GCFI

Proceedings of the

FIFTY – SEVENTH ANNUAL

Gulf and Caribbean Fisheries Institute

ST. PETERSBURG, FLORIDA

NOVEMBER 2004

HOSTED BY:

Florida Fish and Wildlife Conservation Commission

Fish and Wildlife Research Institute

FORT PIERCE, FLORIDA 2006

Proceedings of the

FIFTY – SEVENTH ANNUAL

Gulf and Caribbean Fisheries Institute

ST. PETERSBURG, FLORIDA

NOVEMBER 2004

Library of Congress Catalog Card Number 52-033783

ISSN Number 1553-8486

Edited by:
R. LeRoy Creswell

FORT PIERCE, FLORIDA 2006

The 57th Gulf and Caribbean Fisheries Institute was hosted by:
FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION
FISH AND WILDLIFE RESEARCH INSTITUTE

We would like to extend our grateful appreciation to the following sponsors of the 57th Gulf and Caribbean Fisheries Institute:

Florida Fish and Wildlife Commission
Government of Bermuda
The Nature Conservancy
The Ocean Conservancy
Environmental Defense
Caribbean Fisheries Management Council
Sea Grant Programs of Florida and the Gulf of Mexico
University of Puerto Rico Sea Grant Program
United States Geological Survey
The Pier Aquarium
The University of South Florida, St. Petersburg
National Oceanographic and Atmospheric Administration
National Ocean Service (NOAA)
Florida Keys Marine Sanctuary (NOAA)
National Marine Fisheries Service
Southeast Fisheries Science Center (NMFS)
Southeast Regional Office (NMFS)
Office of Protected Resources (NMFS)

And to the tireless efforts of the staff of the Florida Fish and Wildlife Conservation Commission who served as our host.

57^{th} GULF AND CARIBBEAN FISHERIES INSTITUTE

OPENING REMARKS

Robert Glazer, Chairman

Good morning and welcome to the 57^{th} annual GCFI. First and foremost I want to thank the FWC and the FWRI for agreeing to host this conference. I also want to thank the Board of Directors of GCFI for their guidance and vision. It is with particular personal pleasure that I welcome you to the headquarters of the Fish and Wildlife Research Institute, my home institution.

In many ways, this meeting brings us full circle. In looking back through the Proceedings during the very early days of GCFI, one name, Bob Ingle, kept appearing on the program year after year. Bob worked here on the oyster fisheries of Florida, a very important focus of interest during the early days of GCFI. The building right next door where we will be having our lunches today and Friday is named for him. Yet, this is the first time in the 57 years of GCFI, that we have had our meeting in St. Petersburg.

When we were first putting together this program it quickly became obvious that there was one overriding theme: connectivity. But not just connectivity in the biological sense of the word. Connectivity in the people sense, too. After all, connectivity is what GCFI is all about. It is our goal, indeed our mission, to bring diverse interests together so that they can interact and exchange ideas among each other on the conservation and wise use of our marine resources.

Three particular activities at this GCFI best illustrate this objective. First, GCFI has partnered with the United Nations Environment Programme, NOAA, The Nature Conservancy, Environmental Defense, the Ocean Conservancy and many other organizations throughout the region in a broad partnership called the CaMPAM Network and Forum. It is the expressed goal of this organization to build capacity among managers and their stakeholders of Marine Protected Areas in this region. In this room today are over 12 fishers and over 16 MPA managers funded under a variety of initiatives from south Florida, the insular Caribbean, and the Mexican Gulf of Mexico. They are here for a common goal: to develop the tools that will help them conserve, manage and use the resources in conscientious, well-informed ways, so they can become responsible stewards of the resources we all treasure.

The second activity, the GCFI Education Initiative, was launched last year in Tortola, British Virgin Islands. Without going into too much detail, you will see in the program approximately 26 students who are competing for three Outstanding Student Achievement awards. This award will fund the winner of the award's to travel to the next GCFI.

