed in Sluka et al. 1996a). Among-habitat distribution of grouper depends primarily on a combination of habitat preference and fishing pressure, in addition to other biotic and abiotic factors (Sluka 1995). Within a preferred habitat, distribution will also depend on resource allocation such as food, shelter, and cleaning stations (Sluka 1995). However, patterns of fishing pressure are likely more important than habitat in determining grouper distribution (Sluka et al. 1996a), and studies of habitat preference may therefore be confounded by the effects of exploitation.

Healthy populations of grouper still exist in the Turks and Caicos Islands (TCI), where they support small-scale subsistence fisheries. The Turks and Caicos Islands, located at the southeastern end of the Bahamian Archipelago, support a relatively sparse human population, and a large portion of the archipelago remains uninhabited. Fishing pressure is therefore localized around three population centers: Providenciales, Grand Turk, and South Caicos. Many areas within this archipelago remain virtually unfished. The primary method of harvesting is spearfishing (using a Hawaiian sling) from small (< 5 m) outboard skiffs. Two lobster boats operating out of South Caicos also land grouper as bycatch from their traps. Current management for grouper and other finfish species involves only three regulations:

i) A restriction on the use of trigger-operated spear guns,
ii) A ban on the use of SCUBA for any harvesting, and
iii) A series of small marine reserves in which all extractive activities are disallowed.

The ban on SCUBA effectively restricts the harvest of grouper to depths shallower than ~ 20 meters. Lobster traps are typically set within this depth range also (W. Clerveaux, Turks and Caicos Dept. of Environment and Coastal Resources, personal communication). Populations of grouper in the Turks and Caicos Islands represent an ideal opportunity to study habitat preferences of grouper without the confounding effects of exploitation and to determine the efficacy of small marine reserves in

protecting groupers from localized exploitation. The objectives of this study were:

i) To determine the density of juvenile, intermediate and adult life history stages of groupers in a variety of habitats on the Caicos Bank, Turks and Caicos Islands, and

ii) To compare the density of groupers inside and outside of the Admiral Cockburn Land and Sea Park, a small marine reserve located on the south shore of South Caicos.

METHODS

Study Sites

The study area was located at the eastern end of the Caicos Bank, Turks and Caicos Islands (Figure 1). The Caicos Bank is a shallow, oolitic limestone platform that rises abruptly from depths of 2000 - 4000 m. The platform is bordered by extensive coral reefs. These shelf edge reefs typically occur at 15-20 m depth and drop almost vertically to a depth of several hundred meters.

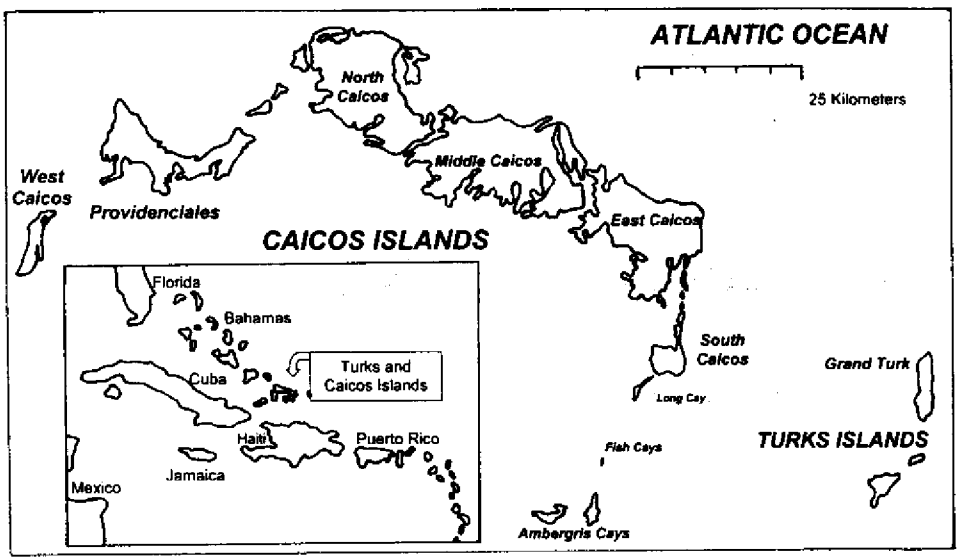


Figure 1. Map of the Turks and Caicos Islands, showing their location within the wider Caribbean region.

The Caicos Bank also supports extensive shallow sand flats, mangroves, seagrass beds, and shallow fringing and patch reefs. The study area was broadly divided into three zones:

i) The Admiral Cockburn Land and Sea Park (ACLSP, Figure 2) from the southeastern tip of South Caicos (High Point) to the southwestern tip of Long Cay (SWLC). This zone is closed to all fishing, although some poaching occurs (author's personal observations).

ii) The area north of the ACLSP from High Point to Plandon Cay. This zone is only lightly fished due to rough sea conditions and the prevalence of sharks.

iii) The area south of the ACLSP from SWLC to Ambergris Cay. Moderate fishing pressure is concentrated in this area, which is shallower and less turbulent than the windward zone north of the ACLSP. Within these three zones, 23 sites representing four habitat types were surveyed. The habitat types included fringing reef, channel reef, patch reef, and shelf-edge bank reef. All habitat types were represented in each of the three zones.

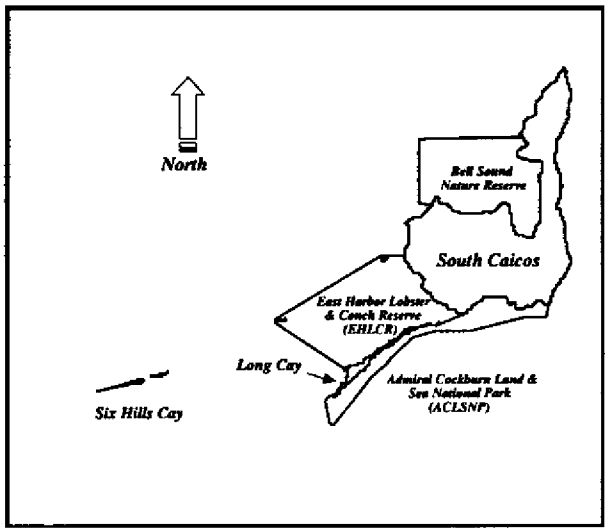


Figure 2. Location of the Admiral Cockburn Land and Sea Park, South Caicos, Turks and Caicos Islands.

Census Technique

In order to compare our results to those of previous studies in other regions, we replicated the survey methods used by Sluka et al. (1996a) and Chiappone et al. (2000). At each site, abundance and total length (to the nearest cm) of six grouper species were visually estimated along 10 - 20 haphazardly-placed transects measuring 20 m x 5 m. The species surveyed included Nassau grouper (*Epinephelus*

striatus), yellowfin grouper (*Mycteroperca venenosa*), tiger grouper (*M. tigris*), red hind (*E. guttatus*), graysby (*E. cruentatus*) and coney (*E. fulvus*). Of these, only the Nassau and yellowfin groupers are commonly targeted by fishers, despite the fact that adult yellowfin grouper have been implicated in cases of ciguatera poisoning (Smith 1997). Groupers observed on the transects were classified according to three size categories. Larger groupers (Nassau, yellowfin and tiger) were categorized as follows: juveniles 0 - 15 cm total length (TL), intermediates 16 - 40 cm TL, and adults > 40 cm TL. Smaller species (red hind, graysby and coney) were categorized as: juveniles 0 - 10 cm TL, intermediates 11 - 20 cm TL, and adults > 20 cm TL.

Statistical Analysis

Data were tested for normality of distribution using the Wilke-Shapiro test and homogeneity of variance using Levene's test. For all species, density data were non-normal and variances were unequal. Monotonic transformations failed to normalize the data or homogenize the variance. Kruskal-Wallis non-parametric analysis of variance was therefore used to compare density of each life history stage among habitats and zones separately. Spearman rank correlations were used to determine the relationship between grouper density and depth.

RESULTS

Non-parametric analysis of variance indicated that the population densities of most grouper species differed among habitats and/or zones during one or more life history stages, and that the patterns of density among habitats and locations differed throughout ontogeny for nearly all species. A weak positive correlation existed between the depth of the transects and the density of intermediate and adult coney ($R = 0.21$, $P < 0.05$ and 0.28, $p < 0.001$, respectively) and adult Nassau grouper ($R = 0.24$, $p < 0.01$). The density of remaining grouper species and life stages showed no relation to depth ($R < 0.2$, $p > 0.05$). The results for each species are presented separately below.

Coney (*Epinephelus fulvus*)

For all life history stages, mean density of coney differed significantly between habitats (Kruskal-Wallis test, $H = 12.52$, $p < 0.01$). Densities of juveniles and intermediates were highest on shelf edge bank reefs and lowest on patch reefs (Figure 3a). Density of adults was also highest on the shelf edge, but did not appear to differ between fringing reefs and patch reefs (Figure 2). Mean density of juvenile coney did not differ among the three zones ($H = 3.75$, $p > 0.1$). Density of intermediate and adult coney was higher in the ACLSP than in either of the fished zones (Figure 3b). None of the life history stages differed in density between the northern and southern zones (Kruskal-Wallis test, $p>0.05$ for all cases).

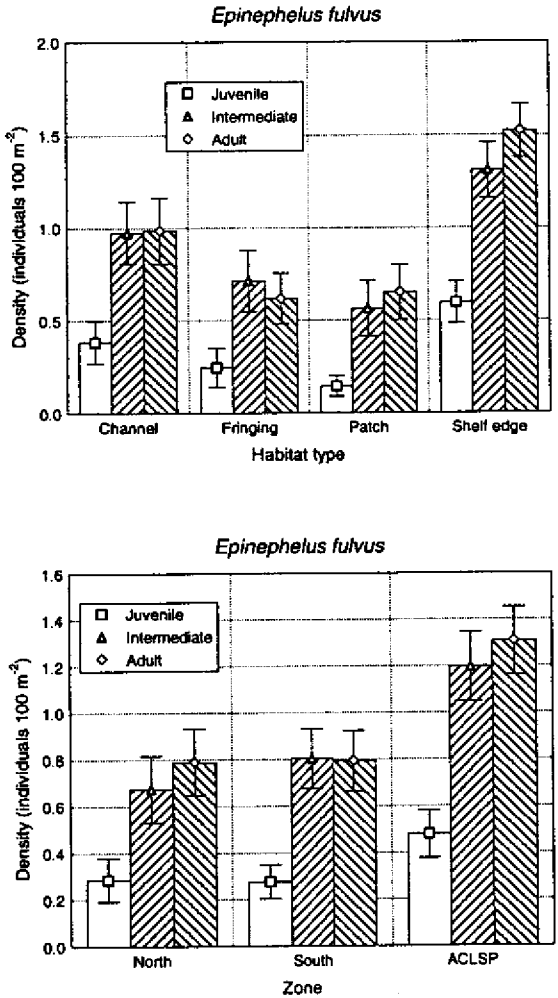


Figure 3. Mean density of coney among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

Graysby (*Epinephelus cruentatus*)

Juvenile graysby were found only on the shelf edge bank reefs (Figure 4a). Intermediate graysby were found in all habitat types. Adults were absent from fringing reefs. There were no significant differences among habitat types in mean density of intermediate or adult graysby (Kruskal-Wallis test, $p > 0.1$). Mean density of graysby did not differ significantly among zones in any life history stage ($p > 0.1$ for all cases), although there was a tendency for juvenile and adult density to be higher in the southern zone of greatest fishing pressure (Figure 4b).

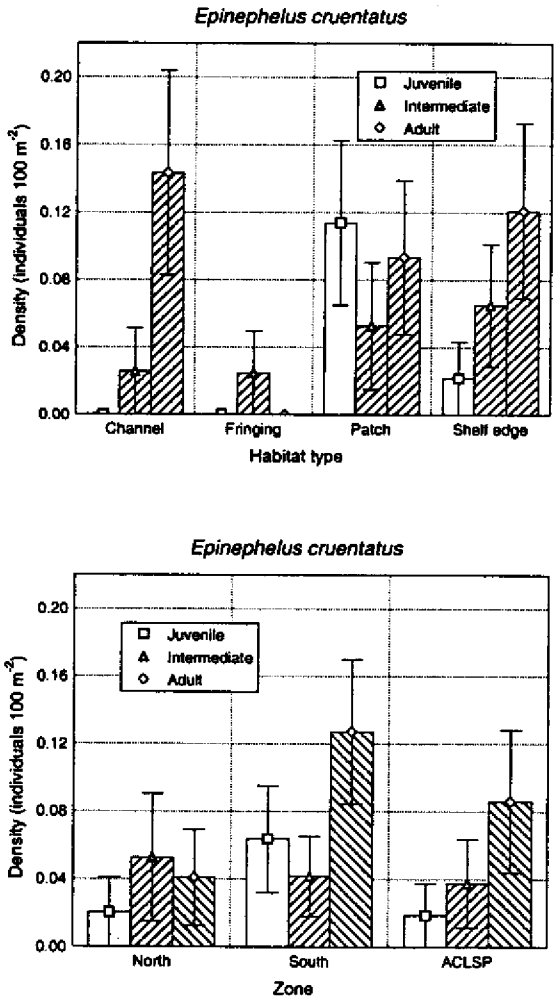


Figure 4. Mean density of graysby among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

Nassau grouper (*Epinephelus striatus*)

There were no significant among-habitat differences in mean density of juvenile or intermediate Nassau grouper (Kruskal-Wallis test, H = 0.66, P >0.01 and H = 1.78, P > 0.01, respectively). Mean density of adult Nassau grouper was significantly higher on shelf edge bank reefs (H = 36.73, P < 0.001, Figure 5a). Similarly, juvenile and intermediate density did not differ between zones, whereas adult density was significantly higher in the lightly fished northern zone than the southern zone or the ACLSP (H=11.96, p < 0.001, Figure 5b).

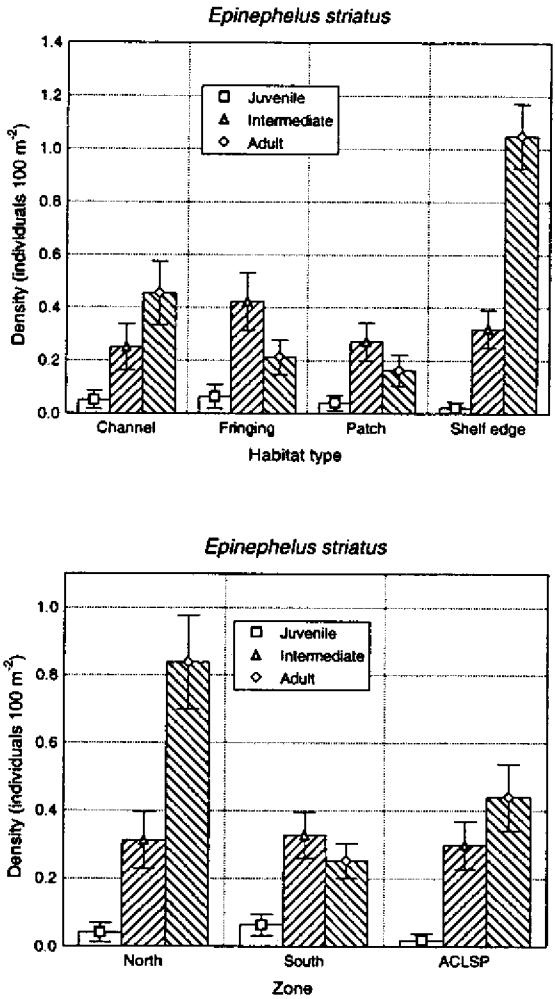


Figure 5. Mean density of Nassau grouper among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

Red hind (*Epinephelus guttatus*)

No juvenile red hind were observed over the course of this study. Mean density of intermediate and adult red hind did not differ significantly among habitats, although there was a tendency toward higher adult density on patch reefs (Kruskal-Wallis test, $p > 0.1$ for all cases, Figure 6a). Density of intermediate red hind did not differ between zones. Adult red hind, however, were significantly less common in the northern zone than in the southern zone or the ACLSP ($H = 6.32$, $p < 0.05$, Figure 6b).

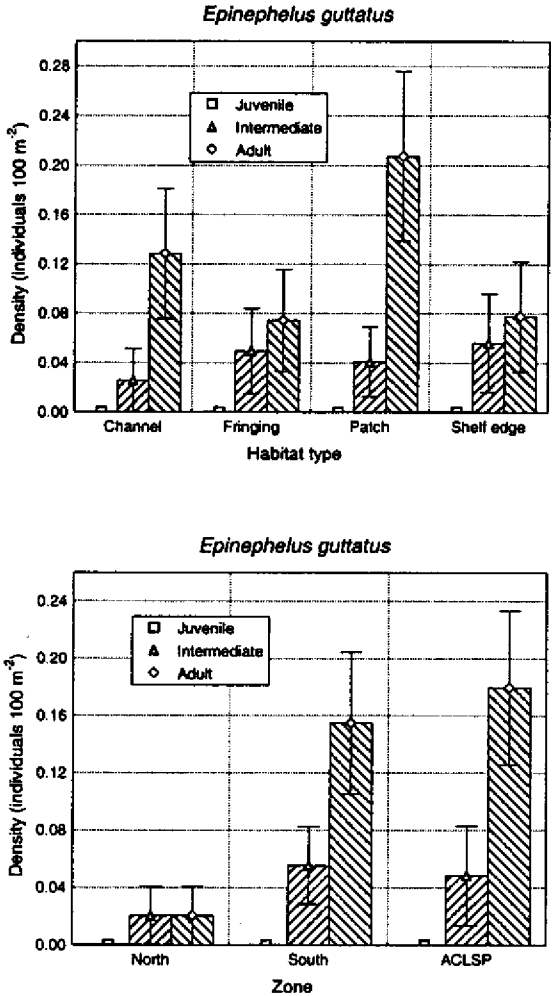


Figure 6. Mean density of red hind among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

Tiger grouper (*Mycteroperca tigris*)

Mean density of juvenile tiger grouper differed significantly among habitats (Kruskal-Wallis test, $H = 3.54$, $p > 0.1$). Juvenile density was highest in channel habitats (Figure 7a). Juveniles were not observed on fringing or shelf edge reefs. Mean density of intermediate tiger grouper did not vary significantly among habitats. Adult density was significantly higher in channel habitats but did not differ between fringing, patch or shelf edge reefs ($H = 9.92$, $p < 0.05$, Figure 7a). Juvenile tiger

grouper did not occur in the northern zone but did not differ significantly in density between the southern zone and the ACLSP. Intermediate tiger grouper were not found in the southern zone, but no significant difference in mean density of intermediates was detected among zones ($H = 4.14$, $p > 0.1$, Figure 7b). Mean density of adult tiger grouper was significantly higher in the ACLSP than in either of the fished zones ($H = 14.80$, $p < 0.001$).

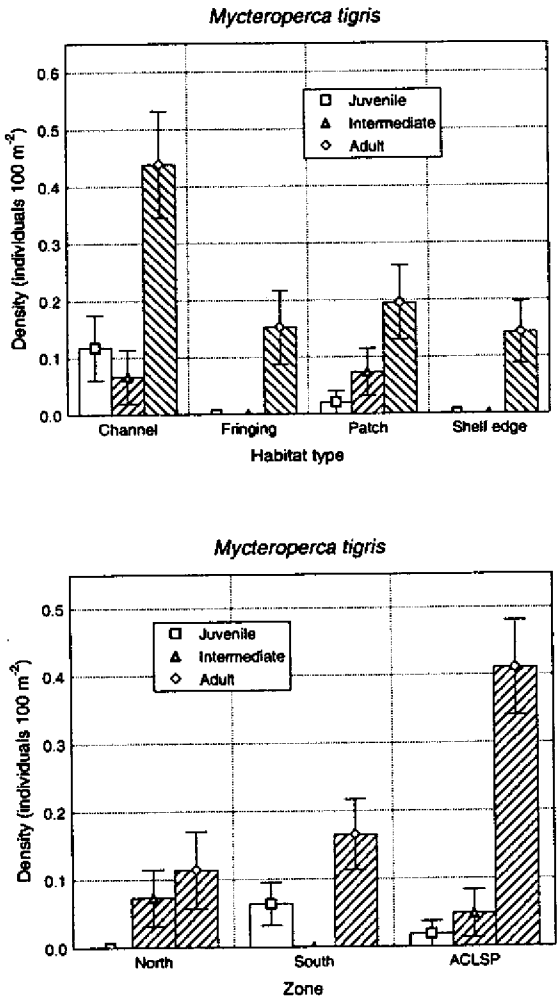


Figure 7. Mean density of tiger grouper among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

Yellowfin grouper (*Mycteroperca venenosa*)

No juvenile yellowfin grouper were observed in this study. Intermediate stage yellowfin grouper were found only on fringing reefs in the northern zone (Figures 8a,b). Mean density of adult yellowfin grouper did not differ significantly among habitats (Kruskal-Wallis test, $H = 3.67$, $p > 0.1$), although there was a tendency for density to be higher on shelf edge reefs than on fringing or patch reefs. Mean adult density differed significantly among zones ($H = 7.85$, $P < 0.05$) and was highest in the ACLSP but did not differ between fished zones (Figure 8b).

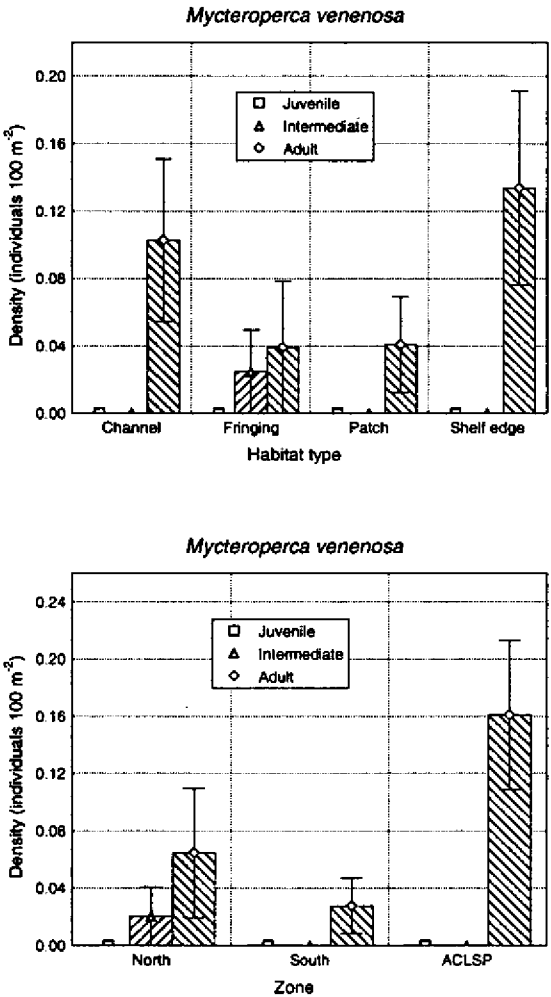


Figure 8. Mean density of yellowfin grouper among different (a) habitat types and (b) zones of fishing pressure at South Caicos, Turks and Caicos Islands.

DISCUSSION

Habitat Preferences of Grouper

Determining essential fish habitat (EFH) for all life stages is imperative to effective conservation of exploited or otherwise threatened stocks (Benaka 1999). However, this task becomes more difficult when the species in question do not appear to prefer a particular habitat type. Areas not inhabited by a species obviously do not constitute EFH, but other areas inhabited by that species may not be essential in maintaining that species' productivity (Minello 1999). Sluka et al. (1996a) suggested that in the absence of obvious habitat preference by Nassau grouper, all areas inhabited by this species must be considered "essential" and protected accordingly. Several studies have investigated habitat preferences of groupers in the wider Caribbean region (Nagelkerken 1981, Alevizon et al. 1985, Sluka and Sullivan 1996, Sluka et al. 1996a,b). Groupers are typically most abundant in moderate to high relief habitats with abundant crevices, ledges or caves (Nagelkerken 1981, Coleman et al. 1996, Sluka et al. 1996b). Smaller species such as coney and red hind may prefer isolated patch reefs (Nagelkerken 1981) and may be more abundant in low-relief habitats (Sluka et al. 1996b). Other studies have shown a preference for deeper waters by larger size classes (Thompson and Munro 1978, Coleman et al. 1996).

In this study, adult Nassau grouper and all life stages of coney were most abundant on deep (15 - 20 m) shelf edge reefs. In contrast, Sluka et al. (1996a) found no differences in either coney or Nassau grouper density among habitat types (channel reefs, fringing reefs, and windward hard-bottom) in the Exuma Cays, Bahamas. This difference may be due in part to the differing geomorphology's of South Caicos and the Exuma Cays. The windward shelf off South Caicos is very narrow and drops from a depth of 15 - 20 m to depths of 300 m or more within 200 - 300 m from shore. The coral reefs occurring on this shelf edge are structurally highly complex, with a high proportion of live coral cover and extensive caves, ledges, and crevices. In comparison, the windward hard-bottom of the Exuma region drops rather less abruptly (author's personal observations) and has low complexity and relief (Sluka et al. 1996a). Sluka et al. (1998) found that Nassau grouper and black grouper (*Mycteroperca bonaci*) were most abundant in moderate to high relief habitats in the Florida Keys. In South Caicos, shelf edge reefs had the highest relief of any habitat. Nagelkerken (1981) reported that coney preferred isolated patch reefs surrounded by sandy bottom, but coney in South Caicos were less abundant on patch reefs than on channel or shelf edge reefs. Sluka et al. (1996a) suggested that coney in the Exuma Cays preferred low-relief habitat, although they found no significant differences in density among habitat types. Chapman and Kramer (1999) found no correlation between depth, substrate complexity or coral cover on the density of coney and graysby in Barbados. The remaining species surveyed at South Caicos showed little difference in density among habitat types.

In synthesis, the results of this and previous studies may indicate a lack of specific habitat preference by several grouper species. In other words, specific

habitats may be or more less suitable depending upon other location-specific factors such as food availability, hydrography, interspecific competition, etc. The tendency of larger species (Nassau, yellowfin and tiger groupers) to be more abundant in shelf edge and channel habitats may reflect habitat selection or may be a function of fishing pressure. Shelf edge reefs are deep (15 - 40 m) and harvesting grouper from these habitats is difficult for most spear fishers using snorkel gear. Channel reefs are subject to tidal flows of several knots. This causes high turbidity and makes spear fishing difficult. Thus, the higher density of adult Nassau grouper on shelf edge reefs could result from the level of natural protection from fishing afforded by the depth of this habitat. This is supported to some extent by the weak but significant correlation between adult Nassau grouper density and depth. The problem with this explanation is that fishing pressure on groupers around South Caicos is low, and density of most grouper species is much higher at South Caicos than elsewhere in the northeastern Caribbean region (see Chiappone et al. 2000). Thus, it remains unclear whether the high density of Nassau grouper on South Caicos shelf edge reefs is a function of habitat selection or fishing pressure. In the case of coney, the higher shelf edge density may reflect habitat preference as this species is not subject to fishing pressure. It is obvious that managing fish stocks based on EFH is easier for those species that have clearly defined habitat preferences. However, Sluka et al. (1996a) point out that groupers use a wide range of habitat types throughout their life cycle. They suggest that in the case of grouper it is more important to protect reefs from fishing than to protect "optimal" grouper habitat from fishing.

The ACLSP as a Fishery Reserve

Mean density of coney, adult tiger grouper and adult yellowfin grouper was significantly higher within the ACLSP than outside the park. Whether or not these patterns of distribution are actually caused by fishing pressure is unclear. In Barbados, where coney are targeted by the trap fishery, their mean density was significantly higher within the Barbados Marine Reserve (BMR) than on fished reefs in 1995 (Tupper and Juanes 1999), but not in 1992 (Rakitin and Kramer 1996) or 1996 (Chapman and Kramer 1999). Coney and tiger grouper are not targeted by South Caicos fishermen, so it seems unlikely that fishing pressure would determine their distribution. The higher mean density of tiger grouper in the ACLSP probably resulted from a single channel reef site at which the density of this species was particularly high.

Of the larger, commercially exploited groupers, density of adult yellowfin grouper was higher within the ACLSP while density of adult Nassau grouper was higher north of the park. This result is opposite of what was expected, since fishing pressure on Nassau grouper is much higher than on yellowfin grouper. There are several possible reasons for this pattern of species density. First, it is possible that yellowfin grouper are more susceptible to fishing pressure than Nassau grouper. Yellowfin grouper generally are less abundant than Nassau grouper (Sluka et al. 1996a,b, Chiappone et al. 2000, this study) and selective removal by spear fishers may deplete yellowfin grouper populations at a faster rate. This assumes that marine

reserves would have a greater protective effect on species that suffer heavier fishing mortality – an idea supported by several published studies (Russ 1985, Russ and Alcala 1989, 1996). Alternatively, the lack of a measurable protective effect on Nassau grouper may stem from its long-distance spawning migration (Bolden 2000). Species that migrate to spawn will inevitably spend some period of time outside of the reserve boundaries. The longer the time spent outside the reserve, the more vulnerable fish become to fishing mortality (Chapman and Kramer 1999). The nearest Nassau grouper spawning aggregation is roughly 40 km from the ACLSP. In contrast, tiger and yellowfin grouper are known to aggregate just 200 - 300 m outside the eastern boundary of the park, at the southeastern tip of South Caicos (see Figure 2). Despite its location outside the park boundaries, this aggregation site is rarely fished due to its depth (25 - 40 m), rough seas, and the frequency of shark encounters (T. Morris, personal communication and author's personal observations). Thus, if Nassau grouper spend longer periods outside the reserve boundaries, they will receive less benefit from the reserve than more sedentary species. Further research into the movements and home range size of larger grouper species is needed. It is very possible that the area covered by the ACLSP (8 km^2) is smaller than the home range of adult Nassau grouper. Nassau grouper density was higher in the Exuma Cays Land and Sea Park (ECLSP) than in surrounding fished areas (Sluka et al. 1996a), but the area covered by the ECLSP is 442 km^2.

Finally, the observed patterns of grouper density with respect to the ACLSP may reflect random variation and may have little to do with fishing pressure. This seems plausible given the low fishing pressures on South Caicos grouper and given that the density of most groupers in fished areas of South Caicos is two to four times greater than in protected areas elsewhere in the Caribbean. For example, Chiappone et al. (2000) reported a mean density of 0.35 individuals per 100 m^2 in the ECLSP and noted that this density was the highest recorded in the northeastern Caribbean. Mean density of Nassau grouper in the ACLSP was 0.67 individuals per 100 m^2. To the north of the ACLSP, mean density was 1.27 individuals per 100m^2.

CONCLUSIONS

Despite recent efforts, it remains unclear whether grouper actively select preferred habitats, although it is apparent that they make use of a wide range of habitat types. The ACLSP may be too small to effectively protect commercially important species such as the Nassau grouper which undergo seasonal spawning migrations. Therefore, effective grouper management may require that marine reserves be used in conjunction with seasonal closures during spawning (see Beets and Friedlander 1999), and perhaps the protection of migration corridors between reserves and spawning aggregation sites.

Given the very high density of South Caicos groupers relative to other Caribbean islands, present levels of fishing pressure may not be intense enough to result in a density differential between fished and protected reefs. However, rapid tourism development on the western island of Providenciales has led to an increased

demand for grouper and snapper, which are popular menu items with tourists. This in turn has led to a rapid decline in the number of groupers seen by recreational divers in Providenciales (M. Taylor, Coastal Resources Management Project, personal communication). Recently, developers began construction of a large resort complex on South Caicos. An influx of tourists to South Caicos may increase the demand for fresh snapper and grouper, resulting in heavier fishing pressure on local grouper stocks. If so, the enforcement of the ACLSP, in conjunction with other management measures as mentioned above, may be an important step in ensuring the sustainability of grouper in South Caicos.

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LITERATURE CITED

Alevizon, W., R. Richardson, P. Pitts and G. Serviss. 1985. Coral zonation and patterns of community structure in Bahamian reef fishes. *Buletin of. Marine Science* **36**:304-317.

Bannerot, S., W.W. Fox Jr., and J.E. Powers. 1987. Reproductive strategies and the management of snappers and groupers. Pages 561-603 in: J.J. Polovina and S. Ralston (eds.) *Tropical Snappers and Groupers: Biology and Fisheries Management*. Westview Press, Boulder, Colorado USA.

Beets J., and A. Friedlander. 1999. Evaluation of a conservation strategy: a spawning aggregation closure for red hind *Epinephelus striatus*, in the U.S. Virgin Islands. *Enironmental. Biology of Fishes* **55**:91-98.

Benaka, L.R. (ed.) 1999. *Fish habitat: essential fish habitat and rehabilitation*. American Fisheries Society Symposium 22, Bethesda, Maryland USA.

Bohnsack, J.A., D.E. Harper, and D.B. McClellan. 1994. Fisheries trends from Monroe County, Florida. *Bulletin of Marine Science* **54**:982-1018.

Bolden, S.K. 2000. Long-distance movement of a Nassau grouper (*Epinephelus striatus*) to a spawning aggregation in the central Bahamas. *U. S. Fisheries Bull.etin* **98**:642-645.

Chapman, M. R. and D.L. Kramer. 1999. Gradients in coral reef fish density and size across the Barbados Marine Reserve boundary: effects of reserve protection and habitat characteristics. *Marine Ecology Progress Series* **181**:81-96.

Chiappone, M., R. Sluka, and K. Sullivan Sealey. 2000. Groupers (Pisces: Serranidae) in fished and protected areas of the Florida Keys, Bahamas and northern Caribbean. *Marine Ecology Progress Series* **198**:261-272.

Coleman, F. C., C.C. Koenig, and L. A. Collins. 1996. Reproductive styles of shallow water groupers in the Eastern Gulf of Mexico and the consequences of fishing spawning aggregations. *Environmental Biology of Fishes* **47**:129-146.

Domeier, M. L. and Colin P. L. 1997. Tropical reef fish spawning aggregations defined and reviewed. *Bulletin of Marine Science* **60**(3): 698-726.

Eggleston, D.B. 1995. Recruitment in Nassau grouper *Epinephelus striatus*: post settlement abundance, microhabitat features, ontogenetic habitat shifts. *Marine Ecology Progress Series* **124**:9-22.

Huntsman, G.R. and W.E. Schaaf. 1994. Simulation of the impact of fishing on reproduction of a protogynous grouper, the graysby. *North American Journal of Fisheries Management* 14:41-52.

Koenig, C., and F. Coleman. 1998. Absolute abundance and survival of juvenile gags in seagrass beds of the Northeastern Gulf of Mexico. *Transactions of the American Fisheries Society* **127**:44-55.

Minello, T.J. 1999. Nekton densities in shallow estuarine habitats of Texas and Louisiana and the identification of essential fish habitat. Pages 43-75 in: L. R. Benaka, (ed.) *Fish habitat: essential fish habitat and rehabilitation.* American Fisheries Society Symposium 22, Bethesda, Maryland USA.

Nagelkerken, W. 1981. Distribution of the groupers and snappers of the Netherlands Antilles. *Proceedings of the Fourth International Coral Reef Symposium.* **2**:479-484.

Rakitin, A., and D.L. Kramer. 1996. Effect of a marine reserve on the distribution of coral reef fishes in Barbados. *Marine Ecology Progress Series* **131**:97-113.

Rosenberg, A., T.E. Bigford, S., Leathery, R.L. Hill, and K. Bickers. 2000. Ecosystem approaches to fishery management through essential fish habitat. *Bulletin of Marine Science* **66**(3):535-542.

Sadovy, Y. 1994. Grouper stocks of the Western Central Atlantic: the need for management and management needs. *Proceedings of the Gulf and Caribbean Fisheries Institute* **42**:43-64.

Sluka, R.D. 1995. *Influence of Habitat on Density, Species Richness, and Size Distribution of Groupers in the Upper Florida Keys, U.s., and Central Bahamas.* Ph.D. dissertation, University of Miami, Coral Gables, FL.

Sluka, R., M. Chiappone, K. Sullivan, K. and R. Wright. 1996a. Assessment of grouper assemblages. Pages 42-71 in: *Habitat and Life in the Exuma Cays, The Bahamas: The Status of Groupers and Coral Reefs in the Northern Cays.* Media Publishing Limited, Nassau, Bahamas.

Sluka, R., M. Chiappone, K. Sullivan, and R. Wright. 1996b. Habitat preferences of groupers in the Exuma Cays. *Bahamas Journal of Science* 4:8-14.

Sluka, R.D., Chiappone, M., Sullivan, K.M., and R. Wright. 1997. The benefits of a marine fishery reserve for Nassau grouper *Epinephelus striatus* in the central Bahamas. *Proceedings of the Eighth International Coral Reef Symposium.* **2**:1961-1964.

Sluka, R., M. Chiappone, K.M. Sullivan, T.A. Potts, J.M., Levy, E.F., Schmitt, and G. Meester. 1998. Density, species and size distribution of groupers (Serranidae) in three habitats at Elbow Reef, Florida Keys. *Bulletin of Marine Science* **62**(1):219-228.

Sullivan, K.M., and R. Sluka. 1996. Ecology of shallow-water groupers (Serranidae) in the upper Florida Keys, USA. Pages 74-84 in: F. Arreguin-Sanchez, J.L. Munro, M.C. Balgos and D. Pauly (eds.) *Biology, Fisheries and Culture of Tropical Grouper and Snappers*. ICLARM Conf. Proc. 48.

Thompson, R. and J.L. Munro. 1978. Aspects of the biology and ecology of Caribbean reef fishes: Serranidae (hinds and groupers). *Journal of Fish Biology* **12**:115-146.

Tupper, M. and F. Juanes. 1999. Effects of a marine reserve on recruitment of grunts (Pisces: Haemulidae) at Barbados, West Indies. *Environmental Biology of Fishes* **55**:53-63.

Field Growth Responses of Juvenile White Trout (*Cynoscion arenarius*) to Continuous Variation in Physical Habitat Conditions

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ABSTRACT

Recruitment of early life stages of many species into shallow inshore estuarine habitats is responsible for high fisheries production. Estuarine habitats are also subject to wide fluctuations in physical conditions which can influence recruitment success through effects on the growth and survival of early life stages. In order to examine field-growth responses of juvenile white trout with respect to continuous variation in physical habitat conditions, we related modal shifts in length distributions of recruiting cohorts to continuous changes in abiotic variables. Weekly shoreline collections of juvenile white trout were made over a five week period between 12 May and 16 June, 1997 at Marsh Point in Mississippi Sound. Using a DataSonde IV®, hourly changes in water temperature, salinity, dissolved oxygen, turbidity, depth, and pH were also recorded throughout the five week recruitment period. Weekly modal shifts in length distributions of white trout reflected proportional changes in length ranging from 0.20 to 0.54; and changes in weekly growth were strongly tied to changes in weekly mean water temperature ($P = 0.013$). Other abiotic variables were unrelated to water temperature on the weekly scale. However, abiotic variables may show different interrelationships depending on the temporal scale on which they are considered, suggesting that their effects on recruitment processes need to be analyzed on the same temporal scale on which recruitment is measured. Comparison of these findings and previous work showed that within-site-temporal variability and between-site-spatial variability in growth rates can be driven by different abiotic variables. Whereas within-site variability in growth of juvenile white trout was primarily driven by water temperature, former work with juvenile mullet in the same system suggested that inter-site variability in growth was primarily determined by salinity.

KEYWORDS: Field growth, abiotic, *Cynoscion arenarius*

INTRODUCTION

Recruitment of early life stages of many species into shallow inshore estuarine habitats is responsible for high fisheries production (Weinstein 1979, Boesch and Turner 1984). Estuarine habitats are also subject to wide fluctuations in physical conditions (Kneib 1997), which may influence fish recruitment success through

effects on the growth and survival of early life stages (Currin et al.1984, Malloy and Targett 1991, Lankford and Targett 1994). Although density dependent biotic factors can directly affect recruitment through survival rates (Myers and Cadigan 1993), many studies of transient estuarine fishes find that abiotic factors are the most important determinants of variability in their early growth rates (Rooker and Holt 1997, Baltz et al. 1998). Moreover, rapid growth may also confer enhanced survival (Peterson et al. 1999). Thus, spatio-temporal variation in abiotic variables and their effects on growth can ultimately translate into differential cohort-specific contributions to stock recruitment. Because estuarine organisms are challenged by a wide array of continuously changing abiotic variables, early growth responses are potentially dynamic and complex. Population responses are tied to underlying autecological effects of abiotic variables that regulate metabolic scope in different ways (Neill et al. 1994). The detection of such responses may become scale-dependent whenever environmental effects acting at lower levels of organization (e.g., cellular) are integrated over higher levels of organization (e.g., population).

Sciaenids represent one of the most commercially and ecologically important groups of estuarine dependent fishes that occur along the Atlantic and Gulf of Mexico coasts (Chao and Musick 1977). The genus *Cynoscion* has a center of origin in tropical coastal waters of the Western Hemisphere; and several species of *Cynoscion* occur within subtropical and temperate coastal waters of the United States. The white trout, *Cynoscion arenarius*, is one of the most common sciaenid fishes within estuaries of the northern Gulf of Mexico. In the Gulf of Mexico, adult white trout spawn offshore during winter and spring and larvae enter estuarine nursery areas after 30 - 94 d (Shaw et al. 1988). White trout larvae are transported by currents to estuaries that may be far from their offshore spawning areas, implying that their recruitment dynamics involve metapopulation processes. White trout recruitment is seasonally bimodal and accordingly, growth rates of juveniles also vary seasonally. In order to examine field-growth responses of early juvenile white trout with respect to continuous variation in physical habitat conditions, modal shifts in length frequency distributions of recruiting cohorts were related on a weekly temporal scale to changes in abiotic conditions at a site where high amplitudes of early juveniles occurred. The significance of the findings is considered with regards to the issue of recruitment variability.

MATERIALS AND METHODS

Field Collections

Between 12 May and 16 June 1997 during the peak spring recruitment period, a series of weekly collections of juvenile white trout were made at Marsh Point (30° 23' 05" N and 88° 48' 40" W) in Jackson County, Mississippi. Marsh Point is ideally situated to receive early life stages of estuarine dependent organisms that are transported across Mississippi Sound (Figure 1). Mississippi Sound represents a diurnal microtidal estuarine system with lunar tides averaging ~ 0.33 m and with

characteristically high turbidity that presumably enhances the survival of recruiting organisms. The semi-natural sandy shoreline of Marsh Point is intermittently covered with scattered marsh vegetation including *Spartina* and scrub. Each weekly collection was taken from 0.6 - 0.8 km of semi-protected shoreline habitat on both sides of the point over muddy sand and mud sediments. A 4.6 m x 3.2 mm mesh seine was used to collect fishes from 1.2 m to 0 m depth by pulling perpendicular into the shore from ~30 meters offshore. The mean depth was 0.5 m. The shoreline site was thoroughly sampled during each visit by making multiple seine hauls for between 2.75 to 3.25 hours. Other fishes commonly collected included menhaden, bay anchovy, silver perch, tidewater silverside, white and striped mullet, croaker, spot and pinfish. Another site was also sampled ~45 kilometers from the Marsh Point site at Henderson Point in Hancock County, but collections did not yield enough white trout to characterize their growth shifts. Fish were labelled and placed on ice in the field and returned to the labbratory where they were kept frozen until measured to the nearest 0.1 mm standard length (SL) using a dial calipers.

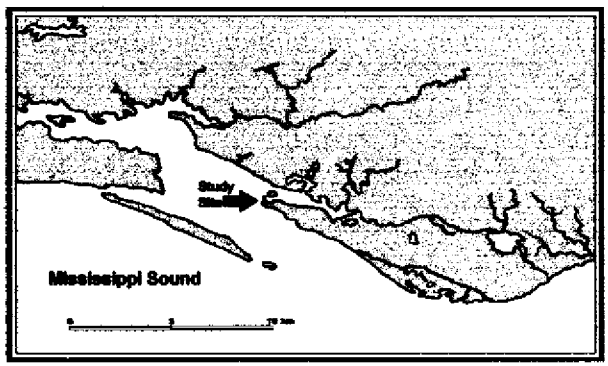


Figure 1. Map showing the study site near Marsh Point.

Abiotic Conditions

Continuous variation in abiotic conditions was monitored throughout the five week study period using a Hydrolab IV DataSonde multiparameter data logger placed at the Gulf Coast Research Laboratory dock, less than 1 km from Marsh Point. Datasondes were deployed in order to log hourly variation in salinity (ppt), water temperature (°C), dissolved oxygen (DO; mg/l), turbidity (NTU), pH, and depth (m; i.e., tidal flux). Datasonde units were typically replaced weekly with recalibrated and serviced units after which recorded data were downloaded to a computer in the laboratory. An equipment failure resulted in missing salinity data for the week of 5 June.

Data Analysis

Individual lengths of juvenile white trout from weekly collections were placed

into 2 mm size classes in order to generate length-frequency distributions. Proportional length-frequency distributions were plotted to identify clear shifts in modal lengths. Differences in modal lengths between consecutive weeks were expressed as the proportion of the earlier length so that growth shifts could be examined relative to changes in abiotic conditions. Daily variability in physical parameters were derived from respective 24 hourly measurements and plotted as time series of the means ± 2 standard errors (s.e.). Cross-correlations among the parameter series were examined on the daily temporal scale at all lags up to ± 7 d. Missing values in the daily series for salinity were interpolated by local quadratic smoothing. Daily abiotic data were further collapsed to the weekly temporal scale in order to address coherence with weekly growth. Changes in parameter weekly profiles were visually compared. Pearson correlations among abiotic variables on the weekly scale were compared with cross-correlations on the daily scale. Weekly water temperature and salinity values were plotted against weekly growth values and the relationship between water temperature and early growth was examined using regression.

RESULTS

Growth Variation

Numbers of early juvenile white trout in collections from Marsh Point varied from 58 to 224 specimens ranging in size between 14 and 64 mm SL. Clear modes representing multiple cohorts were visible within the standardized length frequency distributions across the various collection dates. Modal shifts in length distributions of white trout reflected variation in weekly proportional growth ranging from 0.20 to 0.54 (Figure 2). Moreover, changes in the magnitude of growth did not follow a consistent temporal trend on the weekly scale, although the lowest growth rate was noted from the earliest time interval, while the highest growth rate was observed from the latest time interval.

Daily Variation in Physical Parameters

Daily means in physical parameters varied widely throughout the 35 d monitoring period: water temperature ranged between 22.9 and 31.0° C; salinity ranged between 0.4 and 11.2 ppt; turbidity ranged between 4.85 and 44.8 NTU; depth ranged between 0.3 and 1.1 m; DO ranged between 3.5 and 6.0 mg/l; and pH ranged between 6.5 and 11.5 (Figure 3). Definite fluctuations were evident on the daily temporal scale for all physical parameters. Correlations among the physical parameters were not immediately apparent on the daily scale, however, concurrent dips in multiple parameters occurred on 12 May in water temperature and depth, on 18 May in turbidity and DO, and on 1 June in salinity, pH and water temperature. Hydrographic shifts were suggested by concerted changes in several physical parameters as shown by notable bivariate cross-correlations between various pairs of abiotic variables (Table 1). For example, concurrent daily variation involving

moderate correlations occurred at a lag of +4 to +5 d between water temperature and several other parameters, including salinity, turbidity, and DO. Several other bivariate correlations also were evident at a lag of 0 d.

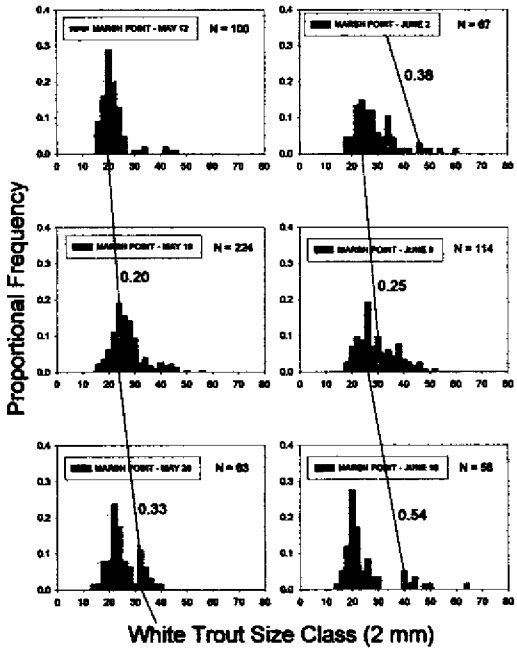


Figure 2. Proportional length-frequency distributions showing shifts in modal sizes of early juvenile white trout sampled at weekly intervals between 12 May and 16 June 1997 from the Marsh Point site. Inferred weekly growth represents the difference in consecutive modal lengths as a proportion of the earlier modal length.

Weekly Variation in Physical Parameters and Growth

Weekly temporal profiles for the physical parameters and proportional growth comprised only five data points, facilitating visual comparisons in order to identify covariation on this temporal scale (Figure 4). Profiles were apparently similar between turbidity and DO, salinity and Ph, and water temperature and proportional growth. Moreover, inverse relationships were indicated between both salinity and Ph with turbidity, depth, as well as DO (Table 1). Physical parameters and growth also fluctuated somewhat on the weekly scale. Although water temperature was apparently related to several other abiotic variables on the daily temporal scale when

lagged 4 or 5 d, it was completely unrelated to the same parameters when considered on the weekly temporal scale without any lag. Other sets of abiotic variables also varied in the strength of their association depending on the temporal scale. Thus, abiotic variables can show different interrelationships depending on the temporal scale of concern. On the weekly temporal scale, water temperature was the only physical parameter that was directly related to early fish growth, as shown by a significant linear regression between these two variables (Figure 5A). Despite its ecophysiological importance, salinity did not seem to bear any relationship with early growth on the weekly scale (Figure 5B). Relatively low weekly growth rates occurred at both ends of the observed salinity range and relatively high growth occurred at a relatively low salinity.

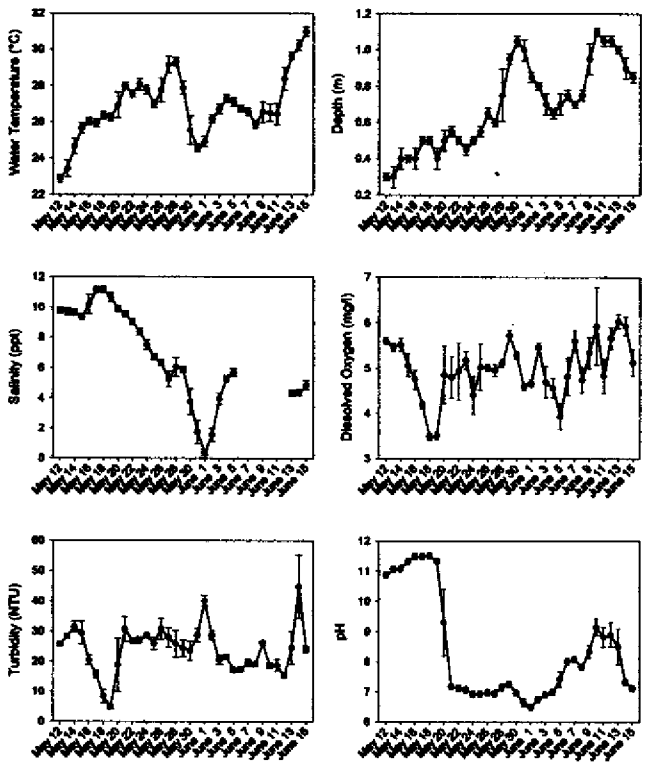


Figure 3. Daily variation in the six physical parameters across the 35 d study period. Plotted values represent means ± 2 s.e derived from the respective 24 hourly measurements.

DISCUSSION

Based on an analysis of recruitment by several species of commercial fishes, Myers and Cardigan (1993) concluded that early life stages determine inter-annual variability in the year class strength of demersal marine fishes. The relevant spatial scale in the recruitment of marine fishes appears to be ~500 km, which supports the hypothesis that large-scale environmental variables drive marine recruitment (Myers et al. 1997). Indeed, many studies of transient estuarine fishes report that abiotic factors are the most important determinants of variability in early growth rates (Rooker and Holt 1997, Baltz et al. 1998). On a weekly scale, within-site variability in growth rates of early juvenile white trout appeared to be driven mainly by water temperature. However, our previous work within the same estuarine system suggested that inter-site variability in the field growth of juvenile mullet is primarily determined by differences in salinity (Peterson et al. 2000), indicating that within-site temporal and between-site spatial variability in growth rates can be driven by different abiotic variables. Even though the lab growth response of mullet was much more strongly linked to temperature than to salinity, a larger difference in salinity than in water temperature occurred between two field sites separated by ~45 km. This underscores the idea that causes of recruitment variability are complex and dynamic. Assuming that enhanced growth increases survival, the existence of spatio-temporal plasticity in early growth could indeed have a strong bearing on recruitment dynamics (Lankford and Targett 1994, Peterson et al. 1999). For example, based on shifts in monthly size distributions, Brusle and Cambrony (1992) documented spatial variability in growth rates of juvenile mullet they attributed to settlement by "microcohorts" within patchy Mediterranean lagoonal habitats.

Table 1. Correlations among abiotic variables and growth on daily and weekly temporal scales. Upper right diagonal displays cross-correlations and lag time in days for weekly values, main diagonal (bold) displays Pearson correlations with growth on the weekly scale, and lower left diagonal displays Pearson correlations among physical variables on the weekly scale. Asterisks denote conventional $P < 0.05$. Correlations are presented for illustrative purposes to show overall patterns in the interrelationships.