Within the Education Initiative, through CaMPAM, GCFI and our partners have developed programs at the conferences that support fishers. This year, after the sad and untimely passing of Peter Gladding, a fisher who many of you met in Xel Ha and who was responsible in large part for the implementation of the Tortugas Reserve, we are starting together with Environmental Defense an annual scholarship in Peter's memory to support travel for a fisher or fishers from the region to the subsequent GCFI.

Finally, in keeping with this broad theme of connectivity, GCFI this year is hosting a workshop of the Western and Central Atlantic Fisheries Commission. WECAFAC exists in part to develop mechanisms for management of trans-boundary fishery resources. There are representatives from many jurisdictions who will be meeting Wednesday afternoon in a first informal meeting to develop long-term strategies for the conservation of these resources.

As you look around this room, you will see representatives from over 25 countries or island groups. I am confident the friendships you make here will be long lasting, the science you learn will guide your actions, and in the spirit of connectivity, you will make use of the opportunities that may present themselves from your colleagues here at FWRI.

Thank you.

TABLE OF CONTENTS

GIS AND REMOTE SENSING IN FISHERIES RESEARCH AND MANAGEMENT

MANAGEMENT AND SOCIO-ECONOMICS OF MARINE FISHERIES

BIOLOGY AND MANAGEMENT OF PELAGIC, NEAR-SHORE, AND REEF FISHES

BIOLOGY AND MANAGEMENT OF THE SNAPPER-GROUPER COMPLEX

MARINE PROTECTED AREAS SCIENCE AND MANAGEMENT IN THE CARIBBEAN REGION

ESSENTIAL HABITATS AND ANTHROPOGENIC IMPACTS

INVERTEBRATE FISHERIES I — MOLLUSKS

INVERTEBRATE FISHERIES II — SPINY LOBSTER

RECREATIONAL FISHERIES

AQUACULTURE DEVELOPMENT IN THE CARIBBEAN

EDUCATION AND MARINE STEWARDSHIP

ABSTRACTS FROM POSTER SESSION

Using GIS Tools for Participatory Management of Coastal Resources in Laborie Bay, Saint Lucia

ALLAN H. SMITH
Caribbean Natural Resources Institute (CANARI)
Administrative Building
Fernandes Industrial Centre
Laventille, Trinidad and Tobago

ABSTRACT

The village of Laborie on the south coast of Saint Lucia has been the site of a three-year study to investigate the relationship between people's livelihoods, their involvement in the management of resource use, and the status of the coral reefs in Laborie Bay. The area is typical of many in the region where reefs provide a variety of goods and services, but until recently little information was available on their extent and status. The most recent maps of the reefs were made in the late 19th Century and included only enough detail to identify hazards to navigation. The information that was available on marine resource use was therefore not related to specific geographic areas. This paper describes the selection and application of appropriate GIS tools and methods to integrate popular knowledge and the data from scientific research. It focuses on the need to distinguish between mapping designed to classify habitats for ecological research, and the identification and mapping of features recognized and used by fishing communities and other resource users. Mapping based on local geographic knowledge was found to be essential in the acquisition, redistribution, and analysis of information and in its application in participatory management processes. The transfer of the GIS-based project management tool to a community-managed resource is discussed.

KEY WORDS: GIS, mapping, participation

GIS para el Manejo de Recursos Costeros en la Bahía de Laborie, Santa Lucia

Laborie en la costa sur de Santa Lucia ha sido el sitio de un estudio de tres años que esta investigando la relación entre gente, su participación en el manejo de recursos, y la condición de los arrecifes en la Bahía de Laborie. El área es típica de muchos en la región en que arrecifes proporcionan una variedad de servicios pero hasta recientemente, habia poca información sobre la condición de los recursos. Los mapas más recientes de los arrecifes se hicieron en el siglo XIX e incluyeron sólo suficiente detalle para identificar los peligros a la navegación. Por lo tanto, la información que estaba disponible sobre el uso de recursos marinos no fue relacionado a áreas geográficas específicas. Este manuscrito describe la selección y la aplicación de GIS y métodos de integrar el conocimiento de los que viven en Laborie y datos de estudios científicos. El enfasis del manuscrito es en la necesidad de distinguir entre la cartografía diseñada para clasificar habitates para investigaciónes ecológicas y la identificación de características reconocida y utilizada por los pescadores de las comunidades. La cartografía basada en el conocimiento de los que viven en Laborie se encontró ser esencial en los procesos de manejo. La transferencia de la tecnologia de GIS para el manejo de los recursos se discute.