Growth	Temp	Salinity	Turbidity	Depth	DO	pH
Temp	**+0.95***	-0.45*; +4	0.47*; +5	0.33; 0	0.40; +5	-0.47*; 0
Salinity	-0.30	**-0.40**	-0.35; 0	-0.82*; -1	-0.34; +1	0.74*; -1
Turbidity	+0.21	-0.89*	**+0.43**	0.25; -3	0.49*; 0	-0.42*; 0
Depth	+0.62	-0.93*	+0.78	**+0.62**	0.37; 0	-0.58*; -7
DO	+0.13	-0.86	+0.87*	+0.69	**+0.29**	-0.36; -5
pH	-0.45	+0.97*	-0.87*	-0.94*	-0.90*	**-0.64**

As a hierarchical phenomenon, recruitment can be examined at multiple scales, ranging from cellular to ecosystem levels of organization. Thus, environmental effects on recruitment should be analyzed on the same spatiotemporal scale as the process of concern and quantified at one level below that on which the process is measured. For example, the limit of temporal resolution of growth in this study was the weekly scale, but other temporal scales of growth in fishes can also be considered, including the instantaneous scale though biochemical assays (Peterson and Brown-Peterson 1992), the daily scale as inferred from otolith growth records (Comyns et al. 1989, Rakocinski et al. 2000), or the inter-annual scale (Planque and Fox 1998).

The finest temporal scale of abiotic measurement available in this study was the hourly interval which could have been collapsed with respect to the daily scale of growth in the same manner that the daily scale of measurement was consolidated in order to relate it to weekly growth. Although water temperature was apparently unrelated to other measured abiotic variables on the weekly scale, patterns of daily variation in physical parameters and growth might have revealed how other abiotic variables were also correlated with daily growth (e.g., those tha correlated with water temperature at +4 or +5 d lag).

In addition, variation in the strengths of associations observed among the physical variables at the two temporal scales suggests that different abiotic variables could emerge as being important to growth variation on different temporal scales. Thus, collapsing the information on a large scale could conceal certain kinds of growth responses to environmental variables. For example, Konstantinov et al. (1990) demonstrated that fish can grow better in fluctuating temperature regimes like those experienced under field conditions than under constant laboratory conditions, because they can take advantage of intermittent cooler temperatures to increase food conversion efficiency. In the Aransas estuary, the recent growth of postlarval red drum (*Sciaenops ocellatus*) was positively correlated with water temperature, whereas there was no apparent connection between long-term growth and water temperature, suggesting other factors like prey availability were ultimately responsible for inter-cohort growth differences (Rooker and Holt 1997). On the other hand, large scale effects can also be overlooked. Estimates of consumption rates by juvenile bluefish (*Pomatomus saltatrix*) in 90 day mesocosm experiments were not accurately predicted from short-term 7 d growth experiments, leading Buckel et al. (1995) to conclude that environmental effects on growth and consumption rates should be studied over the same temporal scale on which the responses are integrated in nature.

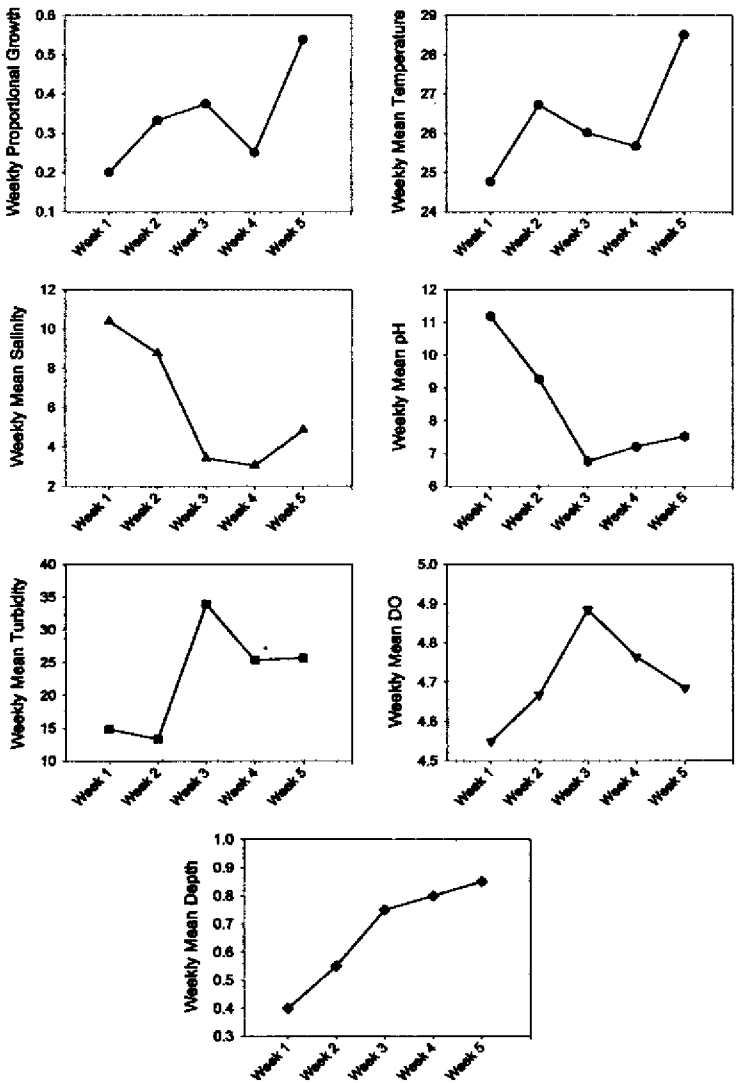


Figure 4. Weekly variation in the six physical parameters and early growth of white trout across the five week study period.

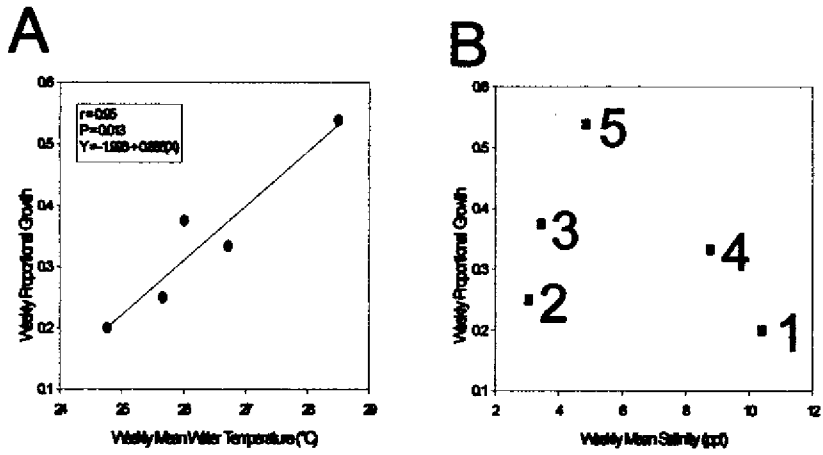


Figure 5. (A) Relationship between weekly proportional growth of white trout and weekly mean water temperature. (B) Relationship between weekly proportional growth and weekly mean salinity. Numbers on salinity plot correspond with the sequence of values from the water temperature relationship shown in 5A.

Water temperature appeared to be strongly associated with weekly growth rates of early juvenile white trout at the Marsh Point site, to the exclusion of other factors. Moreover, growth increased across the entire observed range in water temperature. Water temperature is regarded as the main controlling factor on early growth because it sets the pace of metabolism (Neill et al. 1994); and various workers have noted that temperature optima for many fishes are highest during the early life history stages (Brett 1979, Kitchell 1979, Lankford and Targett 1994). However, as a determinant of many biological rate processes, temperature also elevates the metabolic needs of organisms which must be fulfilled by sufficient food availability. A foraging constraint can severely limit the scope for growth and may lead to mass mortality of young fish (Sukhanov 1989). Juvenile Sea Bass (*Dicentrarchus labrax*) grow better in warmer British waters if food is abundant, however they grow better in cooler waters at low levels of food abundance (Russell et al. 1996). Salinity acts as a masking factor on growth through its potential metabolic demands (Neill et al. 1994). Masking and limiting factors (e.g., dissolved oxygen) can actually shift the optimum temperature away from that which maximizes metabolic activity.

Weekly growth rates of white trout in the field increased monotonically with water temperature and did not appear to be affected by observed changes in salinity at the Marsh Point site. Juveniles of the Atlantic coast cognate species to white

trout, weakfish (*Cynoscion regalis*), grew optimally at 29°C and 20‰ in the laboratory (Lankford and Targett 1994). Feeding rates increased with water temperature at all salinities, thus salinity narrowed the scope for growth by affecting growth efficiency. Very low salinities were especially costly for juvenile weakfish. In the present study, daily means in water temperature ranged between 22.9° and 31.0°C and salinity ranged between 0.4 and 11.2 ‰. These ranges exceed the temperature optimum observed for weakfish and bracket some very low salinities, yet white trout field growth was not apparently masked by the low salinities. Salinity and temperature may interact in some species to elicit growth responses. Hogchoker (*Trinectes maculatus*) grow faster and more efficiently in the laboratory with increasing salinity at cooler temperatures (15 °C), however they grow slower and less efficiently with increasing salinity at warmer temperatures (Peters and Boyd 1972). Perhaps white trout are not as sensitive to variation in salinity, or fish at this site were acclimated to lower salinities in their early life. Acclimation is another recognized factor that may shift the optimum temperature (Neill et al. 1994). Finally, the data may have been too sparse to demonstrate a salinity effect on weekly variability in field growth of early juvenile white trout.

Seasonal or climatic related variation in water temperature can potentially influence the recruitment success of estuarine dependent nekton. Spring and fall pulses of juvenile white trout grow at different rates, with fish showing markedly fast growth rates in summer (Shaw et al. 1988). In marine systems, climatic variation can elicit broad scale variability in the recruitment success of fishes (Myers et al. 1997). In the present study, rather than increasing steadily throughout the five week study period, water temperature and inferred shifts in growth fluctuated somewhat on the weekly scale, notwithstanding the gradual seasonal warming trend. Thus, the contribution of a particular cohort to recruitment would not necessarily be related to its seasonal chronology. Likewise, inter-annual variability in recruitment success may arise from climatic variation.

ACKNOWLEDGMENTS

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LITERATURE CITED

Baltz, D.M., J.W. Fleeger, C.F. Rakocinski, and J.N. McCall. 1998. Food, density, and microhabitat: factors affecting growth and recruitment potential of juvenile saltmarsh fishes. *Environmental Biology of Fishes* 53:89-103.

LITERATURE CITED

Baltz, D.M., J.W. Fleeger, C.F. Rakocinski, and J.N. McCall. 1998. Food, density, and microhabitat: factors affecting growth and recruitment potential of juvenile saltmarsh fishes. *Environmental Biology of Fishes* **53**:89-103.

Boesch, D.F. and R.E. Turner. 1984. Dependence of fishery species on salt marshes: the role of food and refuge. *Estuaries* **7**:460-468.

Brett, J.R. 1979. Environmental factors and growth. Pages 599-677 in: W.S. Hoar, D.J. Randall and J.R. Brett (ed.) *Fish Physiology*, Volume Academic Press, New York, New York USA.

Bruslé J. and M. Cambrony. 1992. Mediterranean lagoons: favorable nurseries and/or dangerous traps for juvenile euryhaline fish? Critical analysis of the growth of grey mullet populations (1st year of life) from several brackish water lagoons in the Languedoc-Roussillon. *Vie et milieu* **42**:193-205.

Buckel, J.A., N.D. Steinberg, and D.O. Conover. 1995. Effects of temperature, salinity, and fish size on growth and consumption of juvenile bluefish. *Journal of Fish Biolology* **47**:696-706.

Chao, L.N. and J.A. Musick. 1977. Life-history, feeding habits, and functional morphology of juvenile sciaenid fishes in the York River estuary, Virginia. *U.S. Fisheries Bulletin* **75**:657-702.

Comyns, B.H., J. Lyczkowski-Shultz, C.F. Rakocinski and J.P. Steen. 1989. Age and growth of larval red drum (*Sciaenops ocellatus*) in the northcentral Gulf of Mexico. *Transactions of the American Fisheries Society* **118**:167-175.

Currin, B.J., J.P. Reed, and J.M. Miller. 1984. Growth, production, food consumption, and mortality of juvenile spot and croaker: a comparison of tidal and nontidal nursery areas. *Estuaries* **7**:451-459.

Kitchell, J.F. 1979. In search of an optimal environment. Pages 31-33 in: Clepper, H. (ed) *Predator-prey Systems in Fisheries Management*. Sport Fishing Institute, Washington, DC USA.

Kneib, R.T. 1997. The role of tidal marshes in the ecology of estuarine nekton. *Oceanography and Marine Biology Review* **35**:163-220.

Konstantinov, A.S., V.V. Zdanovich, and D.G. Tikhomirov. 1990. The effect of temperature fluctuations on metabolic rate and energetics of juvenile fish. *Journal of Ichthyology* **30**:38-47.

Lankford, T.E. Jr. and T.E. Targett. 1994. Suitability of estuarine nursery zones for juvenile weakfish (*Cynoscion regalis*): effects of temperature and salinity on feeding, growth, and survival. *Marine Biology* **119**:611-620.

Malloy, K.D. and T.E. Targett. 1991. Feeding, growth and survival of juvenile summer flounder (*Paralichthys dentatus*): experimental analysis of the effects of temperature and salinity. *Marine Ecology Progress Series* **72**:213-223.

Myers, R.A., G.Mertz, and J. Bridson. 1997. Spatial scales and interannual recruitment variations of marine, anadromous, and freshwater fish. *Canadian Journal of Fisheries and Aquatic Science* **54**:774-780.

Myers, R.A. and N.G. Cardigan. 1993. Density-dependent juvenile mortality in marine demersal fish. *Canadian Journal of Fisheries and Aquatic Science* **50**:1576-1590.

Neill, W.H., J.M. Miller, H.W. van der Veer, and K.O. Winemiller. 1994. Ecophysiology of marine fish recruitment: a conceptual framework for understanding interannual variability. *Netherlands Journal of Sea Research* **32**:135-152.

Peters, D.S. and M.T. Boyd. 1972. The effect of temperature, salinity, and availability of food on the feeding and growth of hogchoker, *Trinectes maculatus* (Bloch and Schneider). *Journal of Experimental Marine Biology and Ecology* 7:201-207.

Peterson, M.S. and N.J. Brown-Peterson. 1992. Growth under stressed conditions in juvenile channel catfish *Ictalurus punctatus* Rafinesque as measured by nucleic acids. *Comparative Biochemical Physiology* **103A**:323-327.

Peterson, M.S., B.H. Comyns, C.F. Rakocinski, and G.L. Fulling. 1999. Does salinity affect somatic growth in early juvenile Atlantic croaker, *Micropogonias undulatus* (Linnaeus)? *Journal of Experimental Marine Biology and Ecology* **238**:199-207.

Peterson, M.S., C.F. Rakocinski, B.H. Comyns, and G.L. Fulling. 2000. Laboratory growth responses of juvenile. *Mugil* sp. to temperature and salinity: delineating optimal field growth conditions *Proceedings of the Gulf and Caribbean Fisheries Institute* **51**:341-352.

Planque, B. and C.J. Fox. 1998. Interannual variability in temperature and the recruitment of Irish Sea cod. *Marine Ecology Progress Series* **172**:101-105.

Rakocinski, C.F., B.H. Comyns, and M.S. Peterson. 2000. Relating environmental fluctuation and the early growth of estuarine fishes: ontogenetic standardization. *Transactions of the American Fisheries Society* **129**:210-221.

Rooker, J.R. and S.A. Holt. 1997. Utilization of subtropical seagrass meadows by newly settled red drum *Sciaenops ocellatus*: patterns of distribution and growth. *Marine Ecology Progress Series* **158**:139-149.

Russell, N.R., J.D. Fish, and R.J. Wooten. 1996. Feeding and growth of juvenile sea bass: the effect of ration and temperature on growth rate and efficiency. *Journal of Fisheries Biology* **49**:206-220.

Shaw, R.F., B.D. Rogers, J.H. Cowan, Jr., and W.H. Herke. 1988. Ocean-estuary coupling of ichthyoplankton and nekton in the northern Gulf of Mexico. *Transactions of the American Fisheries Society* 3:77-89.

Sukhanov, V.V. 1989. A model of temperature-food conditions critical for survival of juvenile fish. *Journal of Ichthyology* **29**:26-35.

Weinstein, M.P. 1979. Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear River, North Carolina. *U.S. Fisheries Bulletin* 77:339-357.

Preliminary Assessment of the Association of Larval Fishes with Pelagic *Sargassum* Habitat and Convergence Zones in the Northcentral Gulf of Mexico

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ABSTRACT

Surface plankton samples were taken adjacent to concentrations of pelagic *Sargassum* during May and July 2000 in the northcentral Gulf of Mexico. Sampling was conducted next to *Sargassum* located both along convergence zones (fronts) and in areas not associated with particular hydrographic features. In addition, collections were taken up to 1.5 kilometers away from the sampled *Sargassum* as a control. A total of 1453 larvae/postlarvae comprising 22 families were collected. Collections were dominated by carangids and exocoetids, but also included specimens of tuna (including bluefin in May), dolphin and billfishes. Species composition and abundance were generally similar for collections taken both adjacent to *Sargassum* located along frontal zones and "control" collections taken within a few hundred meters of the sampled front. These preliminary observations indicate the potential influence of both *Sargassum* habitat and the convergence of water masses associated with frontal zones. The supposition that the convergence of water masses affects the diversity and abundance of fish larvae is further strengthened by the relatively low diversity and abundance of larvae found in collections taken adjacent to large patches of *Sargassum* not associated with particular hydrographic features. Larvae may accumulate in frontal zones both with and without *Sargassum*, but the growth and survival of the larvae of many species may be quite different in both areas.

KEY WORDS: *Sargassum*, fronts, habitat

INTRODUCTION

In the western North Atlantic and Gulf of Mexico pelagic brown algae of the genus *Sargassum* (Family Sargassaceae) forms a critical floating habitat for a diverse assemblage of flora and fauna (Butler et al. 1983, Coston-Clements et al. 1991). In the North Atlantic the center of distribution of pelagic *Sargassum* is in the Sargasso Sea located near the center of the North Atlantic gyre southeast of Bermuda (Sieburth and Conover 1965). This *Sargassum* is comprised primarily of *S. natans* and *S. fluitans* (Winge 1923, Parr 1939), although detached algae of five other species occur in low frequency (SAFMC 1998). The floating algae is transported into the Gulf of Mexico by the Yucatan current, which is termed the Loop current

as it passes through the Gulf. *Sargassum* is often concentrated in long rows by the convergence of surface waters along fronts, Langmuir circulation, or internal waves (Langmuir 1938, Shanks 1988, Kingsford 1990). When currents and winds are negligible, *Sargassum* is generally found in broad irregular mats or scattered clumps. Aggregations of this algae provide refuge for small fish and invertebrates, represent a source of concentrated prey for many organisms, including such diverse taxa as planktivorous invertebrates and large piscivorous fishes, provide a unique nursery habitat for numerous oceanic organisms, and may serve as a spawning substrate for certain marine species (Dooley 1972, Coston-Clements et al. 1991).

Pelagic *Sargassum* habitat has been the focus of considerable attention in recent years relative to its status as essential fish habitat (EFH). In December 1998, the South Atlantic Fishery Management Council (SAFMC) in the final draft of its Fishery Management Plan (FMP) for pelagic *Sargassum* habitat (SAFMC, 1998) recommended restricting, and then phasing out, the harvest of *Sargassum* in south Atlantic marine waters based upon its importance as EFH. After consideration, the National Marine Fisheries Service (NMFS) voted against such a measure unless it included a provision for limited commercial harvest of the algae. The need for protection of this offshore fish habitat is further emphasized in the current draft of the FMP for the dolphin and wahoo fisheries of the Atlantic, Caribbean, and Gulf of Mexico (SAFMC 2000).

Several studies have examined the diversity of macro-organisms associated with pelagic *Sargassum* habitat (Fine 1970, Dooley 1972, Bortone et al., 1977, Butler et al. 1983, Coston-Clements et al. 1991, Settle 1993, Moser et al. 1998), and only one of these studies (Bortone et al. 1977) was conducted in the Gulf of Mexico. Collectively, these studies found over 145 species of invertebrates, four species of sea turtles and 100 species of fishes associated with *Sargassum*, including various life history stages of several important fishery species such as cobia (*Rachycentron canadum*), greater amberjack (*Seriola dumerili*), common dolphin (*Coryphaena hippurus*), tripletail (*Lobotes surinamensis*), wahoo (*Acanthocybium solandri*), tunas (*Thunnus* sp.), and billfishes (family Istiophoridae) (SAFMC 1998). The extent to which these fishes are dependent upon *Sargassum* as a habitat likely varies among their life history stages, but for many species *Sargassum* may play a more significant role in the survival and growth of larval and juvenile life stages than for adults.

Previous studies have concentrated on the macrofauna associated with *Sargassum* habitat, and little is known about the importance of this habitat for the early life-stages of fishes. The present study is a preliminary effort to assess the diversity and abundance of larval and postlarval fishes found adjacent to *Sargassum* located both along convergence zones and in large isolated mats not associated with particular hydrographic features.

MATERIALS AND METHODS

Sampling Locations and Shipboard Procedure

Sampling was conducted during May and July 2000 in the northcentral Gulf of Mexico (Figure 1). Surface samples were taken with a 1m x 2m neuston frame fitted with 947μm mesh Nitex. Tows were of 10 minutes duration at a ship speed of approximately 2 knots, and the net was approximately 50% submerged, i.e. fished the surface layer to a depth of approximately 0.5 m. In addition, several surface collections of five minutes duration were taken with a 0.73 m diameter ring net fitted with 333μm mesh Nitex and a mechanical flowmeter to measure volume of water filtered. Samples were washed into buckets, concentrated with a sieve, preserved in 95% ethanol and returned to the laboratory for sorting and identification.

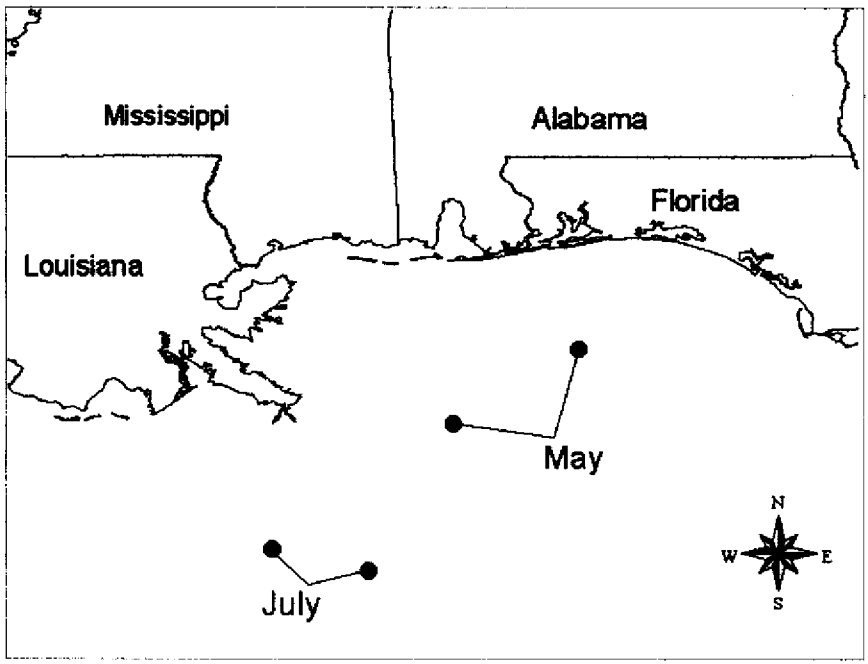


Figure 1. Sampling locations during May, July and 2000 in the northcentral Gulf of Mexico.

RESULTS

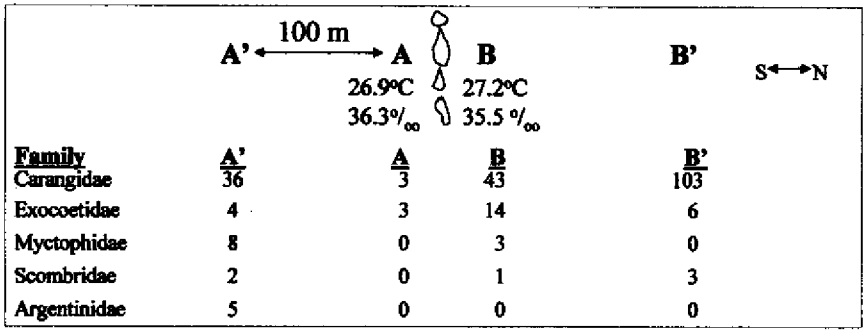
A total of 1453 larvae/postlarvae comprising 22 families were found in surface plankton collections taken during May and July 2000. The relative abundance and diversity of young fishes varied both spatially and temporally. Collections were generally dominated by carangids and exocoetids, but also included specimens of tuna (including bluefin in May), dolphin and billfishes.

May

During May two fronts with associated *Sargassum* were sampled. At the first location surface collections were taken immediately adjacent to a continuous row of *Sargassum* patches with both the ring and neuston nets, and for comparison a neuston "control" collection was taken approximately 100 m from the front (Table 1). Sphyraenid larvae were the most abundant family collected at the front adjacent to the patches of *Sargassum* with both the neuston and ring nets, but no sphyraenid larvae were found in the neuston "control" collection. Carangids and exocoetids were the next most abundant taxa in all three collections, with exocoetids being the most abundant larvae in the neuston "control" collection. All five scombrids (tuna) and the single istiophorid (billfish) and coryphaenid (dolphin) were collected adjacent to the *Sargassum* habitat (Table 1).

Table 1. Larval and post-larval fishes collected in the northcentral Gulf of Mexico with both a neuston and ring net adjacent to Sargassum located along a frontal zone and with a neuston "control" collection taken 100 m from the front. Neuston abundances are numbers of larvae per 10 minute collection, and ring net abundances are numbers of larvae per 100 m^3.

Family	Neuston "Control"	Neuston	Ring Net
Sphyraenidae	0	65	13
Carangidae	17	31	9
Exocoetidae	132	20	7
Mugilidae	0	10	0
Echeneidae	0	6	0
Scombridae	0	3	2
Monocanthidae	2	2	1
Serranidae	0	2	0
Istiophoridae	0	1	0
Coryphaenidae	0	1	0
Myctophidae	1	0	0
Ostraciidae	1	0	0
Scorpaenidae	1	0	0



Family	A'	A	B	B'
Carangidae	36	3	43	103
Exocoetidae	4	3	14	6
Myctophidae	8	0	3	0
Scombridae	2	0	1	3
Argentinidae	5	0	0	0

Figure 2. Larval and post-larval fishes from surface ring-net collections taken in the northcentral Gulf of Mexico during May 2000. Collections were taken both adjacent to Sargassum located along a frontal zone, and approximately 100 m from the front on both sides. Abundances are numbers of larvae per 100 m^3.

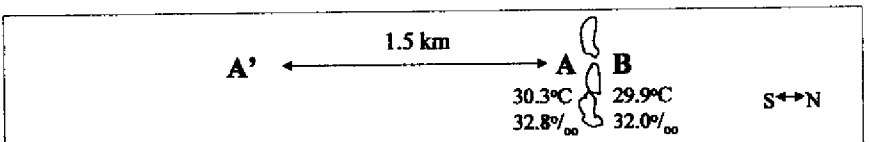
At the second location sampled in May, surface ring-net samples were taken on both sides of a front containing *Sargassum* and approximately 100 m from the front on each side (Figure 2). Surface salinity and temperature on either side of the front differed by 0.8 ‰ and 0.3°C. Carangids were the most abundant taxa collected; 186 specimens were found in the four collections and a density as high as 103 larvae per 100 m^3 was found in a surface collection approximately 100 m from the front (Figure 2). Densities of carangid larvae were lower on the north side of the front, but larvae were again more abundant approximately 100 m from the front than adjacent to *Sargassum* along the frontal zone. Exocoetid larvae were also relatively abundant and were found in all four collections; the highest abundance was found on the south side of the front adjacent to the line of *Sargassum*. Six scombrids were collected and all specimens were larger than 6 mm and could be positively identified as bluefin tuna. It is coincidence that the reported density of these larvae (Figure 2), i.e., number of larvae per 100 m^3, is the same as the actual number collected. Scombrids from the previously sampled front were smaller and could only be identified as *Thunnus* sp.

July

During July, plankton sampling was conducted at both a well-defined front with associated *Sargassum* (Figure 3), and adjacent to a large patch of *Sargassum* that was not associated with a particular hydrographic feature. Sampling at the front was conducted with both the ring and surface nets, and collections were taken adjacent to *Sargassum* on both sides of the front and approximately 1.5 km south of the front (Figure 3). Of the fourteen families of fishes collected, carangids were again the most abundant larvae, and highest abundances were found in collections taken adjacent to *Sargassum* habitat. The distribution of carangids was patchy, however,

as evidenced by the neuston collection taken adjacent to *Sargassum* on the north side of the front in which no carangids were found. Exocoetids were again the second most abundant taxa collected, and highest abundances were found in collections taken adjacent to *Sargassum*. The ichthyofauna was more diverse in collections taken adjacent to *Sargassum* with both the ring net and neuston net (Figure 3), and the few specimens of scombrids, coryphaenids and istiophorids were only collected adjacent to *Sargassum*.

A second station sampled in July was adjacent to a large mat of *Sargassum* that was not associated with a frontal feature. The patch of algae was approximately 100 m long and 50 m wide. Surface collections were taken with both a neuston net and a ring net within a few meters of the edge of the mat. No fish were found in the ring net collection, and only 23 specimens comprising four families were collected with the neuston net. Fifteen of these fish were exocoetids, and the remaining few specimens were pomacentrids (4), balistids (3) and a single gerreid larva.



	A'		A		B	
Family	**R**	**N**	**R**	**N**	**R**	**N**
Carangidae	20	92	54	142	197	0
Exocoetidae	0	6	3	25	3	2
Scombridaae	0	0	1	3	2	0
Serranidae	0	0	0	1	0	0
Istiophoridae	0	0	0	1	0	0
Lobotidae	0	0	0	1	0	0
Coryphaenidae	0	0	0	1	0	1
Mugilidae	0	0	0	1	0	0
Pomacentridae	0	2	1	0	1	1
Syngnathidae	0	1	1	0	1	4
Balistidae	0	0	0	0	0	1
Hemiramphidae	0	0	0	0	0	1
Clupeidae	2	0	0	0	333	0
Myctophidae	1	0	0	0	0	0
Gerriidae	0	0	0	0	0	31

Figure 3. Larval and post-larval fishes from both surface ring-net (R) and neuston (N) collections taken in the northcentral Gulf of Mexico during July 2000. Neuston abundances expressed are numbers of larvae per 10 minute collection, and ring net abundances are numbers of larvae per 100 m^3.

DISCUSSION

The aggregation of fish larvae at fronts may be caused by the spawning behavior of adults and/or the passive accumulation of larvae due to the convergence of surface waters in frontal zones (Kirobe et al. 1988, Sabatés and Masó 1990, Grimes and Finucane 1991, Govoni and Grimes 1992, Brandt, 1993). It is not known how *Sargassum*, which frequently accumulates along fronts, influences the distribution and abundance of fish larvae, but *Sargassum* habitat has certainly been shown to support many species of juvenile fishes (Dooley 1972, Bortone et al. 1977, Conston-Clements et al. 1991, Settle 1993). Only one dated study (Bortone et al. 1977) has examined the abundance and diversity of young fishes associated with *Sargassum* in the Gulf of Mexico, and no studies have examined the ichthyoplankton assemblages found adjacent to *Sargassum* habitat along frontal zones.

Previous studies have shown that juvenile fishes associated with *Sargassum* are usually dominated by the families Balistidae, Monacanthidae and Carangidae (Dooley 1972, Bortone et al. 1977, Settle 1993). This species composition was not reflected in plankton collections. Although present in plankton collections from the present study, balistids and monacanthids were not abundant. Carangids were abundant in plankton collections, but they were dominated by the Atlantic bumper (*Chloroscombrus chrysurus*), a carangid that is not commonly found in *Sargassum*. Exocoetid larvae were also quite abundant, which is expected because the eggs of many species develop in *Sargassum*.

The diversity in plankton collections was generally quite high, and 22 families of larvae/postlarvae were found in this limited study. Several commercially and recreationally important species were collected, including billfishes, dolphin and tuna. The diversity and abundance of fishes was higher in neuston collections than ring net collections because of the larger mouth-opening and longer tow-time for the neuston net. Collections taken as "controls" in May, i.e. collections taken away from a front with its associated *Sargassum*, were removed from a front by approximately 100 m. Results from these "control" collections were inconclusive: carangid and exocoetid larvae were abundant both adjacent to *Sargassum* and at the "control" locations. In addition, all five tuna larvae found at the first station sampled in May were collected adjacent to *Sargassum* at the front, and no tuna larvae were found in the "control" collection. However, at the second front sampled, five of the six tuna larvae were collected at a "control" site

A total of eleven scombrid larvae were collected in the seven May collections, and all specimens larger than approximately 6 mm (n = 6) were identified as bluefin tuna based in part on the presence of one or more melanophores on the dorsal surface of the body (Richards et al. 1990). This species of tuna is expected to occur in these waters during this time based on reported spring spawning (McGowan and Richards 1989). The five smaller scombrids were too small to have developed this pigment and could only be identified as tuna larvae, although it is likely that some of these specimens were also bluefin tuna. The distribution of tuna larvae also brings into question the usefulness of our "control" sites; at the first station sampled in May all five tuna collected were found adjacent to *Sargassum* located along a front, but

at the second front five of the six tuna larvae collected were found at the two "control" sites approximately 100 m from the front.

In July a single front with associated *Sargassum* was sampled and the "control" site was moved further away (1.5 km) from the front. The abundance and diversity of fishes was greater for both ring and neuston net surface collections taken along the front than at the "control" location; fishes collected along the front represented 14 families, whereas fishes from only seven families were found at the "control" location. It is likely that the increased abundance and diversity of larvae and young juveniles along the front is due to both the convergence of surface waters in this region, and the presence of *Sargassum* habitat. The supposition that the convergence of water masses affects the diversity and abundance of fish larvae is further strengthened by the relatively low diversity and abundance of fishes found in both the ring and neuston net collections taken in July adjacent to large a large patch of *Sargassum* not associated with a front. In addition to the passive accumulation of larvae in frontal zones, several species may spawn in the vicinity of *Sargassum* located along fonts. Results from this ongoing study are limited because of the relatively few collections. Future planned research will not only increase the sample size but will include collections taken along fronts with no associated *Sargassum*. Larvae may accumulate in frontal zones both with and without *Sargassum*, but the growth and survival of larvae may be quite different in both areas.

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LITERATURE CITED

Bortone, S.A., P.A. Hastings and S.B. Collard. 1977. The pelagic-*Sargassum* ichthyofauna of the eastern Gulf of Mexico. *Northeast Gulf Science* **1**(2):60-67.

Brandt, S.B. 1993. The effect of thermal fronts on fish growth: a bioenergetics evaluation of food and temperature. *Estuaries* **16**(1):142-159.

Butler, J.N., B.F. Morris, J. Cadwallader, and A.W. Stoner. 1983. Studies of *Sargassum* and the *Sargassum* community. Bermuda Biological Station Special Publication No. 22.

Coston-Clements, L., L.R. Settle, D.E. Hoss, and F.A. Cross. 1991. Utilization of

the *Sargassum* habitat by marine invertebrates and vertebrates - a review. *NOAA Tech. Memo. NMFS-SEFSC*-296. 32 pp.

Dooley, J.K. 1972. Fishes associated with the pelagic *Sargassum* complex, with a discussion of the *Sargassum* community. *Contributions in Marine Science* **16**:1-32.

Fine, M.L. 1970. Faunal variation on pelagic *Sargassum*. *Marine Biology* **7**:112-122

Govoni, J.J. and C.B. Grimes. 1992. The surface accumulation of larval fishes by hydrodynamic convergence within the Mississippi River plume front. *Continental Shelf. Research* **12**(11):1265-1276.

Grimes, C.B. and J.H. Finucane. 1991. Spatial distribution and abundance of larval and juvenile fish, chlorophyll and macrozooplankton around the Mississippi River discharge plume, and the role of the plume in fish recruitment. *Marine Ecolology Progress Series* **75**:109-119.

Kingsford, M.J. 1990. Linear oceanographic features: a focus for research on recruitment processes. *Australian Journal of Ecology* **15**:391-401.

Kiørboe, T., P. Munk, K. Richardson, V. Christensen, and H. Paulsen. 1988. Plankton dynamics and larval herring growth, drift and survival in a frontal area. *Marine Ecolology Progress Series* **44**:205-219.

Langmuir, I. 1938. Surface motion of water induced by wind. *Science* **87**:119-123.

McGowan, M.F. and W.J. Richards. 1989. Bluefin tuna, *Thunnus thynnus*, larvae in the Gulf Stream off the southeastern United States: satellite and shipboard observations of their environment. *U.S. Fisheries Bulletin* **87**:615-631.

Moser, M.L., P.J. Auster and J.B. Bichy. 1998. Effects of mat morphology on large *Sargassum*-associated fishes: observations from a remotely operated vehicle (ROV) and free-floating video camcorders. *Environmental Biology of Fishes*. **51**:391-398.

Parr, A.E. 1939. Quantitative observations on the pelagic *Sargassum* vegetation of the western North Atlantic. *Bulletin of Bingham Oceanographic College* **6**:1-94.

Richards, W.J., T. Potthoff, and J. Kim. 1990. Problems identifying tuna larvae species (Pisces: Scombridae: *Thunnus*) from the Gulf of Mexico. *U.S. Fisheries Bulletin* **88**:607-609.

Sabatés A. and M. Masó, 1990. Effect of a shelf-slope front on the spatial distribution of mesopelagic fish larvae in the western Mediterranean. *Deep-Sea Research* **37**(7):1085-1098.

SAFMC. 1998. Final fishery management plan for pelagic *Sargassum* habitat of the south Atlantic region. *South Atlantic Fisheries Management Council*, Charleston, South Carolina USA. 90 pp.

Settle, L.R. 1993. Spatial and temporal variability in the distribution and abundance of larval and juvenile fishes associated with pelagic *Sargassum*. M.S. Thesis. University of North Carolina. Wilmington, North Carolina USA. 64 pp.

Shanks, A.L. 1988. Further support for the hypothesis that internal waves can cause shoreward transport of larval invertebrates and fish. *Fisheries Bulletin* **86**:703-714.

Sieburth, J.N. and J.T. Conover. 1965. *Sargassum* tannin, an antibiotic which retards fouling. *Nature* **208**:52-53.

Winge, O. 1923. The Sargasso Sea, its boundaries and vegetation. *Report on the Danish Oceanographical Expeditions 1908-1910, to the Mediterranean and Adjacent Seas* **3**(2):3-34.

The Across-shelf Larval, Postlarval, and Juvenile Fish Communities Associated with Offshore Oil and Gas Platforms West of the Mississippi River Delta

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ABSTRACT

The fisheries aggregation value of oil and gas platforms in the continental shelf waters of the northern Gulf of Mexico is well recognized, but the assessment of early life stages associated with these structures has not been adequately addressed. Ichthyoplankton assemblages were sampled at three offshore platforms: Green Canyon 18 (GC 18; 230 m depth, shelf slope); Grand Isle 94 (GI 94; 60 m depth, mid-shelf); and South Timbalier 54 (ST 54; 20 m depth, inner shelf) with passive plankton nets and light-traps. Family richness was highest at GC 18 (52), followed by GI 94 (43), and ST 54 (42). At the genus level, richness was highest at GI 94 (114), followed by ST 54 (86) and GC 18 (82). Clupeiforms dominated samples at all sites, comprising 59-97% of the total catch. Carangids and scombrids dominated the reef-associated fish assemblages at all sites, with blenniids becoming prominent in inshore collections. Other relatively common reef-associated fish were serranids and lutjanids (GC 18), pomacentrids and opisthognathids (GI 94), and *Rhomboplites aurorubens* (ST 54). The ichthyoplankton assemblages sampled at each site were relatively dissimilar, based on Schoener's Index of Similarity, with the highest index value for any two sites being 0.45 for GI 94 and ST 54 (0-1 scale). No significant difference was observed between mean Shannon-Weiner diversity indices calculated for plankton net samples at each site. For light-trap samples diversity was lowest at GC 18, significantly higher at GI 94, and then decreased inshore at ST 54. The presence of early preflexion larvae and presettlement postlarvae and juveniles in our collections indicate that both local spawning and settlement/recruitment may be occurring at these platforms.

KEY WORDS: Gulf of Mexico, oil and gas platforms, ichthyoplankton

INTRODUCTION

The introduction and proliferation of offshore oil and gas structures in the northern Gulf of Mexico has undoubtedly affected the marine ecosystem. The central and western Gulf is dominated by a mud/silt/sand bottom with little relief or hard bottom habitat, and there are approximately 4,000 oil and gas structures in

these federal waters. Parker et al. (1983) reported only 2,780 km^2 of natural available reef in the central and western Gulf. Although Gallaway (1998) calculated that oil and gas platforms in the northern Gulf provided 11.7 km^2 (or 4.0%) of the total "reef" habitat, the fact that platforms represent vertical artificial substrate that extends from the bottom to the surface (photic zone), regardless of location and depth, increases their significance. Since fish populations are usually limited by available energy, recruitment, or habitat, it is important to determine if platforms:

i) Provide critical habitat for early life history stages;
ii) Serve as new or additional spawning habitat; and
iii) Influence energy flow through the ecosystem by aggregating prey.

Oil and gas platforms can enhance fisheries by providing attachment substrate for habitat-limited sessile invertebrates, thereby creating food and habitat for reef-dependent species that are trophically-dependent on sessile and motile invertebrates associated with reefs (Gallaway 1981, Bohnsak and Sutherland 1985, Stephan et al. 1990, Bohnsak 1991). Since reef fish assemblages are among the most diverse and taxonomically rich in the aquatic biosphere (Sale 1991), platform communities may significantly enhance biodiversity. In addition, oil and gas structures may offer refugia for species which are trophically-independent of the biofouling community (i.e., reef-associated species; Choat and Bellwood 1991), but are ecologically-important resident, seasonal, or transient members of the hard substrate fish community (Gallaway et al. 1980). The extensive range (latitudinally and longitudinally) of this artificial substrate may also serve as migratory routes for tropical and subtropical species.

The objective of this study was to characterize and compare the larval, postlarval, and juvenile fish assemblages, particularly reef-oriented taxa, associated with three offshore oil and gas platforms off Louisiana representing different depth zones across the continental shelf. This objective was accomplished by collecting a wide variety of taxa and sizes utilizing two sampling techniques, light-traps and passive plankton nets. These methodologies complemented each other, since nets effectively sample yolk-sac, larval, and some postlarval fishes, whereas light-traps sample photopositive species at overlapping and larger sizes to give us more complete estimates of sizes (cohorts or inferred ages) and developmental/early life history stages present (Choat et al. 1993).

MATERIALS AND METHODS

Sampling occurred along a transect west of the Mississippi River Delta with site selection for platforms based upon the work of Gallaway et al. (1980) and Gallaway (1981) who reported that nekton communities around platforms could be categorized by water depth in the northern Gulf. Three communities were characterized: a coastal assemblage (water depths < 27m), an offshore assemblage (water depths 27 to 64 m), and a bluewater/tropical assemblage (water depths > 64m). The platforms selected encompass all three zones. Mobil's Green Canyon (GC) 18, which lies in about 230 m of water on the shelf slope (27°56'37"N,

91°01'45"W), was sampled monthly during new moon phases over a 2-3 night period during July 1995 - June 1996. Mobil's Grand Isle (GI) 94B, which lies in approximately 60 m of water at mid-shelf (28°30'57"N, 90°07'23"W), was sampled twice monthly during new and full moon phases over a three night period during April - August 1996. In addition, during May extra samples during the first quarter and third quarter moon phases were collected. Exxon's South Timbalier (ST) 54G, which lies in approximately 20 meters of water on the inner shelf (28°50'01"N, 90°25'00"W), was sampled twice monthly during new and full moon periods in during April - September 1997.

Sampling protocols for GC 18, GI 94, and ST 54 were similar. At GC 18, all sampling began one hour after sunset and was completed one hour before sunrise. The major sampling station for each platform was located in the internal central region along a stainless steel, small diameter guidewire (monorail) tethered to the first set of the platform's underwater, cross-member, support structures. At this central station, replicate trap collections (N = 2) were taken three times each night at near-surface (1 - 2 m depth) and at a depth between 15 and 23 m, depending upon the individual platform's underwater configuration of the first set of cross-member supports. Subsurface samples were collected by lowering a trap without floatation. Light-traps were deployed for 10 minute periods. Passive, horizontal plankton net collections were taken three times at both depths during each night at the central station using a metered, 60 cm diameter, 333μm mesh net. The nets had a vane (to help orient into the current) which was fixed to a gimbled attachment on the net ring, which allowed the net to be set and retrieved closed for the at depth deployment. In addition, three collections each night were made with a floating light-trap which was tethered and free drifted away (off-platform) from the platform (approximately 20 m) on the down current side of the platform. Sampling effort was modified at GI 94 and ST 54 to obtain one (rather than two) replicate subsurface and surface collection per gear, and one off-platform light-trap collection per set, with still three sets taken per night.

Community similarity between sites was measured using Schoener's Index of Niche Overlap (Schoener 1970) which was calculated by combining fish collected by all gears within each site. Only fish identified to at least the genus level were used in the similarity analyses. Since this type of analysis can be heavily influenced by large abundances of a single species, it was done without the most dominant taxa at each site included. At times, the sampling efforts differed temporally between sites, so the samples used for comparisons were limited to only those months where samples were collected for both sites in a pairing. Only April-August samples were used to compare GC 18 to GI 94 and ST 54. Full data sets were used in comparisons between GI 94 and ST 54. Shannon-Weiner diversity indices (Magurran, 1988) were calculated for each sample collected at GC 18, GI 94, and ST 54. Differences in mean diversity between sites were analyzed with ANOVA models using gear as a main effect. Post-ANOVA tests (Tukey's Studentized Range, α=0.05) were used to determine which sites where significantly different. Only fish identified at least to the level of genus were included in the diversity analyses.

RESULTS

A total of 67 families were represented in our plankton net and light-trap collections from the three platform sites. The number of families represented in passive plankton net collections decreased from 45 at GC 18 (shelf slope) to 40 at GI 94 (mid-shelf) and 34 at ST 54 (inner shelf). In contrast, the number of families represented in light-trap collections was fairly consistent, from 37 at GC 18 and GI 94 to 34 at ST 54. The number of taxa collected, however, peaked at GI 94 for both plankton nets (83) and light-traps (90). The number of taxa collected in plankton nets and light-traps at GC 18 (64 and 59) and ST 54 (59 and 65) were similar. At GC 18, plankton nets collected fish from more unique families (15) and taxa (25) than the light-traps (7 and 18, respectively). At GI 94, plankton nets collected twice as many unique families as the light-traps (6 vs. 3), but light-traps collected more unique taxa (31) than plankton nets (26). At ST 54, plankton nets and light-traps collected equal numbers of unique families (8), while the light-traps collected more unique taxa than the plankton nets (27 vs. 19).

Reef-dependent and reef-associated fish (Choat and Bellwood 1991) made up a relatively small percentage of the total plankton net and light-trap collections (with clupeiforms removed from the total catch) at the three platforms (Table 1). At GC 18, these groups of fish comprised 18% and 32% of the plankton net and light-trap collections, respectively. Dominant groups included scombrids and carangids, as well as *Holocentrus* spp., *Pomacentrus* spp., and *Pristipomoides aquilonaris*. At GI 94, reef-dependent and reef-associated fishes comprised 10% of the plankton net catch and 17% of the light-trap catch. Blenniids were prominent in light-trap collections, while carangids were dominant in plankton nets. At ST 54, these fishes comprised less than 1% of the plankton net collections and only 8% of the light-trap collections. Carangids, blenniids, and scombrids were the dominant reef-associated taxa.

At GC 18, light-traps (n = 319) and plankton nets (n = 125) collected 1,114 and 3,943 fish, respectively, over the course of the year (Table 1). Clupeiform fishes, primarily unidentified engraulids, *Opisthonema oglinum*, *Anchoa nasuta/hepsetus*, and *Engraulis eurystole* dominated the samples, comprising 59% of the total catch for both gear types combined. Dominant non-clupeiform fishes included the reef-associated *Auxis* spp., *Caranx crysos*, and *Caranx hippos/latus*, and the sciaenid *Sciaenops ocellatus*.

At GI 94, light-traps (n = 474) collected 31,353 fish and plankton nets (n = 329) collected 14,401 fish. Clupeiforms dominated the total catch (66%). The most common taxa collected included *Anchoa* spp., *A. nasuta*, *Engraulis eurystole*, and *Opisthonema oglinum*. Among the most common non-clupeiform fishes were demersal taxa such as synodontids (primarily *Synodus foetens* and *S. poeyi*), and *Symphurus* spp., as well as the reef-associated blenniids (*Hypsoblennius invemar* and *Parablennius marmoreus*) and scombrids (*Auxis* spp. and *Euthynnus alletteratus*).

Table 1. Size ranges (SL in mm) and percent of the total catch by gear for dominant taxa (>1%) collected by at least one gear type. Percentages are calculated after the exclusion of clupeiform fishes. Asterisks (*) indicate taxa from reef-associated or reef-dependent families.

	Light-trap		Plankton net	
Taxon	**Size Range**	**%**	**Size Range**	**%**
Green Canyon 18 (July 1995-June 1996)				
Cyclothone braueri	3.2-7.2	5.8	4.0-13.0	1.8
Saurida brasiliensis	3.2-9.8	5.8		
Trachinocephalus myops	16.2-35.0	1.8		
Bregmaceros cantori	1.5-6.7	2.0	1.3-6.8	4.5
Gobiesox stromosus	2.6-3.2	2.0		
Holocentrus spp.*	6.0-37.5	4.0		
*Caranx crysos**	5.0-65.0	12.0	2.5-16.5	3.3
*Caranx hippos/latus**	3.0-54.0	6.4	2.0-32.0	10.9
*Chloroscombrus chrysurus**			1.9-7.0	1.6
*Elagatis bipinnulata**			2.0-3.5	1.3
*Pristipomoides aquilonaris**			2.3-40.0	3.9
Eucinostomus spp.	6.5-11.2	3.3		
Cynoscion arenarius	2.5-4.5	1.1	2.0-4.4	6.9
Micropogonias undulatus	3.2-4.5	1.1		
Sciaenops ocellatus			1.8-3.9	12.3
Pomacentrus spp.*	9.0-19.3	4.7		
Mugil cephalus	2.4-21.5	3.8	2.2-5.0	9.0
Microdesmus lanceolatus			2.0-11.0	1.5
Microdesmus longipinnis	2.4-4.9	1.8		
Auxis spp.*	3.3-59.0	13.3	2.2-10.5	7.6
*Euthynnus alletteratus**	6.2-87.0	5.1	3.0-12.0	2.5
*Scomberomorus cavalla**	3.0-4.5	1.3		
*Scomberomorus maculatus**			2.0-10.1	2.1
Ariomma spp.			2.1-2.5	7.8
Peprilus burti	1.7-4.2	2.0	1.4-3.3	1.2
Citharichthys spilopterus			3.0-8.0	2.1
Syacium spp.	3.5-6.5	2.7		
Symphurus spp.	2.2-8.0	5.3	2.8-9.0	6.9
Grand Isle 94 (April-August 1996)				
Saurida brasiliensis	4.5-55.0	7.9	2.7-22.5	6.2
Synodus foetens	6.0-43.0	30.6	4.2-22.5	1.8
Synodus poeyi	5.3-45.0	15.6	2.0-16.5	1.2
Bregmaceros cantori	2.0-29.0	3.0	2.0-15.5	16.6
*Caranx crysos**			2.5-15.0	2.1
*Chloroscombrus chrysurus**			2.1-16.5	1.5
Lutjanus spp.*			3.0-5.5	1.0
Cynoscion arenarius			1.9-5.2	2.2
*Sphyraena guachancho**			2.6-7.3	2.7

Table 1 continued.

	Light-trap		Plankton net	
Taxon	**Size Range**	**%**	**Size Range**	**%**
*Hypsoblennius hentz/jonthas**	4.3-12.0	2.5		
*Hypsoblennius invemar**	3.5-14.5	13.8		
*Parablennius marmoreus**	4.4-23.7	12.3		
*Scartella/Hypleurochilus**	3.6-12.5	1.7		
Microdesmus lanceolatus			2.4-25.0	2.2
Auxis spp.*	4.0-36.0	1.4	2.5-10.3	10.3
*Euthynnus alletteratus**	3.1-60.0	5.3	2.7-8.7	10.7
Etropus crossotus			2.5-9.0	2.6
Syacium spp.			2.1-8.5	3.0
Symphurus spp.			2.0-12.8	22.5
South Timbalier 54 (April-September 1997)				
Saurida brasiliensis	26.4-43.0	1.2		
Synodus foetens	9.0-44.5	38.9		
Bregmaceros cantori			2.2-11.7	2.1
*Caranx crysos**	6.5-24.5	2.0		
*Caranx hippos/latus**	5.5-35.0	3.8		
*Chloroscombrus chrysurus**	2.5-25.0	1.5	2.0-18.4	17.4
Cynoscion arenarius	2.0-7.0	7.0	1.9-7.8	53.3
Menticirrhus spp.			2.4-5.0	1.9
*Hypsoblennius hentz/jonthas**	3.4-12.5	4.4		
*Hypsoblennius invemar**	5.7-13.8	3.6		
*Scartella/Hypleurochilus**	2.0-14.3	5.0		
Microdesmus lanceolatus			3.2-20.8	1.3
Microdesmus spp.			2.0-3.3	1.3
Auxis spp.*	4.9-25.0	1.7		
*Euthynnus alletteratus**	7.0-22.5	9.1		
*Scomberomorus cavalla**	3.5-20.0	1.1	2.4-4.2	2.9
*Scomberomorus maculatus**	2.5-40.5	6.0	1.9-10.2	4.4
Peprilus burti	3.5-22.0	1.9	2.1-12.0	1.0
Peprilus alepidotus	2.5-24.7	1.3	1.8-5.0	1.6
Etropus crossotus	2.8-12.7	1.1	3.0-13.1	2.1
Symphurus spp.			2.0-14.5	2.3
Sphoeroides spp.	6.7-16.0	1.6		

At ST 54, light-traps (n = 194) and plankton nets (n = 89) collected 6,116 and 91,583 fish, respectively. Overall, clupeiforms, primarily clupeids, dominated the collections at ST 54, comprising 97% of the total catch for both gear types combined. Of the non-clupeiform fishes collected, sciaenids (*Cynoscion arenarius*), synodontids (*Synodus foetens*), and the reef-associated carangids (*Chloroscombrus chrysurus*) were dominant.

Schoener's Index of Similarity values range from 0 (no similarity) to 1 (identical taxonomic compositions). Similarity values between the sites were relatively low, with the highest similarity occurring between the mid-shelf site, GI 94, and the inner shelf site, ST 54 (0.45). The next highest value was between GC 18 and ST 54 (0.35), followed by GI 94 and GC 18 (0.29). Shannon-Weiner Diversity Index

values for plankton net collections were not significantly different between the sites (Tukey's Studentized Range test, $\alpha = 0.05$; Figure 1). Diversity peaked for light-trap samples at GI 94, where index values were significantly higher than the other sites. Light-trap collections at GC 18 had a significantly lower mean diversity index than the other sites, while diversity at ST 54 was intermediate.

DISCUSSION

Overall, reef-dependent taxa (chaetodontids, pomacentrids, labrids, and scarids) were relatively rare and never comprised over one percent of the total catch for either gear at any site. Pomacentrids and chaetodontids were collected only at the shelf slope and mid-shelf sites, while labrids and scarids were also collected at the inshore site. Our total of 67 families collected at oil and gas platforms throughout the course of this study is comparable with previously published surveys from the Gulf of Mexico (61 families, Ditty et al. 1988; 74 families, Richards et al. 1984), but is generally less than surveys that included more tropical waters (85 families, McGowan, 1985; 91 families, Limouzy-Paris et al. 1994; 96 families, Richards 1984; 100 families, Richards et al. 1993). While reef-dependent fish were uncommon, reef-associated fish (e.g., carangids, scombrids, blenniids) were much more common and many times represented a significant component of the community assemblage at each site.

In general, the dominant reef-associated fish at all sites were carangids and scombrids, although the relative abundances of taxa within these families changed across the shelf. *Caranx crysos*, *C. hippos/latus*, and *Auxis* spp. were dominant taxa at GC 18. *Euthynnus alletteratus* were more prominent at GI 94, while *Chloroscombrus chrysurus* and *E. alletteratus* were dominant at ST 54. While these taxa are pelagic predators as adults, they attain high numbers near reefs and serve as an energetic link that returns nutrients from off-reef feeding to the reef environment via defecation (Choat and Bellwood 1991). A wide size range was represented by these fish as well, from small preflexion sizes to larger juveniles, suggesting that both local spawning and juvenile recruitment and settlement may be occurring at these sites.

Reef-associated and reef-dependent taxa, though rare, were present at the platform sites, and differed in some respects across the shelf. At GC 18, serranids were present, most of which were from the poorly known subfamily Anthiinae. Anthiine adults are residents of rocky reefs on the outer shelf and are not usually found on shallow, inshore reefs (Thresher 1984). Other serranids included *Epinephelus* spp. and *Mycteroperca* spp. Lutjanids were also present, primarily *Pristipomoides aquilonaris*, one of the most common residents of mid- and outer shelf reefs (Hoese and Moore 1977). Other noteworthy taxa included unidentified blennies, *Holocentrus* spp., (reef-associated) and *Pomacentrus* spp. (reef-dependent). Based on the adult community description of offshore artificial and natural reefs (Gallaway 1981), we expected this site to have the most speciose and diverse reef fish assemblage, but that was not the case with our larval and juvenile

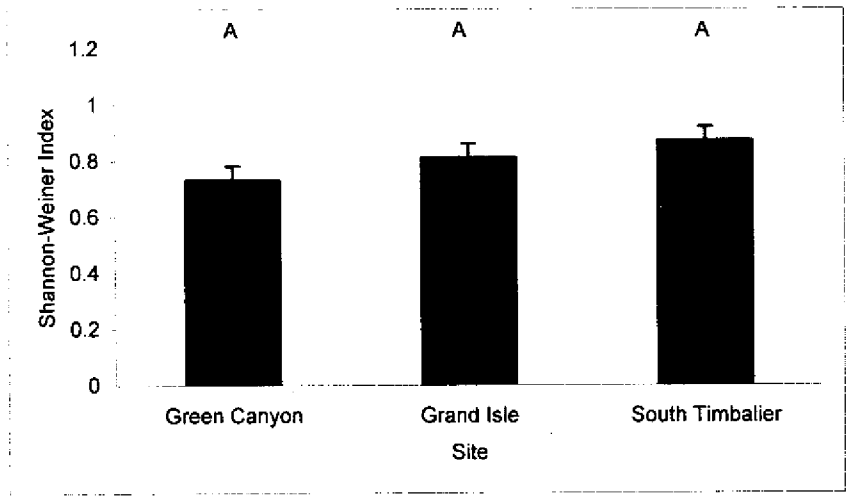
collections. This may be because reef fish communities are limited, in part, by the supply of pelagic larvae, usually from upstream sources rather than the resident populations (Sponaugle and Cowen 1996, Victor 1986). Reefs and platforms located on the shelf slope would theoretically have significantly fewer upstream sources of potential recruits than those on the mid-shelf, where other natural hard-bottom or reef habitats may be more abundant, or where the density of platforms is orders of magnitude greater. Therefore, the extremely remote location of GC 18 (shelf slope) is probably the limiting factor with regards to the pool of available larvae to be sampled.

At GI 94 there was greater taxonomic richness among reef fish than at GC 18. By far the most dominant reef-associated fish taxa at GI 94 were blenniids, particularly *Parablennius marmoreus* and *Hypsoblennius invemar*. These fishes are perhaps one of the most common taxa affiliated with oil and gas platforms, but are probably underestimated in visual surveys due to there small size, cryptic coloration, and tendency to hide in attached barnacle shells. At GI 94, unidentified gobiids and pomacentrids, primarily *Chromis* spp. and *Pomacentrus* spp. were also present. Unique to this site was the collection of opisthognathids in surface waters (plankton nets as well as surface and off-platform light-traps) during the spring-early summer. Adult *Opisthognathus aurifrons* are reported to be tropical (south Florida, Bahamas, northern South America) and rarely collected on the mid-to-outer shelf (Hoese and Moore 1977, Robins et al. 1986). Adult *O. lonchurus* are also reported to inhabit the northeast Gulf as well as tropical waters (Robins et al. 1986). The presence of these larvae reinforces the notion that oil and gas platforms may play a role in extending the ranges of more tropical forms that would otherwise be habitat limited in the northcentral Gulf.

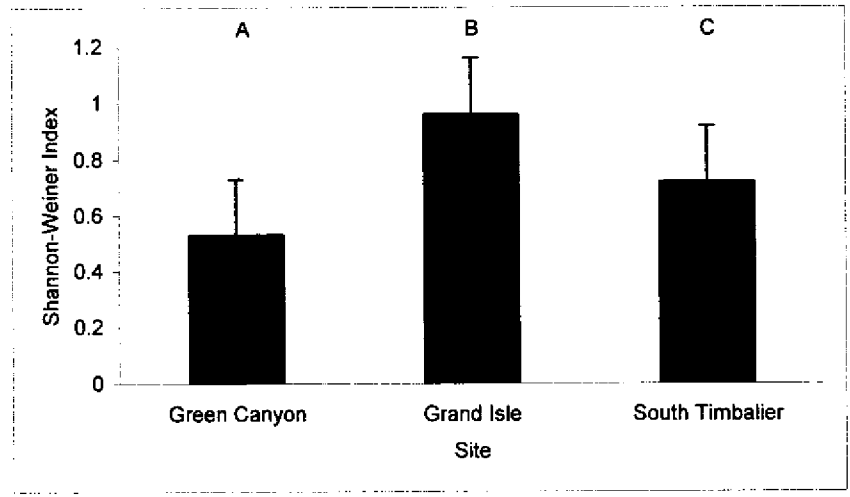
Other taxonomic differences in reef-associated fish composition were observed between GI 94 (mid-shelf) and GC 18 (outer shelf). At GI 94, lutjanids were also relatively common, with *Rhomboplites aurorubens* the dominant species, followed by *Lutjanus* spp. While *Pristipomoides aquilonaris* was the primary lutjanid at GC 18, none were collected at this mid-shelf site. With regards to serranids, the dominant group was serraniines (e.g., *Diplectrum* spp., *Centropristis* spp., and *Serranus* spp.), while relatively few anthiines were collected. Also noteworthy was the relatively high abundance of mullids collected at GI 94, particularly *Upeneus parvus*, a common species on the mid-to-inner shelf (Hoese and Moore 1977).

At ST 54, the most abundant reef/structure-associated fishes were blenniids and gobiids. Unlike GI 94, *Parablennius marmoreus* was relatively uncommon. The dominant species at ST 54 were *Scartella/Hypleurochilus* spp., *Hypsoblennius hentz/ionthas,* and *H. invemar*. Difficulties in identification prevent us from confidently separating *H. hentz* from *H. ionthas* and *Scartella* spp. from *Hypleurochilus* spp. but all of these taxa are common in nearshore areas and hard-bottomed habitats, such as oyster reefs and pilings (Hoese and Moore 1977). In general at ST 54, reef fish, although not abundant, were relatively well represented in terms of number of taxa, rivaling that of GI 94. However, other than blenniids and gobiids, abundances of other reef fish were very low (less than a total of 10

individuals collected per taxa) but included *Rhomboplites aurorubens* and unidentified pomacentrids, serranids, and ephippids.



Plankton net



Light-trap

Figure 1. Mean Shannon-Weiner diversity index values (with standard error barts) for plankton net and light-trap collections from each sampling site. The same letter above each bar indicates no significant difference between sites based on Tukey's Studentized Range tests (α = 0.05). Different letters indicated significant differences.

The low reef fish abundances are not surprising, particularly for the more tropical taxa such as haemulids, labrids, and scarids. The adults of these taxa are more typical of the outer shelf assemblages (Gallaway 1981). Similarly with regards to reef fish larvae and juveniles, this trend of decreasing taxonomic richness towards the more inshore environments is supported somewhat by our study, particularly with regards to scarids. Even though an inner shelf platform would be downstream from potentially more offshore sources of larvae and recruits, perhaps the relatively greater distances involved necessitate extended pelagic larval durations and the potentially less favorable inshore environmental conditions may result in increased mortality (Leis 1991).

In an effort to examine the relative similarity in taxonomic assemblages between the different sites we computed Schoener's Index of Similarity for each site. In general, the index values indicate that the sites were not very similar, with the highest similarity value between any two sites being 0.45 for GI 94 and ST 54 (mid- and inner shelf). This is not unexpected since we purposely chose sampling sites in different depth zones across the shelf where there should be some faunal transitions (Gallaway et al., 1980; Gallaway, 1981). The highest similarity index for GC 18, however, was with ST 54, the inner shelf platform, whereas we might have expected GC 18 to most similar to GI 94. This somewhat unexpected result is probably due to the previously mentioned, large number of reef taxa collected at GI 94 that were unique to that site. Reef fish taxa such as *Chromis* spp., *Abudefduf taurus, Mullus auratus, Ophioblennius atlantica, Pseudopeneus maculatus, Opisthognathus aurifrons*, and *Opisthognathus lonchurus* were collected only at the GI 94 platform. Other taxa (ephippids and scarids) were collected at GC 18 and ST 54, but not at GI 94.

The mean diversity indices for the plankton net collections taken at the platform sites were not significantly different from each other, ranging from 0.73-0.83 (Figure 1). In general, observed statistical differences in Shannon-Weiner diversity indices between sites were limited to light-trap collections. Light-trap collections were significantly more diverse at GI 94, a result of being less dominated by clupeiform fishes than ST 54, and of collecting more taxa, particularly reef fish taxa, than GC 18. In general, taxonomic richness in light-traps was highest at GI 94, with 90 taxa identified to genus as compared to 65 taxa at ST 54, the platform with the second highest number of taxa. Inshore (particularly estuarine) areas are generally characterized as having lower diversity than adjacent shelf waters and are dominated by a few highly abundant taxa (Nybakken 1988). This pattern is generally attributed to the fluctuating nature of the nearshore environment, particularly with regards to salinity and temperature, and the lack of physiological specializations needed to deal with this estuarine environmental variability (Nybakken 1988). This, in part, may explain the relatively low diversity indices for ST 54 the inshore site. In contrast, species richness and abundance is generally relatively low on the outer shelf, due to the homogeneity of the bottom substrate (Bond 1996). As previously discussed, topographical relief is disjunct throughout the northcentral Gulf (especially west of the Delta) and the sea floor is basically dominated by expanses of mud and silt.

Again, this homogeneity and the previously discussed lack of a large amount of upstream supply of larvae may in part explain the low taxonomic diversity observed in the light-trap collections at GC 18.

This study represents the first comprehensive look at the ichthyoplankton assemblages associated with oil and gas platforms in the northern Gulf of Mexico and is also a first (yet preliminary) attempt at comparing such assemblages across different depth zones and geographical regions. It is apparent that a diverse recently spawned larval, postlarval, and juvenile fish community can be captured in the waters within and near platforms, and these structures may therefore be important to reef-associated and reef-dependent fish. Though many taxa were represented in our collections, it is difficult to discern the reasons why some fish were present at these artificial structures. Some, like the clupeiforms, are extremely abundant, very photopositive, and may be behaviorally attracted to such structures with a large, consistent light-field. Other taxa like blennies may be attracted to the numerous habitats created by the biofouling community (e.g., barnacles) on the platform legs and cross-members, as well as the associated zooplankton food resources. Pelagic species, like carangids and scombrids, have more generalized habitat requirements, but may also be attracted to the structure (reef-associated) or to concentrations of zooplankton and forage fish that are inhabiting the platform and immediately surrounding waters. For whatever reason, based on the results from this study the oil and gas platforms serve a potentially important function as a hard-substrate habitat and could, therefore, lead to increased production.

LITERATURE CITED

Bohnsak, J.A. 1991. Habitat structure and the design of artificial reefs. Pages 412-426 in S.S. Bell, E.D. McCoy, and H.R. Mushinsky, (eds.) *Habitat Structure: The Physical Structure of Objects in Space*. Chapman and Hall, London.

Bohnsak, J.A. and D.L. Sutherland. 1985. Artificial reef research: a review with recommendations for future priorities. *Bulletin of Marine Science* **37**:11-19.

Bond, C E. 1996. *Biology of Fishes*. Saunders College Publishing, Orlando, Florida USA.

Choat, J.H. and D.R. Bellwood. 1991. Reef fishes: their history and evolution. Pages 39-66 in: P. F. Sale, (ed.) *The Ecology of Fishes on Coral Reefs*. Academic Press, San Diego, California USA.

Choat, J.H, P.J. Doherty, B.A. Kerrigan, and J.M. Leis. 1993. A comparison of towed nets, purse seine, and light-aggregation devices for sampling larvae and pelagic juveniles of coral reef fishes. *Fishery Bulletin* **91**:195-209.

Ditty, J.G., G.G. Zieske, and R.F. Shaw. 1988. Seasonality and depth distribution of larval fishes in the northern Gulf of Mexico above latitude 26°00'N. *Fishery Bulletin* **86**:811-823.

Gallaway, B.J., L.R. Martin, R.L. Howard, G.S. Boland and G.D. Dennis. 1980. A case study of the effects of gas and oil production on artificial reef and demersal

fish and macrocrustacean communities in the northwestern Gulf of Mexico. *Expo Chem 1980*, Houston, Texas USA.

Gallaway, B.J. 1981. An ecosystem analysis of oil and gas development on the Texas-Louisiana continental shelf. U.S. Fish & Wildlife Service, Office of Biological Services, FWS/OBS-81/27, Washington, D.C. USA.

Gallaway, B. J. 1998. Cumulative ecological significance of oil and gas structures in the Gulf of Mexico: Information search, synthesis, andecological modeling: Phase I, Final Report. U. S. Geological Survey, Biological Research Division, Washington, D.C. USGS/BRD/CR-1997-0006.

Hoese, H.D. and R.H. Moore. 1977. *Fishes of the Gulf of Mexico: Texas, Louisiana, and Adjacent Waters*. Texas A&M University Press, College Station., Texas USA.

Leis, J.M. 1991. The pelagic stage of reef fishes: the larval biology of coral reef fishes. Pages 183-230 in: P.F. Sale, (ed.) *The Ecology of Fishes on Coral Reefs*. Academic Press, San Diego, California USA.

Limouzy-Paris, C., M.F. McGowan, W.J. Richards, J.P. Umaran and S S. Cha. 1994. Diversity of fish larvae in the Florida Keys: results from SEFCAR. *Bulletin of Marine Science* **54**(3):857-870.

Magurran, A.E. 1988. *Ecological Diversity and Its Measurement*. Princeton University Press, Princeton, New Jersey USA.

McGowan, M.F. 1985. *Ichthyoplankton of the Flower Garden Banks, northwest Gulf of Mexico*. Doctoral Dissertation. University of Miami, Miami, Florida USA.

Nybakken, J.W. 1988. *Marine Biology: An Ecological Approach*. Harper and Row, New York, New York USA.

Parker, R.O., Jr., D.R. Colby T.P. Willis.1983. Estimated amount of reef habitat on a portion of the U.S. South Atlantic and Gulf of Mexico continental shelf. *Bulletin of Marine Science* **33**:935-940.

Richards, W. J. 1984. Kinds and abundances of fish larvae in the Caribbean Sea and adjacent areas. NOAA Technical Report NMFS-SSRF-776.

Richards, W. J., T. Potthoff, S. Kelley, M. F. McGowan, L. Ejsymont, J. H. Power and R. M. Olvera. 1984. SEAMAP 1982-Ichthyoplankton. NOAA Technical Memorandum NMFS-SEFC-144.

Richards, W. J., M. F. McGowan, T. Leming, J. T. Lampkin and S. Kelley. 1993. Larval assemblages at the Loop Current boundary in the Gulf of Mexico. *Bulletin of Marine Science* **53**(2):475-537.

Robins, C. R., G.C. Ray, and J. Douglass. 1986. *A Field Guide to the Atlantic Coast Fishes of North America*. Houghton Mifflin Company, Boston.

Sale, P. F. 1991. *The Ecology of Fishes on Coral Reefs*. Academic Press, New York, New York USA.

Schoener, T. W. 1970. Non-synchronous spatial overlap of lizards in patchy habitats. *Ecology* **51**:408-418.

Sponaugle, S. and R.K. Cowen. 1996. Nearshore patterns of coral reef fish larval supply to Barbados, West Indies. *Marine Ecology Progress Series* **133**:13-28.

Stephan, C. D., B.G. Dansby, G.C. Matlock, R.K. Rieckers, and R. Rayburn. 1990. Texas artificial reef fishery management plan. Texas Parks and Wildlife Department of Fisheries Management Plan Serial 3.

Thresher, R. E. 1984. *Reproduction in Reef Fishes*. T.F.H. Publications, Inc.

Victor, B. C. 1986. Larval settlement and juvenile mortality in a recruitment-limited coral reef fish population. *Ecological Monographs* **56**:145-160.

A Preliminary Study of the Summer Feeding Habits of Juvenile Florida Pompano (*Trachinotus carolinus*) from Open and Protected Beaches of the Northeastern Gulf of Mexico

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ABSTRACT

Relatively little information is available on the feeding habits of the Florida pompano (*Trachinotus carolinus*) from the northeastern Gulf of Mexico. The productive shallow water habitats of coastal barrier islands in this region of the Gulf offer a diverse array of potential prey items for this commercially important fish. During July 2000 the digestive tracts of 78 juvenile pompano were collected from barrier island habitats in Mississippi (Horn, Ship, and Petit Bois Islands), Alabama (Dauphin Island), and West Florida (Santa Rosa Island), preserved, and examined for food items. Comparisons of the prey organisms found were made based on fish size and collection site (e.g. open beaches of the Gulf or the protected beaches of the bay/sound) from the four islands. Of the 78 juvenile pompano examined all but three contained identifiable food items, which represented at least 32 different prey items. Crustaceans, primarily juvenile mole crabs (*Emerita* spp.), were the dominant food items of the juvenile pompano. Mole crabs occurred at all but one of the eight collecting sites. Diet diversity was slightly higher for fish from open beach habitats than for fish from the protected beaches of the bay or sound sides of the islands [Mississippi Sound/ Mobile Bay/ Pensacola Bay]. Fish collected from the protected north sides of the islands fed on more estuarine organisms (e.g., *Neanthes succinea*, *Corophium louisianum*) than those fish examined from open beach Gulf habitats. Our preliminary data indicate that during the summer months, juvenile pompano are opportunistic feeders utilizing the most readily available food resources within the habitats they forage. Juvenile pompano from open beach habitats appear to feed on juveniles of prey species (*Donax* spp., *Emerita* spp.) known from the diet of adults.

KEY WORDS: Juvenile pompano, *Trachinotus carolinus*, feeding, Gulf of Mexico

INTRODUCTION

The Florida pompano, *Trachinotus carolinus* (Linneaeus), a member of the family Carangidae, is a common nearshore species ranging from Cape Cod to northeastern Brazil. Our study was designed to determine and compare the differences in prey selection of juvenile pompano (14 - 94 mm) from open and

protected beaches on four barrier islands in the northeastern Gulf of Mexico.

The Florida pompano, referred to here as "pompano," is an important food and game fish along the coast of the southeastern United States, with Florida having the largest commercial landings (Pattillo, et al. 1997). Most of the previous reports dealing with the biology of pompano has been summarized by Pattillo et al. (1997). Juvenile pompano are reported to be abundant in the surf zone (Gunter 1958, Bellinger and Avault 1971, Benson 1982). Both juveniles and adults are known to exhibit schooling behavior (Benson 1982)

Spawning takes place offshore in early spring to late summer and all life stages are free swimming (Pattillo et al. 1997). According to Ditty et al. (1988), pompano planktonic larvae are present in the Gulf of Mexico from May through August. The fish are considered juveniles when they reach a standard length (SL) of 7 mm. Juveniles arrive in the surf zone when they are about 10 - 15 mm total length and leave for deeper water when they reach 75 - 150 mm. Juveniles are found in the shallow water beaches of the northern Gulf from April to October, and they move south along the coast in response to colder winter temperatures (Pattillo et al. 1997).

Pompano occur in both in oceanic and estuarine waters and are reported to feed on benthic and epibenthic organisms (Armitage and Alevison 1980, Bellinger and Avault 1971, Fields 1962, Finucane 1969, Modde.and Ross 1983). Juvenile pompano are known to exploit food sources in or adjacent to the swash zone of northern Gulf beaches (Modde and Ross 1983), however they are also reported to feed in peripheral estuarine habitats (Bellinger and Avault 1971, Finucane 1969). They have been reported to be diurnal feeders (Modde and Ross 1983, Pattillo et. al. 1997), and adults have been reported to feed during the day primarily on benthic bivalves (Pattillo et al. 1997). The adults have well developed pharyngeal plates, which allow them to feed on hard-shelled items such as bivalves and mole crabs (Finucane 1969, Bellinger and Avault 1971). Juvenile pompano are opportunistic feeders that often utilize the surf zone to feed on prey items which become dislodged or disoriented by wave action and vulnerable to predation (Pattillo et al. 1997). The smaller fish feed on benthic and pelagic invertebrates including polychaetes, calanoid copepods, amphipods, gastropod larvae, and insects. Studies by Hildebrand and Schroeder (1928), Berry and Iverson (1967), and Bellinger and Avault (1971) indicated that the diversity of these food items decrease as the fish grows, probably indicating that adult fish are more selective in their choice of prey. Modde and Ross (1983) are the only authors to present information on the diet of pompano in the northeastern Gulf of Mexico (Horn Island, Mississippi), however, little detailed information on the specific identification of prey items was reported. The most extensive feeding study of juvenile pompano in the Gulf of Mexico was conducted by Bellinger and Avault (1971). Their study was based on the examination of 899 juvenile fish collected from two Louisiana beach sites west of the Mississippi River. However, with few exceptions, most of the food items were only identified to major taxonomic categories (e.g., class and order). Two

other relevant studies are those of Armitage and Alevizon (1980), who studied juvenile and adult fish from the east coast of central Florida, and Fields (1962) who examined juveniles from the coast of Georgia.

MATERIALS AND METHODS

Juvenile pompano were collected from four barrier islands along the coasts of Mississippi, Alabama, and West Florida (see Figure 1). In addition, a few adult specimens were collected using hook and line from West Ship Island to be used for comparison of diet with the juveniles. The seven collecting sites for juveniles were (1) the southwest tip of Horn Island, (2) north side of Horn Island (middle), (3) south side Horn Island (middle), (4) north Petit Bois Island, (5) north side of Dauphin Island, (6) south side of Dauphin Island, (7) north side of Santa Rosa Island, and (8) South Santa Rosa Island.

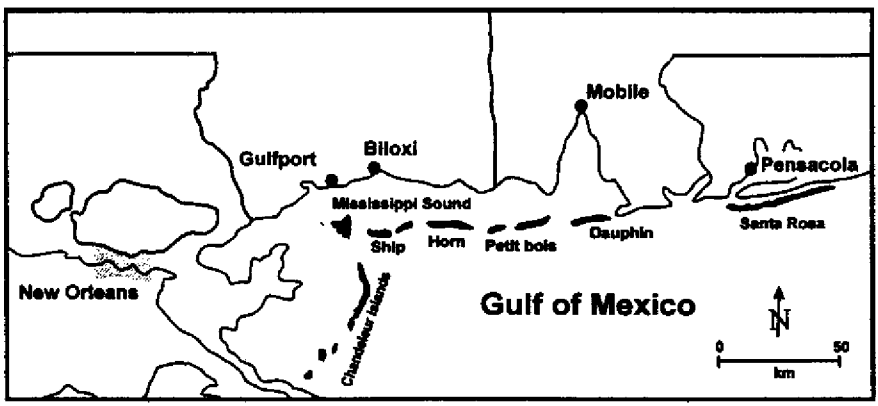


Figure 1. *Trachinotus carolinus* collection sites during June 2000.

The fish were collected with a 7 foot diameter cast net with ½ inch mesh, a 10 foot diameter cast net with ¼ inch mesh, and a 20 foot seine. When feasible, a minimum of 10 fish from each collection site were collected and examined. The number of fish specimens from each station was taken by availability. The salinity, air, and water temperature were taken at each station. Once collected, the fish were preserved in 10% formalin on site, and after a minimum of six days they were transferred to 70% ethanol. In the laboratory, the standard length (SL) of each fish was recorded. The entire digestive tract of each fish was removed. Utilizing both dissecting and compound microscopes, prey items from the entire digestive tract were counted and identified to lowest possible taxon. To compensate for the large differences in size and number of each of the prey items,

the items were taken as a percentage of each fishes' total stomach contents. The percentage of prey items for each individual fish was calculated, the averages for all fish examined were combined, and this value was divided by the total number of fish examined. These percentages are reflected in Figures 2 - 10. All calculations, graphs, and tables were made using Microsoft Excel 2000. Fish with empty stomachs were not included in calculations of diet composition. The miscellaneous category encompasses all prey organisms that composed 2% or less of the diet.

RESULTS

Seventy-eight juvenile pompano were collected from eight different barrier island collections sites during July 2000 (Table1). The digestive tracts of only three fish, two from the north side of Santa Rosa Island (station 7) and one from the southwest tip of Horn Island (station 1) contained no food items. The digestive tracts of the 75 juvenile pompano containing food material yielded a total of 1046 recognizable prey organisms representing at least 32 different species of invertebrates and fish (Appendix A). The summer feeding habits of juvenile pompano prey composition varied with collection site. Figures 2 and 3 indicate the similarities and differences in the prey consumed by pompano from the north (protected beaches) and south (open Gulf beaches) sides of the barrier islands during our study. The diet of the fish collected on the north side was composed of 22 different prey items, the small burrowing isopod *Exosphearoma diminuta*, being the most abundant prey organism recovered (Figure 2). The diet of fish collected from the south sides of the islands was composed of 26 different prey items with *Emerita* spp. being the most abundant prey item (Figure 3).

Table 1. Location, date of collection, temperature, salinity, and number of juvenile pompano collected during July 2000

Site #	Collection Site	Date	Air Temp °C.	WaterTemp .°C	Sal. ‰	# of Fish
1	SW Tip of Horn Island	07/11/2000	34	32	33	16
2	North Horn Island (mid	07/20/2000	31	32	34	10
3	South Horn Island (mid)	07/20/2000	34	26	35	10
4	North Petit Bois Island	07/07/2000	34	30	32	5
5	North Dauphin Island	07/23/2000	33	31	31	5
6	South Dauphin Island	07/23/2000	31	30	33	10
7	North Santa Rosa Island	07/24/2000	35	31	33	10
8	South Santa Rosa Island	07/24/2000	30	30	35	12

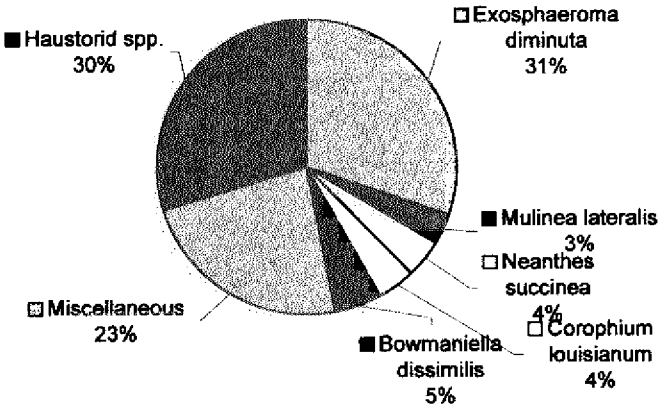


Figure 2. Important prey species recovered from 29 juvenile *Trachinotus carolinus* collected from the protected beaches, north sites of Horn,Petit Bois, Dauphin, and Santa Rosa Islands

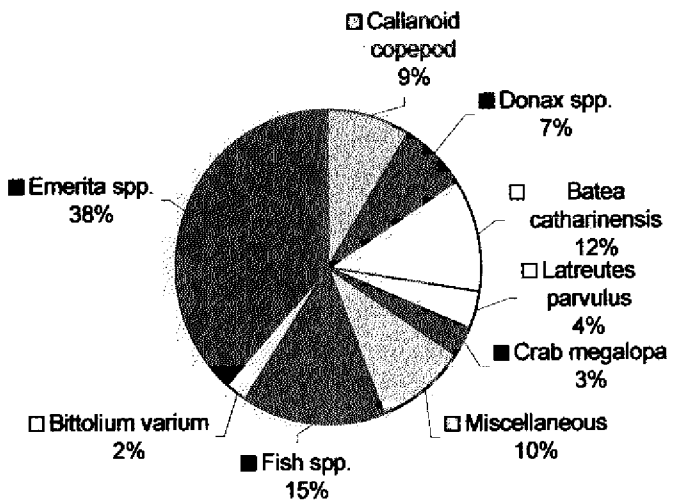


Figure 3. Important prey species recovered from 46 juvenile *Trachinotus carolinus* collected from the open beach, south sides of Horn, Petit Bois, Dauphin, and Santa Rosa Islands.

In general the food items identified during this study were indicative of shallow-water, sand dwelling organisms (Stations 1, 4, 6-8), however, there were notable exceptions (Stations 2,3,5). At Station 2, a protected beach area on the north side of Horn Island, the fish examined had been feeding in two different habitats, a protected sand beach and adjacent sea grass beds (*Halodule wrightii*). At this site a mixture of prey organisms, including sand beach species (*Emerita* spp. and *Exosphaeroma* diminuta), and grass bed forms (*Astryis [=Metrella] lunata Bittolium*[=*Bittium*] *varium, Hippolyte zostericola),*occurred in the diet of the fish examined.

When collections were made at Station 3, an open Gulf beach site on the south side of Horn Island, a large patch of drift algae with associated crustaceans (*Batea catharinensis* and *Latreutes parvulus*) was present. These two crustaceans, which are not typical of open beach habitats, made up an important part of the food items for the fish examined from this site.

A third site (Station 5) on the north side of Dauphin Island was an atypical habitat for pompano. This site is adjacent to sand/silt beach with near by *Spartina* salt marshes and submerged obstructions. The diet of the five pompano from this site consisted of typical estuarine epibenthic and soft bottoms forms such as the polychaetes, *Neanthes succinea* and *Polydora* sp. and the crustaceans, *Corophium louisianum* and *Sphaeroma quadridentatum*. No typical sand beach forms (e.g., *Emerita* spp., *Exosphaeroma diminuta*) were observed.

Based on the size of fish, the prey data for the juvenile pompano was divided into four size classes (Figures 4 - 7) and prey composition of each size class was determined. In the first size class (SL 14 - 34 mm), 23 different diet items were identified with sphaeromatid isopods (*Exosphaeroma diminuta*) and haustoriid amphipods (*Haustorius jayneae* and *Lepidactylus* sp. A) being the major dietary components consumed. The next size class, SL 35 - 55 mm, contained 25 different food items with juvenile mole crabs, *Emerita* spp., and haustoriid amphipods comprising of the major part of the prey organisms identified.

The third size class, SL 56 - 76mm, consumed 27 different prey items, the major food organism being *Emerita* spp. Only 14 prey items made up the final size class, 77 - 94mm, with juvenile coquina clams, *Donax* spp., being an important prey species. The food organisms found in fish of this size class reflected that reported for adult pompano.

Figure 9 illustrates the numerical representation of the major prey items consumed by all the 74 juveniles examined with food items in their digestive tracts. The juvenile diet was comprised of mostly *Emerita* spp. (20%) and *Exosphaeroma diminuta* (12%).

During July 2000 we also collected and examined the digestive tracts of four adult fish (SL 375 - 421 mm) from an open beach site off Ship Island, Mississippi. The diet of these was comprised of only 5 different prey items with *Donax* spp. being the most abundant and important prey item (Figure 10). Except for the commensal crab, *Pinnixa beherae*, which is associated with the ghost shrimps (*Callichirus islegrande*), the other prey organisms observed

(*Gynocuna dalli, Ancinus depressus, Parahaustorius* sp.) are relatively small, sand dwelling species.

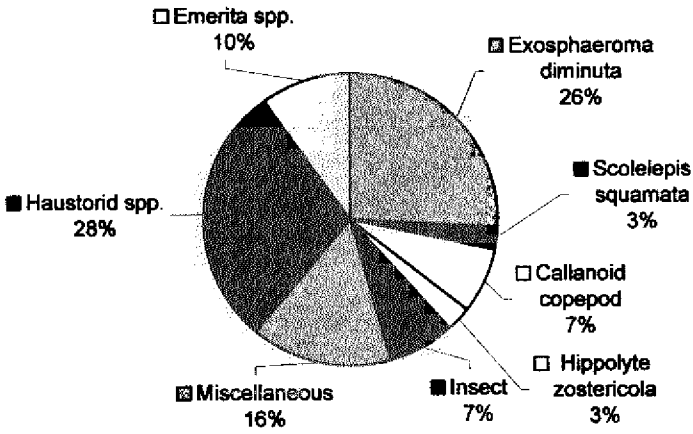


Figure 4. Total diet composition of 18 juvenile *Trachinotus carolinus*, SL 14 - 34 mm

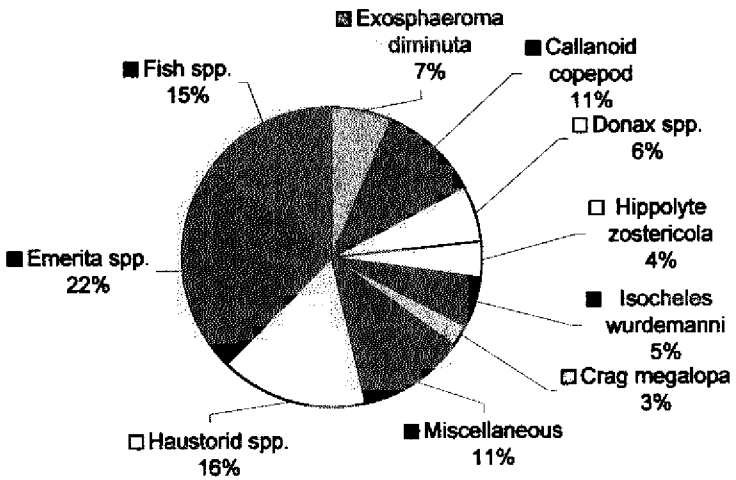


Figure 5. Total diet composition of 32 juvenile *Trachinotus carolinus*, SL 35 - 55 mm

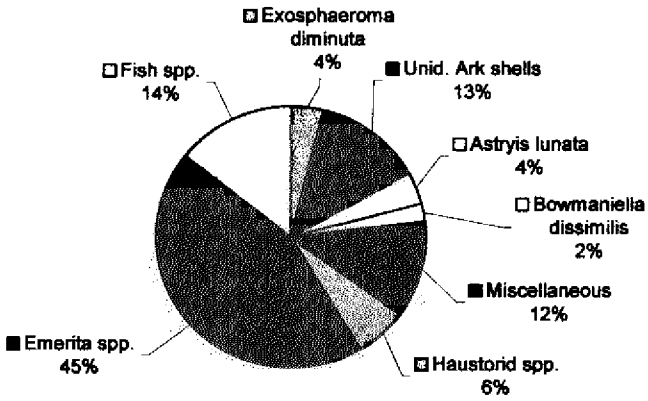


Figure 6. Total diet composition of 19 juvenile *Trachinotus carolinus*, SL 56 - 76 mm.

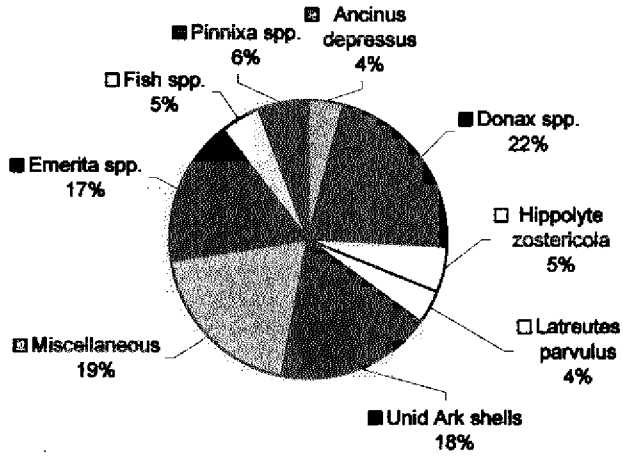


Figure 7. Total diet composition of five juvenile *Trachinotus carolinus*, SL 77 - 94 mm

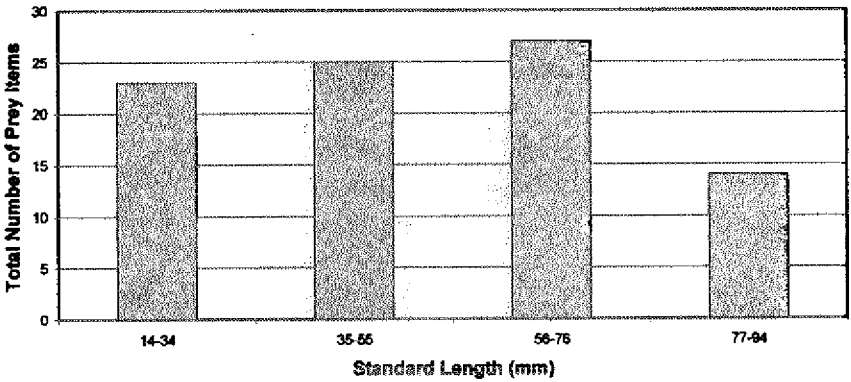


Figure 8. Total number of prey species found in the four juvenile size classes of Trachinotus carolinus collected from both protected and open beach sites on Horn, Petit Bois, Dauphin, and Santa Rosa Islands.

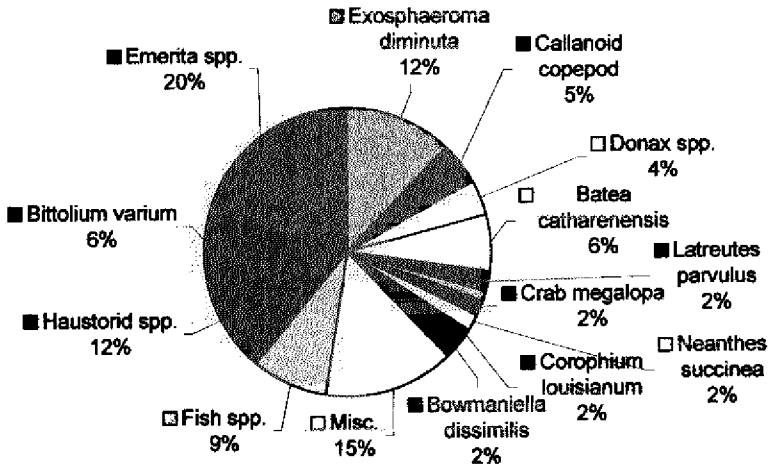


Figure 9. Major prey species comprising the diets of all size classes of juvenile *Trachinotus carolinus*, n = 74; sizes = 14 - 94 mm

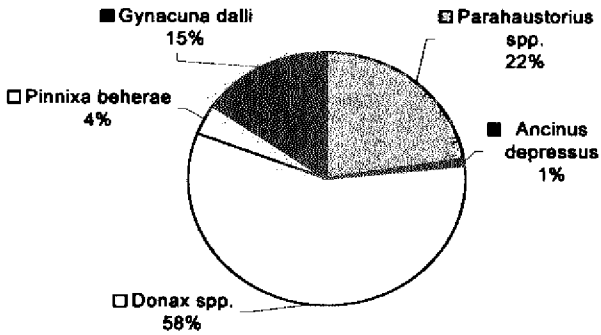


Figure 10. Total prey items recovered from four adult *Trachinotus carolinus*, SL 375 - 421 mm collected from the protected, north side of West Ship Island, Mississippi

DISCUSSION

These preliminary observations support earlier reports that juvenile pompano are opportunistic feeders (Pattillo et al.). Even though we examined a relatively limited number of fish collected during the month of July, our data indicate that pompano may feed on a greater variety of invertebrates than previously reported. In our study at least 32 dietary organisms were identified as distinct taxa. This included a variety of estuarine and grass bed organisms, such as *Neanthes succinea, Astryis lunata, Bittolium varium, Cymadusa compta, Corophium louisianum* and typical beach species, including juvenile *Donax* spp., *Ancinus depressus*, juvenile *Emerita* spp., *Exosphaeroma diminuta*, and haustoriid amphipods.

A review of the literature (see Pattillo et al. 1997) and the very limited observations made during our study, indicate that adult pompano in the northern Gulf of Mexico feed largely on the same types of prey as the juveniles (e.g., *Donax* sp., mole crabs, and haustoriids and *Harengula jaguana*), but focus their feeding efforts on the adult stages, whereas, smaller pompano feed on the juveniles of these prey species, plus a variety of smaller, more diverse food organisms. As in many other carnivorous fish species, it would be ecologically inefficient or not feasible for larger pompano to expend the energy required to consume the smaller more diverse organisms eaten by juveniles. Thus, there is a selective process to specialize on larger and more abundant prey. Hildebrand and Schroeder (1928), Berry and Iverson (1967), and Bellinger and Avault (1971),

have indicated that adult pompano are more selective in their choice of prey and have evolved strong pharyngeal teeth for crushing hard shells of *Donax*. spp. These clams are considered one of the most, if not the single most, important food organisms in the diet of adult pompano (Pattillo, et al. 1997). In contrast Finucane (1969a) stated that pompano feeding becomes more diversified as the fish moves toward adulthood. Based on our preliminary observations there was an increase in the variety of food organisms with an increase for fish in the 14 mm to75 mm SL size range, but then an apparent decrease in diversity of prey organisms for fish in the 76 - 94 mm SL range (Figure 8). This may indicate that the older juveniles are becoming more selective as they reach adulthood; however, our observations, are only tentative because they are based on a small sample size of pompano with a SL greater than 75 mm.

There was a slightly greater diversity of prey items from fish collected at the open beach (Gulf) sites than those from the more protected north side sites, however, this could be an artifact of sampling. For example, presence of drift algae and its associated atypical beach fauna at Station 3 may have skewed our limited observations in this respect.

Some of the juvenile pompano we examined had been feeding on small juvenile fish (*Anchoa* sp. and *Harengula jaguana*). Modde and Ross (1983) stated that prey volume of *Harengula jaguana(=H. pensacolae)* increased slightly with fish length. In our study, fish were part of the prey in all four size classes. In one instance, the stomach of a 42 mm (SL) pompano contained three fish that were between 20 and 24 mm in length. Notwithstanding, fish appear to be important dietary items because they are generally much larger than the other prey items consumed and supply more energy than the smaller crustaceans and molluscs.

FUTURE STUDIES

In the future we plan to conduct a much more extensive ontogenetic and temporal study beginning in the spring (April/May) when juvenile fish first arrive in the surf zone until the they leave in the fall (October/November). Our study area will be expanded eastward to the southwestern Gulf coast of Florida and westward to eastern Louisiana.

In these subsequent collections, we will collect more juvenile and adult fish over a wider range of standard lengths to determine if the trend toward a less diverse diet in larger fish is supported.

Diurnal studies at one or more collecting sites in Mississippi, Alabama, or West Florida are planned to determine:

i) When pompano are most actively feeding,
ii) If there are changes in prey selection during different periods of the day,
iii) If juveniles actively feed at night, and
iv) Digestive elimination rates.

ACKNOWLEDGMENTS

We would like to thank Dawne Hard for her assistance with data management and graphics support. Jerry Mclleland and Sara LeCroy for their help with identification of prey and editing of this paper. In addition, we would like to thank Chet Rakocinski for his help with statistical analysis and editing. Finally, we would like to thank John Harsh at the University of Southern Mississippi- Hattiesburg for his statistical guidance.

LITERATURE CITED

Armitage T.M. and W.S. Alevizon.1980. The diet of the Florida Pompano (*Trachinotus carolinus*) along the east coast of Central Florida. *Florida Scientist* **43**(1):19-26.

Bellinger, J.W. and J.W. Avault, Jr. 1970. Seasonal occurrence, growth, and length-weight relationship of juvenile pompano, *Trachinotus carolinus* in Louisiana. *Transactions of the American Fisheries Society* **99**(2):353-358.

Bellinger, J.W. and J.W. Avault, Jr. 1971. Food habits of juvenile pompano, *Trachinotus carolinus,* in Louisiana. *Transactions of the American Fisheries Society* **100**(3):486-494.

Benson, N.G., (ed.). 1982. Life history requirements of selected finfish and shellfish in Mississippi Sound and adjacent areas. U.S. Fish Wildl. Serv. Biol. Rep., FWS/OBS-81/51:45-46.

Berry, F. and E.S. Iverson. 1967. Pompano: Biology fisheries and farming potential. *Proceedings of the Gulf and Caribbean Fisheries Institute* **19**:116-128.

Ditty, J.G., G.G. Zieske, and R.F. Shaw. 1988. Seasonality and depth distribution of larval fishes in the Northern Gulf of Mexico above 260 00' N. *U.S. Fisheries Bulletin* **86**(4):811-823.

Fields, H.M. 1962. Pompanos *(Trachinotus* spp.) of the south Atlantic coast of the United States. *U.S. Fisheries Bulletin* **62**:189-222.

Finucane, J.H. 1969a. Ecology of the pompano (*Trachinotus carolinus*) and the Permit (*T. falcatus*) in Florida.*Transactions of the American Fisheries Society* **98**(3):478-486.

Gunter, G. 1958. Population studies of the shallow water fishes of an outer beach in south Texas. Publ. Inst. Mar. Sci., Univ. of Texas **5**:186-193.

Hildebrand, S.F., and W.C. Schroeder. 1928. Fishes of Chesapeake Bay. *Bulletin of the U.S. Bureau of Fisheries* **43**:1-366

Modde, T. and S.T. Ross. 1983. Trophic relationships of fishes occurring within a surf zone habitat in the Northern Gulf of Mexico. *Northeast Gulf Science* **6**(2):109-120.

Pattillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco. 1997. Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries. Pages 222-227 in: Volume II: Species life history summaries. ELMR Rep. No. 11. NOAA/NOS Strategic Environmental Assessments Division, Silver Spring, Maryland USA.

APPENDIX A.

Taxonomic listing of the prey organisms recovered from the digestive tracts of 78 juvenile Florida pompano collected along the coasts of Alabama, Mississippi and West Florida during July 2000.

Phylum Annelida
- Class Polychaeta
  - Family Nereidae
    - *Neanthes succinea* (Frey and Leukart, 1847)
  - Family Spionidae
    - *Scolelepis squamata* (O. F. Muller, 1806)
  - unidentified. remains

Phylum Mollusca
- Class Gastropoda
  - Order Mesogastropoda
    - Family Cerithiidae
      - *Bittolum varium* (Pfeiffer, 1840)
  - Order Neogastropoda
    - Family Columbellidae
      - *Astryis lunata* (Say, 1826)
- Class Bivalvia
  - Family Crassatellidae
    - *Gynocuna dalli* (Vanatta, 1904)
  - Family Donacidae
    - *Donax texasianus* Philippi, 1847*
    - *Donax variablis* Say, 1822
  - Family Mactricidae
    - *Mulinea lateralis* (Say 1822)
  - unidentified . mollusc remains

Phylum Arthropoda
- Subphylum Crustacea
  - Class Copepoda
    - Subclass Calanoidea
      - unidentified. sp. (spp?)
  - Class Malacostraca
    - Order Mysida
      - Family Mysidae

Bowmaniella dissimilis Coifman, 1939
Order Tanaidacea
Family Kalliapseudidae
Kalliapseudes sp. A(undescribed)
Order Isopoda
Family Sphaeromatidae
Ancinus depressus (Say, 1818)
Exosphaeroma diminuta Menzies and Frakenburg, 1965
Sphaeroma quadridentatum (Say, 1818)
Order Amphipoda
Family Ampithoidae
Cymadusa compta (Smith, 1873)
Family Bateidae
Batea catharinensis Muller, 1865
Family Haustoriidae
Haustorius jayneae Foster and LeCroy, 1991
Lepidactylus sp. A
Parahaustorius sp. A
unidentified. Haustorid spp. remains
Family Corophiidae
Corophium louisianum Shoemaker, 1934
Family Hyalidae
Parhyale hawaiensis (Dana, 1853)
Order Decopoda
Family Penaeidae
penaeid sp. (small juv.)
Infraorder Caridea
Family Hippolytidae
Hippolyte zostericola (Smith, 1873)
Latreutes parvulus (Stimpson, 1866)
unidentified. caridean remains
Infraorder Anomura
Family Hippidae
Emerita talpoida Say, 1817
Emerita benedicti Schmitt, 1935
Emerita spp. (juvenile remains)
Family Diogenidae
Isocheles wurdemanni Stimpson, 1862
Family Porcellanidae
unidentified Porcellanid remains
Infraorder Brachyura
Family Portunidae
unidentified small juveniles
Family Pinnotheridae

Pinnixa behreae Manning and Felder, 1989
Pinnixa sp.

Phylum Chordata
Subphylum Vertebrata
Class Osteichthyes
Family Engraulidae
Anchoa sp. (juvs.)
Family Clupeidae
Harengula jaguana Poey, 1865 (juvs.)

* Small, juvenile *Donax texanius* were found but were very difficult to identify and were recorded with D. *variablis* as *Donax*. spp

Preliminary Observation of Reproductive Failure in Nearshore Queen Conch (*Strombus gigas*) in the Florida Keys

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ABSTRACT

In the Florida Keys, queen conch, *Strombus gigas*, occur nearshore in hard-bottom communities and offshore in seagrass meadows and rubble zones adjacent to the reef tract. Queen conch in nearshore aggregations have not been observed reproducing (mating or spawning) since our monitoring program began in 1987. However, reproduction has commonly been observed in offshore aggregations. Reciprocal transplants of conch with flared lips were made between pairs of nearshore and offshore sites, resulting in each site having both nearshore and offshore conch. Nearshore conch were not observed mating or spawning in their native nearshore region during this study. Nearshore conch transplanted offshore were not observed mating; however, three months after transplantation, nearshore conch were observed spawning at offshore sites. Offshore conch transplanted nearshore mated and spawned, but at reduced frequencies compared with conch that remained offshore. These preliminary results suggest that some component of the nearshore environment affects reproduction in conch and that transplanting nearshore conch to the offshore region restores the reproductive viability of transplanted conch.

KEY WORDS: Queen conch, reproduction, transplanting

INTRODUCTION

Queen conch, *Strombus gigas*, occur within two distinct regions on the oceanside of the Florida Keys archipelago: nearshore and offshore. Conch within the two regions are isolated from one another by Hawk Channel, which runs parallel to the Florida Keys and lies between the island chain and the offshore reef tract (Berg and Glazer 1995). Hawk Channel consists of a fine-grained, soft-sediment substrate, which is unsuitable conch habitat and thus serves as a barrier to queen conch migration (Glazer and Berg 1994).

Since 1987, researchers monitoring queen conch stock abundance throughout the Florida Keys have not observed any reproductive activity among conch in nearshore aggregations; however, anecdotal reports indicated that conch in the nearshore region reproduced as recently as the mid-1980's (Brian LaPointe, personal communication 1998). Conversely, reproductive behavior has commonly been observed among conch in offshore aggregations (Glazer and Berg 1994). Glazer and Quintero (1998) conducted a histological examination of conch from these two regions and found that the gonads of offshore conch were viable and capable of undergoing gametogenesis, whereas the gonads of nearshore conch were nonfunctional. In the present study, we examined differences in reproductive behavior (i.e., mating and spawning frequency) between nearshore and offshore conch by transplanting nearshore conch to the offshore region and offshore conch to the nearshore region.

METHODS

During March, April, and May 1999, we transplanted queen conch with flared lips from two nearshore to two offshore sites and vice versa, so that all four sites would have both nearshore and offshore conch. Nearshore sites were located at Tingler's Island (24° 41' N, 81° 05' W) and Duck Key (24° 45' N, 80° 55' W) in water 1-2m deep (Figure 1). Offshore sites were located at Alligator Reef (24° 51' N, 80° 37' W) and Pelican Shoal (24° 30' N, 81° 37' W) in water 5-11m deep (Figure 1). Reciprocal transplants of queen conch were made between Tingler's Island and Alligator Reef and between Duck Key and Pelican Shoal (Table 1). Fewer conch were collected and tagged from nearshore sites (Table 1) because aggregations were smaller there than at the offshore sites.

We used monel wire to secure a numbered, stainless-steel tag to each conch's shell spire. In addition, colored plastic tape was tied to the spires to facilitate recapture. From March 1999 through November 1999, each site was searched weekly except during periods of inclement weather. Divers using SCUBA surveyed offshore sites, while nearshore sites were surveyed by snorkeling. We quantified the mating activity of queen conch by counting the number of copulating pairs; spawning activity was quantified by counting the number of females laying egg-masses. For statistical purposes, data from the two nearshore sites were pooled and treated as the nearshore region; data from the two offshore sites were treated in the same fashion. Data were also pooled by season. Spring consisted of March, April and May; summer consisted of June, July, and August; fall consisted of September, October, and November.

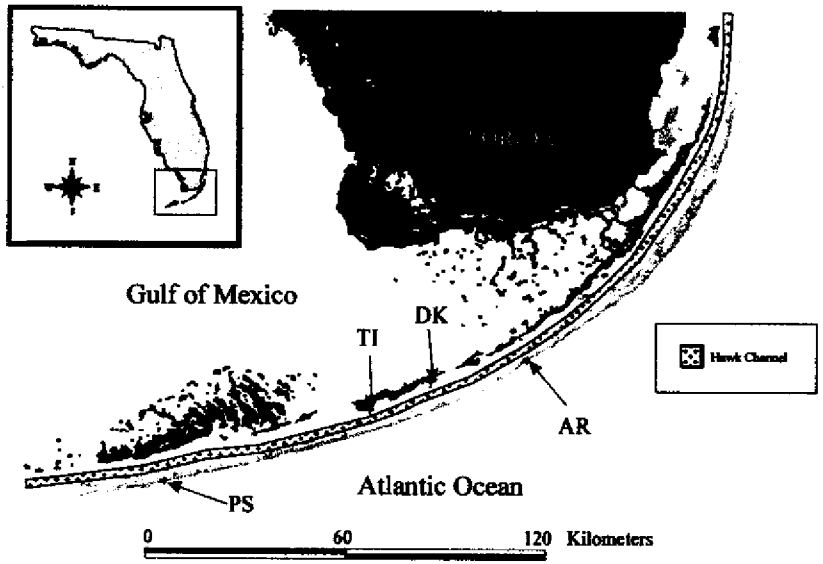


Figure 1. Sites in the Florida Keys where the queen conch transplant study was conducted. The nearshore region is landward of Hawk Channel; the offshore region is southeast of Hawk Channel. Nearshore sites included Tingler's Island (TI) and Duck Key (DK). Offshore sites included Pelican Shoal (PS) and Alligator Reef (AR).

Table 1. Number of queen conch collected and tagged at each site for the reciprocal transplant study in the Florida Keys. The number of conch released at the site of initial capture, the number transplanted, and the transplant location are also given. Letters in parentheses indicate whether the location was in the offshore (o) or nearshore (n) region.

Source Location	# Collected & Tagged at Source Location	# Released at Source Location	# Transplanted	Transplant Location
Alligator Reef (o)	201	101	100	Tingler's (n)
Tingler's (n)	44	21	23	Alligator Reef (o)
Pelican Shoal (o)	199	99	100	Duck Key (n)
Duck Key (n)	132	59	73	Pelican Shoal (o)

PRELIMINARY RESULTS

Mating

Differences in mating frequencies were observed between the native nearshore conch and the native offshore conch. Nearshore conch were not observed mating at either their native nearshore sites or at the offshore sites where they were transplanted, whereas offshore conch were observed mating at both their native offshore sites and at the nearshore sites to which they had been transplanted (Table 2). Mating frequency of offshore conch was highest during the spring and decreased during subsequent seasons at both nearshore and offshore sites (Table 2). The mating frequency of offshore conch transplanted to the nearshore region decreased from 11.8% in the spring to 0.0% in the fall, whereas the mating frequency of offshore conch that remained offshore decreased from 5.3% in the spring to 0.9% in the fall (Table 2). All mating occurred between native offshore conch with the exception of two offshore females that were transplanted nearshore, who were observed mating with untagged nearshore males.

Spawning

We also observed differences in the frequency with which nearshore and offshore conch spawned. Nearshore conch were not observed spawning at their native nearshore sites; however, nearshore females transplanted to the offshore region spawned during the summer and fall with frequencies of 12.5% and 18.5%, respectively (Table 2). Native offshore females were observed spawning at offshore and nearshore sites; however, females transplanted nearshore spawned far less frequently than females that remained offshore. The spawning frequency of offshore female conch decreased over time at their native offshore sites from 46.2% in the spring to 5.3% in the fall. Spawning frequency of offshore females transplanted to the nearshore region also decreased over time: from 8.9% in the spring to 0.0% in the fall.

DISCUSSION

Residence by queen conch in the nearshore region had a severe detrimental impact upon their reproductive behavior as neither mating nor spawning were observed in native nearshore conch. The fact that neither mating nor spawning was observed among native nearshore conch residing in the nearshore region in this study or in our ongoing monitoring program, coupled with the histological deficits reported by Glazer and Quintero (1998), suggests that conch native to the nearshore region are incapable of reproducing while residing nearshore. In addition, offshore conch transplanted to the nearshore region were observed spawning less frequently than offshore females that remained offshore. In fact, after six months, the reproductive behavior of offshore conch transplanted nearshore ceased entirely. Conch that remained offshore were observed mating and spawning throughout the entire study.

Table 2. Frequency of mating (both males and females) and spawning (females only) of native and transplanted queen conch, by season. "Native" refers to conch that were released at their initial capture site. "Transplant" in the Nearshore Region refers to conch that were moved nearshore from their original offshore location. "Transplant" in the Offshore Region refers to conch that were moved offshore from their original nearshore location. N represents the number of observations.

	Nearshore Region			
	N	% Mating	N	% Spawning
Spring				
Native	37	0.0	6	0.0
Transplant	169	11.8	56	8.9
Summer				
Native	106	0.0	34	0.0
Transplant	490	2.9	215	4.7
Fall				
Native	20	0.0	9	0.0
Transplant	46	0.0	21	0.0

	OffshoreRegion			
	N	% Mating	N	% Spawning
Spring				
Native	95	5.3	39	46.2
Transplant	19	0.0	10	0.0
Summer				
Native	467	2.4	188	17.0
Transplant	83	0.0	40	12.5
Fall				
Native	232	0.9	95	5.3
Transplant	51	0.0	27	18.5

There were two occasions when offshore females that were transplanted to the nearshore region mated with native, untagged nearshore males. This suggests that the males were always capable of reproduction and/or that the presence of reproductive offshore females stimulated mating behavior in nearshore males. Preliminary results from histological examinations suggest that some nearshore males may be reproductively viable (Nancy Brown-Peterson, unpublished data), and Reed (1995) reported that male conch demonstrated a preference for mating with spawning females. Either way, males appear less susceptible to whatever chronic effect nearshore conditions have on females.

Transplanting nearshore conch to the offshore region appeared to mitigate the deleterious effects that the nearshore environment had on conch reproductive behavior. Nearshore females transplanted to the offshore region were observed laying eggs throughout the summer and fall (Table 2). However, the peak spawning period of the transplanted nearshore conch was several months later than the peak spawning period of the native offshore conch. Nevertheless, there is reason to conclude that the timing of both groups' reproductive behavior may eventually become similar. Apparently, it takes at least three months after transplantation for the adverse effects of the nearshore environment to be mitigated, explaining the lag

in peak spawning for the transplanted nearshore conch. Had we conducted the transplanting earlier in the year (e.g., January instead of March), the out-of-phase spawning may have been prevented.

Nearshore female conch transplanted offshore were observed spawning, but not mating. We cannot confirm that these nearshore females mated after transplantation, but we suspect that mating must have occurred offshore because of the deficits in nearshore conch described above. The observed mating frequency was low (<12%); however, this is not unexpected because Randall (1964) reported similar mating frequencies for conch in the Virgin Islands. Therefore, we suspect that the lack of observations (Table 2) of nearshore conch mating in the offshore region may have been an artifact of the low probability of encountering that activity and of the low number of nearshore conch transplanted offshore.

The implications of this study have a direct bearing on our ongoing queen conch stock restoration program in the Florida Keys. We have been examining the efficacy of producing and releasing hatchery-reared conch in an effort to increase the queen conch spawning stock. The present study clearly demonstrates that the goal of increasing the reproductive population will not be realized if conch are released into nearshore sites. Transplanting large numbers of naturally recruiting nearshore conch to the offshore region may be more cost-effective than producing juvenile conch in a hatchery, especially if survival rates of transplanted conch are equivalent or greater than those of hatchery outplants. However, before a transplantation program can be implemented, we must 1) ascertain if reproductive output will truly be augmented, 2) determine if the larvae produced from nearshore transplants are as viable as larvae produced by native offshore conch, and 3) determine if larvae produced from transplanted conch are retained within the Florida Keys.

The goal of this study was to compare the reproductive behavior of nearshore and offshore conch in the Florida Keys; however, several new areas of research are now open for inquiry. A more detailed histological study will provide further information on reproductive condition. Efforts should also focus on identifying the anthropogenic and/or environmental factors that are affecting the reproductive viability of nearshore animals. Other areas in the Caribbean have shallow-water, nearshore aggregations of queen conch in which reproduction has never been observed, including Mexico (Alberto de Jesus Navarrete, personal communication, 2000) and the Turks and Caicos (Wesley Clerveaux, personal communication, 2000). Therefore, identifying the key elements involved in the reproductive failure of nearshore conch in the Florida Keys may prove to be important for the entire region.

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LITERATURE CITED

Berg, C.J. and R.A. Glazer. 1995. Stock assessment of a large marine gastropod (*Strombus gigas*) using randomized and stratified towed-diver censusing. *ICES Marine Science Symposia* **199**:247-258.

Glazer, R.A. and C.J. Berg, Jr. 1994. Queen conch research in Florida: an overview. Pages 79-95 in: R. S. Appeldoorn and B. Rodriguez (eds.). *Queen conch biology, fisheries, and mariculture*. Fundación Cientifica Los Roques. Caracas, Venezuela.

Glazer, R.A. and I. Quintero. 1998. Observations on the sensitivity of queen conch to water quality: implications for coastal development. *Proceedings of the Gulf and Caribbean Fisheries Institute* **50**:78-93.

Lee, T.N., C. Rooth, E. Williams, M. McGowan, A.F. Szmant, and M.E. Clarke. 1992. Influence of Florida Current, gyres, and wind-driven circulation on transport of larvae and recruitment in the Florida Keys coral reefs. *Continental Shelf Research* **12**:971-1002.

Randall, J.E. 1964. Contributions to the biology of the queen conch, *Strombus gigas*. *Bulletin of Marine Science* **14**:246-295.

Reed, S.E. 1995. Reproductive anatomy and biology of the genus *Strombus* in the Caribbean: I. Males. *Journal of Shellfish Research* **14**(2):325-330.

Water Quality Monitoring and Data Collection in the Mississippi Sound

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ABSTRACT

The United States Geological Survey and the Mississippi Department of Marine Resources are collecting data on the quality of the water in the Mississippi Sound of the Gulf of Mexico, and streamflow data for its tributaries. The U.S. Geological Survey is collecting continuous water-level data, continuous and discrete water-temperature data, continuous and discrete specific-conductance data, as well as chloride and salinity samples at two locations in the Mississippi Sound and three Corps of Engineers tidal gages. Continuous-discharge data are also being collected at two additional stations on tributaries. The Mississippi Department of Marine Resources collects water samples at 169 locations in the Gulf of Mexico. Between 1800 and 2000 samples are collected annually which are analyzed for turbidity and fecal coliform bacteria. T he continuous data are made available real-time through the internet and are being used in conjunction with streamflow data, weather data, and sampling data for the monitoring and management of the oyster reefs, the shrimp fishery and other marine species and their habitats.

KEY WORDS: Water quality, data collection

INTRODUCTION

The Mississippi Department of Marine Resources (MDMR) and the U.S. Geological Survey (USGS) are collecting data on the quality of water in the Mississippi Sound of the Gulf of Mexico in support of the MDMR missions to protect the public health from diseases associated with the consumption of raw shellfish and to assist in the management of shellfish and their habitats as renewable resources. Data are being collected in the Mississippi Sound of the Gulf of Mexico as well as in its estuaries.

PURPOSE AND SCOPE

This report describes data-collection efforts of the MDMR and USGS in the Mississippi Sound. Included in the report are:

i) Type of data collected,

ii) Methods of data collection,
iii) Description of data-collection sites, and
iv) Preliminary results of data collected for instrument verification.

Data are being collected on the quality of water in the Mississippi Sound and its estuaries. The Mississippi Sound is the part of the Gulf of Mexico that lies between the Mississippi Coast and the barrier islands, and extends from the mouth of the Pearl River to the Mississippi-Alabama State boundary. Data collection consists of the compilation of discrete water samples for laboratory analysis and the operation of in situ hydrological parameter monitors for the recording of continuous data. The MDMR collects discrete water samples at 169 locations. The MDMR-USGS operates continuous water-quality monitors and collects water samples at seven locations in the coastal region. The USGS also operates continuous hydrological monitors and velocity sensors at two additional locations.

DATA COLLECTION

Water-quality monitoring and data collection by the MDMR and the USGS are described in the following two sections.

Mississippi Department of Marine Resources Data Collection

The primary purpose of the MDMR sampling program is to protect the public health from diseases associated with the consumption of raw shellfish as stated in guidelines set forth by the National Shellfish Sanitation Program (NSSP). The NSSP was developed in 1925 in response to requests from State and local public health officials for assistance in controlling disease associated with the consumption of raw shellfish. Their requests came after widespread outbreaks of typhoid fever in Chicago, New York, and Washington, D.C., in 1924 that were traced to contaminated oysters (U.S. Department of Health and Human Services 1997). The National Food and Drug Administration has the oversight of the shellfish industry at the Federal level; however, the development and enforcement of regulations is the responsibility of the individual States. The Mississippi Department of Marine Resources is the agency responsible for regulation of the harvest and handling of shellfish in Mississippi.

The Mississippi Sound has been divided by the MDMR into eight harvest areas extending from the mouth of the Pearl River across the Mississippi Sound to the Mississippi-Alabama State boundary (Figure 1). The MDMR has established 169 water-sampling stations in the Mississippi Sound, with individual harvest areas containing between 10 and 40 sampling stations.

Sample collection by the MDMR begins after an oyster reef area is closed to harvest. Area closure is primarily based on two factors:

i) the stage of the Pearl River at Pearl River, La., and
ii) 24-hour rainfall amounts at nearby weather stations.

Flow from the Pearl River is critical to the quality of water in Mississippi Sound because water entering the Mississippi Sound flows east along the coastline between the shore and the barrier islands. This flow pattern brings the water over most of the oyster reefs in the western part of Mississippi Sound. Flows that are significantly above base flow carry increased amounts of bacteria and other pollutants. As water from the river flows across oyster reefs, pollutants in the water are taken up by filter feeders such as oysters. Human consumption of the contaminated shellfish can cause severe illness. The base-flow stage of the Pearl River at Pearl River, LA., is approximately five feet. When the river stage reaches 10 feet, the MDMR starts closing areas to the harvesting of shellfish. If the river reaches a stage of 12.5 feet, additional areas are closed.

Rainfall is a closure factor due to pollutants that are contained in storm-water runoff from urban areas. A recorded rainfall of 1 inch within 24 hours will cause the closure of some harvest areas, primarily those near to the shore. A 24-hour rainfall of 2 inches or more causes the closure of additional areas.

After an area has been closed to harvest by the MDMR, representatives of that agency will collect water and shellfish tissue samples to be analyzed for fecal-coliform bacteria. The area remains closed to harvest until both the water and tissue samples reach acceptable concentration levels for fecal-coliform bacteria. The MDMR collects between 1,800 and 2,000 samples annually in this sampling program.

In addition to protecting the public health, the MDMR is responsible for the management of oyster reefs and other marine life and their habitat as renewable resources. The shellfish industry has a significant impact on the economy of Mississippi, especially for the Mississippi Gulf Coast region. The average annual oyster harvest for the past 10 years (1989-99) was 1.5 million pounds of meat. The oyster harvest in 1997 was 3.5 million pounds and had a dockside value of 5.3 million dollars. The industry employs thousands of people in the coast region including harvesters, processors, and shippers, and wholesalers. Approximately 200 commercial and 35 recreational oyster permits as well as hundreds of dealer and processor licenses, are sold annually.

Water temperature, specific conductance, and salinity are important hydrological parameters providing a tool for the management of marine organisms and their associated habitats. First, these parameters serve as indicators of the presence of freshwater from streams flowing into the gulf, as the freshwater will cause a significant decrease in the specific conductance. Second, temperature and salinity are critical to the propagation of oysters and maintaining productive reefs. In addition, these two parameters affect the distribution, growth and survival of all marine organisms in the Mississippi Sound. As part of its mission to manage the oyster reefs, the MDMR has a program in which it seeds the spat (oyster babies) on the reefs to stimulate oyster growth. There are optimum ranges in temperature and salinity for maximum oyster growth, and detecting long-term trends in temperature and salinity will help the MDMR plan and predict oyster growth and harvest as well as indicate if additional areas are also suitable for seeding.

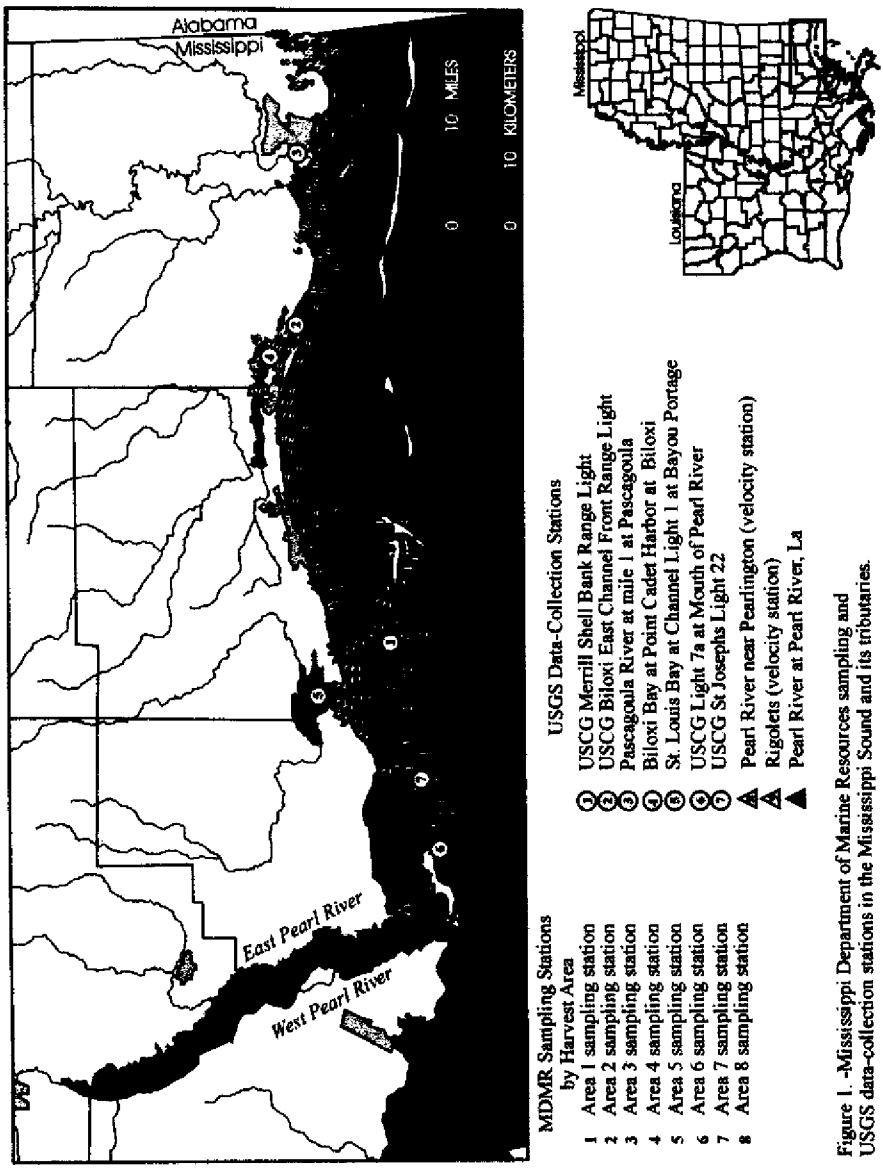


Figure 1.-Mississippi Department of Marine Resources sampling and USGS data-collection stations in the Mississippi Sound and its tributaries.

Figure 1. Mississippi department of Marine Resources sampling and USGS data collection stations in the Mississippi Sound.

U.S. Geological Survey Data Collection

Through a cooperative agreement which supports the MDMR mission of resource management, the MDMR and USGS have established seven data-collection stations where temperature, specific conductance, and salinity data are collected in Mississippi Sound and its estuaries, and two stations where velocity data are collected. The instrumentation at the continuous-data collection stations consists of a stage sensor, water-quality probe, velocity sensor where required, data-collection platform, satellite-transmission equipment, 12-volt battery, and solar panel. At each station, water level (stage), temperature, and specific conductance are measured and recorded hourly. Salinity is computed *in situ* by the probe using temperature and specific conductance data and is recorded hourly. Velocity data are collected and recorded hourly. The recorded data are transmitted via satellite to the USGS office in Pearl, Mississippi. Data are then made available to the MDMR via the Internet. An example of the data made available to the cooperator is shown in Figure 2. The velocity stations were not established as a part of the MDMR-USGS data-collection program but the data are used to help show the effects of the Pearl River on the water quality of Mississippi Sound.

Water samples are also collected by the USGS and analyzed for specific conductance, salinity, and dissolved chloride at the USGS laboratory in Ocala, Florida. Since the specific conductance measured by the probes may be affected by dissolved constituents other than chloride, the salinity values computed by the probes may vary from those obtained from the laboratory. A comparison of the computed salinity and laboratory salinity is shown in Figure 3. Water-quality data and samples collected by the USGS are collected according to the methods described by Wilde, and others, (1998).

The selection of locations for the continuous water-quality data-collection stations was dependent on the availability of a suitable structure in or near a shellfish harvest area. The first station established was on the U.S. Coast Guard (USCG) Merrill Shell Bank Front Range Light approximately five miles south of Pass Christian, Miss. (Figure 1). This monitoring station is located in one of the most productive oyster harvest areas in the Mississippi Sound. The second monitoring station was established on the USCG Biloxi East Channel Front Range Light, approximately two miles southeast of Biloxi Bay. The next three monitoring stations were established at U.S. Army Corps of Engineers tidal gages on the Pascagoula River mile 1 at Pascagoula, Back Bay of Biloxi at Ocean Springs, and St. Louis Bay at Channel Light 1 in Bayou Portage. These three stations are operated in cooperation with the Corps of Engineers to take advantage of existing data-collection efforts. Although these stations are located in estuaries, they are located where the water level and water quality are affected by the Mississippi Sound. These stations are located in areas sampled by the MDMR and were established to help determine the influence of the tributaries on the water quality of the sound. The final two water-quality monitoring stations established were at the mouth of the Pearl River and at St. Josephs Pass. These were established to give better spatial definition of the effects of the Pearl River on the water-quality in

Mississippi Sound.

The stations where velocity data are collected along with water-quality data are at USCG light 22A in the Pearl River near Pearlington and at the railroad bridge in the Rigolets. These stations were established to determine the flow characteristics of their respective waterways. The data collected will also be used in conjunction with the data collected by the MSMR and USGS.

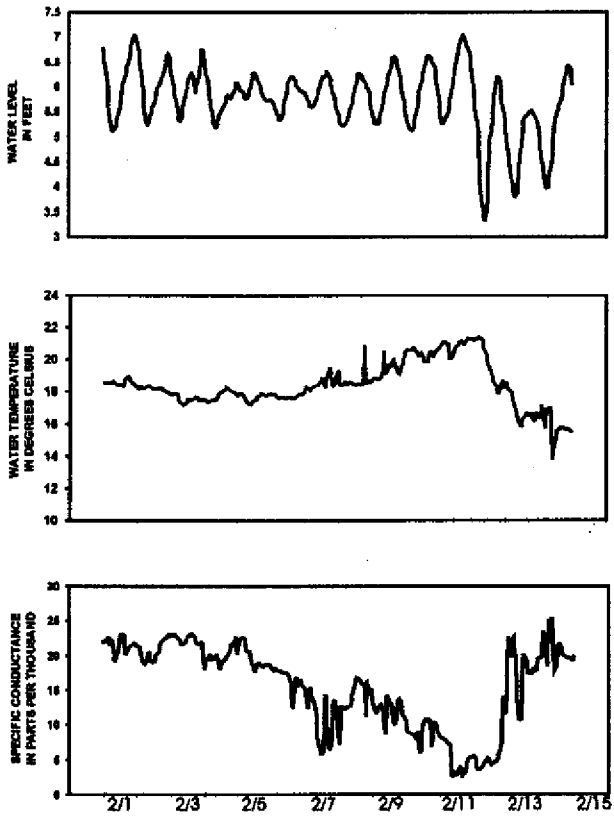


Figure 2. Water level, temperature, and salinity for Biloxi East Front Range Light for the period February 1 through February 15, 1999.

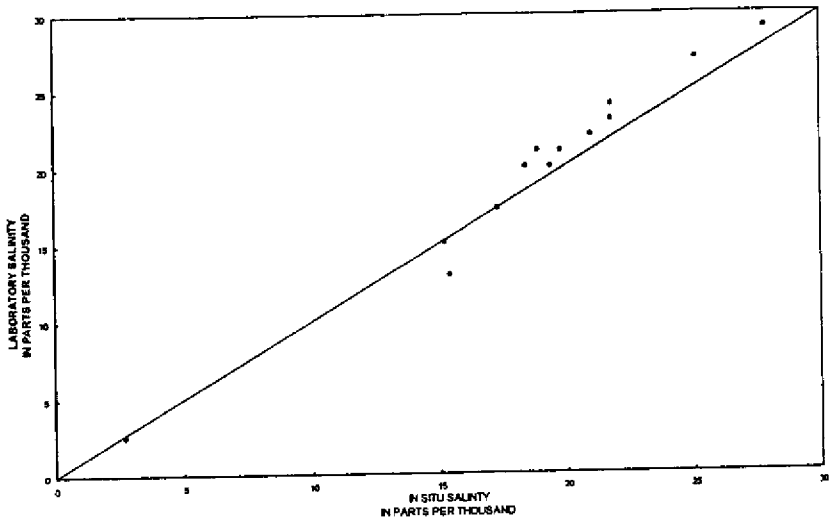


Figure 3. Comparison of in situ salinity to laboratory salinity for Mississippi Sound monitoring stations.

RESULTS

Preliminary analysis of the data obtained from the MDMR-USGS monitoring and sampling program have shown that the salinity values computed *in situ* by the probe using the temperature and specific conductance data correlate well with the data obtained from the laboratory analysis for the normal ranges of salinity. However, limited data for periods of low salinity do not allow accurate definition of the relation when the salinity decreases due to freshwater influence.

An insufficient amount of data exists at this time to develop correlations between flows of the Pearl River and other tributaries and spatial variations in the water quality across the Mississippi Sound.

DISCUSSION

The U.S. Geological Survey, in cooperation with the Mississippi Department of Marine Resources, Office of Fisheries, is collecting data on the quality of water in the Mississippi Sound of the Gulf of Mexico and its tributaries. The Mississippi Department of Marine Resources collects water samples at 169 locations in the Gulf of Mexico. Between 1,800 and 2,000 samples are collected annually and are analyzed for fecal-coliform bacteria. The U.S. Geological Survey is collecting continuous water level, water-temperature, specific-conductance, and salinity data, as well as supplemental chloride and salinity samples at seven locations in or near the Mississippi Sound. The continuous data are made available through the Internet and are being used in conjunction with stream flow, weather, and supplemental-sampling data for the monitoring and management of the oyster reefs and other marine species and their habitats.

LITERATURE CITED

Wilde, F.D., and others. 1998. National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations; book 9, variously paginated.

U.S. Department of Health and Human Services. 1997 [revised]. *Guide for the Control of Molluscan Shellfish.* 406 pp.

Diagnóstico para la Creación de una Reserva de la Biosfera en los Arrecifes de Campeche, México

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RESUMEN

Campeche es uno de los cuatro estados de la vertiente del Atlántico que posee un desarrollo arrecifal con características únicas en el Golfo de México. El área de análisis incluyó una superficie de 12 437 km^2, la zona pertenece a la provincia fisiográfica conocida como Carso Yucateco, cuyo accidente fisiográfico más notable es la barrera coralina que se desarrolla desde arrecife Alacranes en Yucatán hasta Cayo Arenas en Campeche. Se analizan seis estructuras arrecifales emergentes que forman un arco desde el oeste hacia el nordeste con crecimientos arrecifales a 18,35,70,80 y 90 m de profundidad. En cada estructura arrecifal se realizaron transectos batimétricos con equipo de sondeo y radar. A excepción de Arcas y Arenas los afloramientos están formados por restos coralinos. El relieve topográfico fue de 1.6 m en promedio con pendientes abruptas a moderadas. La vegetación insular es diversa con 29 especies de plantas, incluyendo exóticas e introducidas, en algunos cayos arenosos es incipiente o inexistente. La flora marina está representada por 14 especies de macroalgas. En la fauna se registraron 30 especies de corales escleractínios, 11 octocorales, 19 esponjas, 2 hidrozoarios, 2 poliquetos y un número considerable de peces, varios de los cayos son zonas de desove para tiburones y tortugas. En la mayoría de los cayos se presentan poblaciones importantes de aves marinas principalmente *Sula* y *Fregatas*. Estos arrecifes son áreas importantes para la pesca comercial de langosta, caracol y mero las cuales están reguladas por leyes pesqueras vigentes y en donde es necesario una reglamentación más específica. De acuerdo a las características morfo-fisiográficas, faunísticas y florísticas registradas se define la zonación específica del polígono propuesto con zonas núcleo, z. de amortiguamiento y z. de restauración.

PALABRAS CLAVE: Arrecifes, áreas protegidas, Campeche, Golfo de México.

Diagnosis for Creation of a Biosphere Reserve in the Reefs of Campeche, Mexico

ABSTRACT

Campeche is one of the four states in Mexico on the Atlantic slope having reef development unique within the Gulf of Mexico. The area within this analysis includes a 12 437 km^2 surface in the Yucatan Karst physiographic province, whose

most notable aspect is the coral barrier that runs from the Alacranes Reef in the state of Yucatan to Arenas Key in Campeche. A nalysis is made of six emergent reef structures that form an arc from west to northeast, with reef growths at 18, 35, 70, 80 and 90 m depth. Using radar and sounding equipment, bathimetric transects were made of each reef structure. With the exception of Arenas and Arcas keys, the islands are formed of coral remains. Average topographical relief was 1.6 m with abrupt and moderate slopes. Insular vegetation is diverse, including 29 plant species, some introduced or exotic; on some of the sand keys vegetation is incipient or nonexistent. Marine flora is represented by 14 macroalgae species. Marine fauna includes 30 scleractin coral species, 11 octocorals, 19 sponges, 2 hydrozoas, 2 polychetes and numerous fish; many of the keys are spawning zones for sharks and turtles. Most of the keys are also host to sizable marine bird populations, principally *Sula* and *Fregatas*. These reefs are important areas for commercial capture of lobster, conch and grouper, which is currently regulated by fishing laws, though more specific regulation is needed. Utilizing the recorded morpho-physiographic, faunal and floral characteristics, a detailed zonation is defined for the proposed reserve polygon, with nucleus, buffer and restoration zones.

KEY WORDS: Reefs, protected areas, Campeche, Gulf of Mexico.

INTRODUCCIÓN

Las costas de México tanto del Pacífico como del Atlántico, poseen ecosistemas sumamente importantes como son los arrecifes coralinos, lagunas costeras, estuarios, humedales y manglares. Estos recursos costeros son desde el punto de vista diversidad y economía un patrimonio esencial para el país (Ferre-D'Amare 1985).

Actualmente, en la Península de Yucatán se han llevado acabo acciones concretas con respecto a la conservación y el desarrollo sustentable de los ecosistemas marinos. El estado de Quintana Roo, ya cuenta con las siguientes cinco áreas naturales protegidas: Isla Contoy, Costa Occidental de Isla Mujeres, Punta Cancún y Punta Nizuc, Cozumel, Sian Ka'an y Banco Chinchorro, en sus modalidades de Parques Nacionales y Reservas de la Biosfera o Reservas Especiales.

En lo que se refiere al Golfo de México, ya existen áreas arrecifales protegidas como son el caso del Parque Nacional Arrecifes de Veracruz en ese Estado y el Parque Nacional Arrecife Alacranes en Yucatán. En cuanto a los arrecifes de Campeche, debido a su alto valor ecológico, genético, estético y a sus recursos naturales es necesario todo esfuerzo institucional a nivel: federal, estatal y local, que asegure su conservación, manejo y sustentabilidad en el tiempo.

El Laboratorio de Arrecifes Coralinos de la Unidad Mérida del CINVESTAV-IPN realizó los estudios para que el Gobierno de Campeche, por conducto de la Secretaría de Ecología-Medio Ambiente-Recursos Naturales y Desarrollo Pesquero del estado de Campeche, solicitará su declaratoria como un Área Natural Protegida y su inclusión en el SINAP (Torruco y González 1997a). En el presente trabajo se analiza la superficie general propuesta para su conservación, así como la importancia

de su amplio potencial ecológico y económico.

MATERIAL Y MÉTODOS

El área esta ubicada en las costas del estado de Campeche que pertenecen a la provincia fisiográfica conocida como el Carso Yucateco (Novak et al. 1992). Cuenta con cuatro estructuras arrecifales emergentes y sumergidas respectivamente: Cayo Arenas, Cayo Nuevo, Triángulos, Arcas, Banco Nuevo, Banco Pera, Bajo Obispos y Bancos Ingleses (Figura 1).

En la definición de la poligonal del área propuesta, fue necesario delimitar las zonas arrecifales de las costas de Campeche, los vértices se establecieron mediante campañas de muestreo en el Barco Marsep-1 del Cetmar de Campeche. En cada cayo se realizaron transectos batimétricos utilizando el ecosonda y radar FURUNO de la embarcación. Adicionalmente, al inicio y al final de cada cayo y transecto batimétrico se obtuvo el posicionamiento satelital con un GPS portátil Magellan NAV5000.

Se realizaron perfiles de relieve en los cayos, la descripción submarina se realizó mediante fototransectos y las observaciones del fondo con buceo libre y autónomo en un intervalo de profundidad de 1 a 50 m (Torruco 1995). Se utilizaron cartas de navegación de la Secretaría de Marina (SM 1981 a y b) y topográficas del INEGI (INEGI 1981). En los cayos se realizaron perfiles del relieve con métodos topográficos estándar con el conteo respectivo de aves marinas y cobertura vegetal (González y Torruco 2000a).

RESULTADOS

Relieve Topográfico

El relieve en todos los cayos es bajo con un promedio de 1.6 m y pendientes de abruptas a moderadas, la mayoría de las islas, son alargadas con una forma de media luna originada por la influencia de las corrientes, la estructura arrecifal sigue el mismo patrón de media luna en la mayoría de ellos. Todas las islas de Triángulos poseen una vegetación incipiente y en algunos casos inexistentes, sin embargo Triángulos Este y Sur presentan poblaciones importantes de aves, particularmente pájaros bobos y rabihorcados: *Sula* spp., *Fregatas magnificiens* y *Larus* spp. Presentan una vegetación extensa y más diversa con algunas especies introducidas como: Casuarinas, Palmas de coco y *Uva marina*, entre otras. Su topografía muestra dos montículos con dos depresiones en la isla, los cuáles son las áreas preferidas por los rabihorcados para asentar sus nidos. Los pájaros bobos, habitan en la zona central que presenta una menor pendiente.

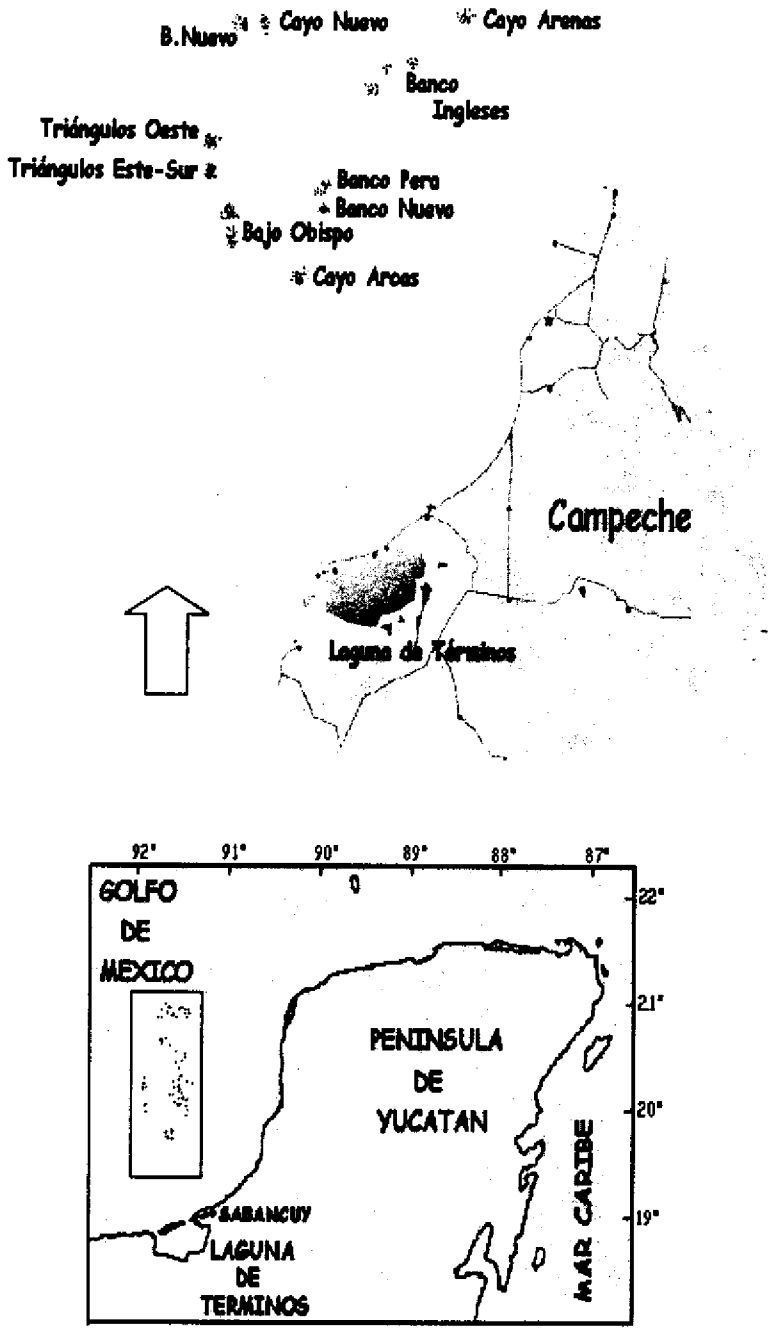


Figura 1. Ubicación geográfica de los Arrecifes de Campeche, México.

Características Biológicas

El Arrecife Arenas incluye asociaciones de las especies: *Porites porites, Porites astreoides, Acropora cervicornis, Acropora palmata, Favia fragum, Diploria strigosa, Millepora alcicornis, Halimeda incrassata* y *Penicillus dumetosus.* Cayo Nuevo: *A. palmata* con *Palythoa* y algas filamentosas. Arrecife Triángulos: *A. palmata, P. asteroides, F. fragum, Agaricia agaricites*, algas coralinas incrustantes, anémonas coloniales: *Palythoa caribbeaerum* y *Zoanthus sociatus, Halimeda, Diploria* y *Montastrea.* Cayo Arcas: formado por *A. palmata* arborescente, *Diploria, Montastrea, P. porites* y *A. cervicornis.* Banco Nuevo y Pera: son los arrecifes sumergidos más cercanos al continente con *A. agaricites, Montastrea sp.*, algas calcáreas del género *Lithothamnium, P. astreoides, Diploria,* hidrozoarios del género *Millepora*, anémonas coloniales *P. caribbeaerum y Z. sociatus.* Bajo Obispo: este sistema arrecifal presenta paredes simples y fusionadas con taludes externos de fuertes pendientes. Bancos Ingleses: son también paredes arrecifales simples y fusionadas con taludes externos de pendientes moderadas (Torruco y González 1997b).

Comparación Biótica

Los arrecifes de Campeche presentaron 207 especies con una alta biodiversidad y grado de desarrollo con respecto a: Isla Cozumel, Costa Occidental Isla Mujeres, Punta Nizuc, Punta Cancún, Alacranes, Isla Contoy, Puerto Morelos y Tulúm, en la mayoría de los siguientes grupos funcionales: Hexacorales, Octocorales, Hidrozoarios, Anémonas, Esponjas, Macroalgas, Poliquetos y Equinodermos, es importante señalar que estos sistemas presentan diferentes esquemas de protección (González 2000b).

Aspectos Histórico

La zona presenta una gran importancia sobre todo en los encallamientos de barcos en los bajos arrecifales. Se registraron los siguientes 12 pecios con su geoposicionamiento: Wachos, Don Francisco, Santa Fé, Namditos, Atoradero, Cheroquee, Lorencillo, Cubano, Malujoca, Mario Quemado, Jaina, Catalán.

Aspectos Socioeconómicos

Es difícil establecer para los arrecifes coralinos un *estatus* socioeconómico real, sobre todo en los arrecifes de Campeche en donde su principal giro es la utilización pesquera y la extracción de crudo (Ferre-D'Amare 1995). Por otro lado, el arrecife y sus zonas emergentes no presentan un asentamiento humano permanente, los islotes de Cayo Nuevo, Triángulos Este y Sur no presentan ningún asentamiento, los Cayos de Arcas y Arenas son los que presentan una mayor población que incluye a dos guardafaros, un destacamento de infantes de marina de cuatro elementos, que en el caso de Arcas el destacamento es más numeroso: tres infantes más y un radiocomunicador, además en ambas islas se presentan con frecuencia pescadores que realizan estancias de poco tiempo, la isla de Triángulos Oeste tiene sólo dos guardafaros.

Las islas actualmente sirven como bases esporádicas de pesca y refugio de pescadores de escama y de algunos invertebrados de importancia comercial. En los alrededores de Cayo Arcas se presenta la construcción y funcionamiento de plataformas de extracción de crudo y estaciones de bombeo, de donde se extrae hasta el 70% de la producción nacional. El uso tradicional de la flora y fauna en algunos cayos es inexistente, la fauna generalmente tiene implicaciones alimenticias y ornamentales, en algunos casos con especies de moluscos y corales. Es conveniente considerar que aunque el material arrecifal no es utilizado para la construcción de edificios o estructuras como ocurrió en el pasado con otros sistemas arrecifales, la mayoría de las islas están construidas por restos coralinos.

Asimismo, no existe algún antecedente sobre la protección del área, sin embargo esta regida tanto por: la ley federal del mar, la ley de pesca, la ley general del equilibrio ecológico y la protección al ambiente, la ley orgánica de la Armada de México, así como las leyes aplicables a estas zonas.

Superficie Propuesta

Las coordenadas extremas utilizadas en la formación de los vértices del área total propuesta siguieron la isobata de las 28 brazas (51.24 m) y son: hacia el norte 22°15'N-91°10'W, hacia el sur 20°10'N-92°00'W, al este 22°05'-91°05'W y al oeste 21°15'N-92°25'W, con ello se delimitó la poligonal con una área de 12 437 Km^2 (Figura 2a). El área propuesta involucra el 9.6% de la Sonda de Campeche, lo cual significaría una área protegida 8.6 veces mayor que la Reserva de la Biosfera de Banco Chinchorro, hasta hoy la más grande en aguas marinas Mexicanas (Torruco et al. 1996). No obstante, debido a los problemas que implicaba en cuanto a la vigilancia y coordinación de sus acciones, así como a la protesta de la CANAINPES por las restricciones a la pesca, fue necesario redefinir los límites con diez áreas núcleo y una área de amortiguamiento que interconecta a todas las áreas, lo que disminuyó considerablemente los conflictos con los sectores pesquero e industrial (Figura 2b).

DISCUSIÓN

Está propuesta planteó un esquema de zonificación de sus áreas arrecifales, con la finalidad de proteger mediante zonas núcleo a la mayoría de los sistemas arrecifales sumergidos, lo que implicó el 37.85% del total. Está área fue definida considerando sus fronteras con el mar territorial, lo que permitirá una continuidad hacia los arrecifes en sus procesos oceánicos y biológicos, asimismo permitirá establecer normas de utilización concretas en relación a la navegación, transporte de materiales y disposición de desechos, entre otros.

Estás zonas núcleo incluyen los niveles de biodiversidad más altos de estos sistemas arrecifales, además de estar ubicadas en posiciones cercanas a los cayos emergentes, lo cual es una medida necesaria para la recolonización y repoblación de estas zonas, cuyo papel puede ser de amortiguamiento y de utilización más intensa.

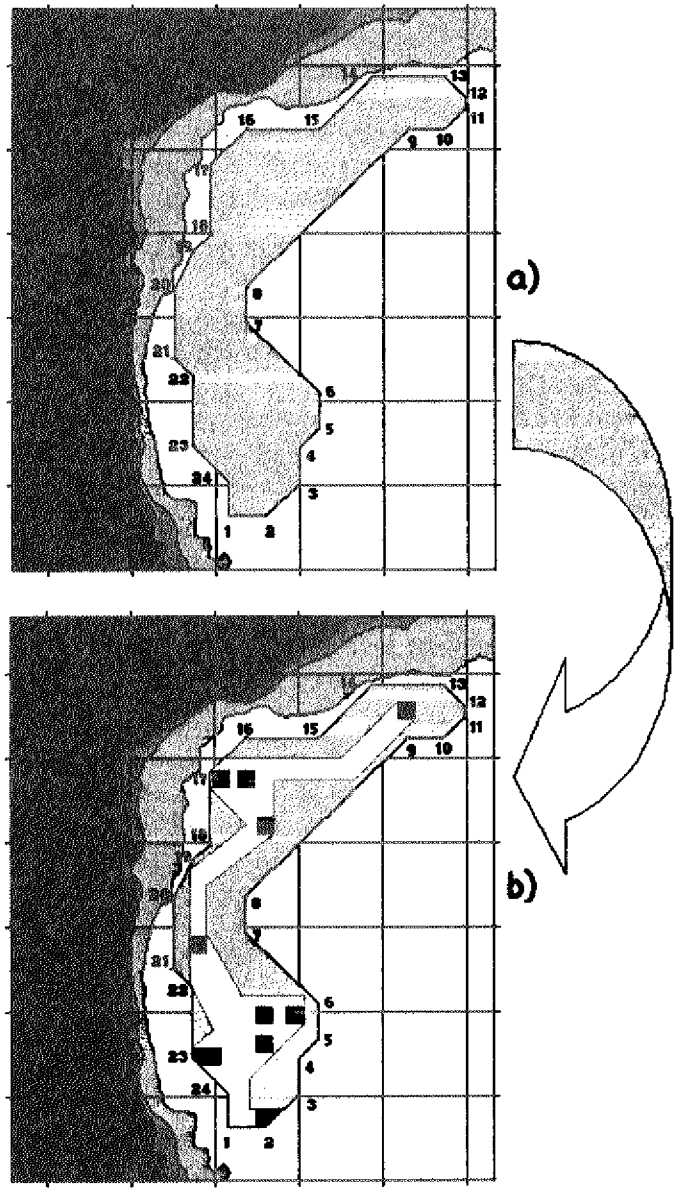


Figura 2 a y b. Poligonal propuesta y coordenadas extremas para el ANP: Arrecifes Coralinos de Campeche.

La elaboración de un programa operativo eficiente es complejo, ya que debe amalgamar concertaciones con los diferentes sectores que hasta ahora hacen uso de estos sistemas arrecifales, además de identificar sectores de utilización racional. Es

por ello, que es indispensable la participación activa y comprometida de todos los sectores interesados en la conservación y aprovechamiento de estas áreas arrecifales. Actualmente, se cuenta con la caracterización, delimitación y zonificación con límites precisos de estos sistemas. No obstante, es de vital importancia seguir con el proceso de su declaratoria e incluirlas en el SINAP, debido a que son zonas con alta biodiversidad y ocupan un lugar importante con respecto a otras áreas protegidas.

LITERATURA CITADA

Ferre D'Amare, A.R. 1985. Coral reefs of the Mexican Atlantic. A Review. *Proc. 5 Int.Coral Reef Congr.* Tahiti. **6**:349-354

Ferre-D'amare, A.R. 1995. Prospección de los arrecifes coralinos de Cayo Arcas y Cayo Triángulo, Campeche, México.Impacto ambiental de una década de actividades de la Industria Petrolera. *Sian ka'an* serie documentos **4**: 40-47.

González M.A. y D. Torruco. [In press]. *Vegetación sumergida y de cayos arenosos en los arrecifes de Campeche, México.* Acta Botánica Mexicana.

González M.A. y D. Torruco. [In press]. *Lineamientos de Manejo y Conservación para los arrecifes de Campeche.* IV Congreso Nacional de Areas Naturales Protegidas, México.

INEGI, 1981. *Cartas de Climas de México. Instituto Nacional de Estadística, Geografía e Informática.*

Novak,M.J., W.D.Liddell and D. Torruco. 1992. Sedimentology and community structure of reefs of the Yucatan Peninsula. *7th. Int. Coral Reef Symposium.* Guam.

SM, 1981a. *Contribución a la sedimentología y morfología de la Plataforma continental frente a las costas de Campeche, México.* Primera Dir. Inv. Ocean/G-81-01

SM, 1981b. *Contribución a la sedimentología y morfología de la Plataforma continental frente a las costas de Campeche, México.* Segunda parte. Dir. Inv. Ocean/G-81-02

Torruco, D. 1995. *Faunística y ecología de los corales escleractinios en los arrecifes de coral del sureste de México.* Ph.D. Dissertation. Universitat de Barcelona, España. 268 pp.

Torruco, D. M.A. González and M.A. Liceaga. 1996. The role of GIS in the ecological basis for management of a reef system in the Mexican Caribbean: the Chinchorro Bank case. *Ecoinforma Global Network*, Miami. 37-2.

Torruco, D. y M.A. González. [1997a]. Propuesta de ANP Zonas Arrecifales de Campeche: Descripción y Diagnóstico. SEMARNYD/Gob. Campeche, México 81 pp. Unpubl. MS.

Torruco, D. y M.A. González. 1997b. *Arrecifes y Corales de Campeche.* CINVESTAV/SEMARNYD. Gobierno del Estado, ISBN:970-18-0705-97.