PALABRAS CLAVES: GIS, recursos costeros, Santa Lucia

INTRODUCTION

Laborie is a small village located on the south coast of Saint Lucia. In 2001 a three-year research project was started to investigate the relationship between people's livelihoods, their involvement in resource management, and the status of reef resources (CANARI 2003). The project was entitled *People and the Sea* and aimed to provide guidance towards the identification of alternatives to Marine Protected Areas for the management of coastal resources. The rationale was that while there has been a global emphasis on MPAs in recent years, it is apparent that this approach is not appropriate in all circumstances. Alternative approaches are needed in places where the resource base cannot support the establishment of an MPA, but where those resources are nevertheless critical to people's livelihoods. Laborie was selected because it is representative of Caribbean coastal communities, and it provided an opportunity to study, test, and develop a livelihoods–based approach to management. This approach included the study of participatory institutions to increase stakeholder participation in planning and management, and options to increase economic benefits from activities such as the reef fishery, sea urchin harvesting, seaweed cultivation, and heritage tourism.

Research on reefs in St. Lucia has focused mainly on the west coast, and particularly within the Soufriere Marine Management Area (SMMA). Ongoing activities include monitoring of reef communities, assessment of the effectiveness of fishery reserves, the impact of reserves on fishing communities, and analysis of the participatory process that has been critical to the functioning of the SMMA and is seen as a model for MPAs in the eastern Caribbean.

Much less attention has been given to the south and east coasts, and there was little information available on distribution of reefs in Laborie Bay. The *People and the Sea* was designed and implemented with a high level of stakeholder participation, and it was important therefore to be able to integrate popular knowledge and scientific information. Appropriate tools were needed to facilitate the collection and redistribution of information and to relate the information to features and places recognized and used by the Laborie community.

METHODS

A review of existing documented information on marine habitats in Laborie Bay showed that little was available. As with many islands in the eastern Caribbean, Saint Lucia's reefs have not yet been mapped in any detail, and it was soon evident that there was no recently published information on the distribution of reefs in Laborie Bay. Given that habitat mapping can be a very costly exercise there was a need to make the best use of any existing material, and to build on that using cost-effective methods and equipment. This would involve firstly the collection of existing information of any type and complementing it with data gathered through field surveys and information provided by the Laborie community.

Available background material included the following:

i) Reproductions of various historical maps with little or no detail of marine features but with some useful background to current popular names,
ii) Original hand-painted maps from the mid 18th Century indicating soundings, reefs and anchorages,
iii) Topographic maps at 1:2,500, 1:10,000, 1:25,000 and 1:50,000, the most recent compiled in 1995 from a 1992 aerial survey,
iv) Navigational charts showing general reef distribution but at a very coarse level of detail, intended only to identify the seaward boundary of reefs as potential navigational hazards and mainly based on 19th Century surveys, and
v) Aerial photos made for land cartography but including marine features to a distance of approximately 1.25 km from shore, from series made in 1941, 1966, 1977 and 1992.

A suitable GIS application was needed in order to make use of these materials, and to integrate the information to be obtained through habitat surveys and community consultation. The program Map Maker Pro was chosen based on the following criteria:

i) Ability to exchange spatial data with GIS applications already in use in the country,
ii) Ability to use both raster and vector formats,
iii) Ability to calibrate (georeference) raster images using the local grid and datum,
iv) Affordability,
v) Ability to use GPS data,
vi) Ability to convert among raster file formats,
vii) Availability of these features in one program without the need for add-on modules or third-party software, and
viii) Potential for use and maintenance by the Laborie community for ongoing development planning and management of reef resources.

The process of mapping reefs and other habitats began by calibrating topographic maps and identifying as much as possible of the marine features from the calibrated airphotos. The next stage was to gather first-hand information from people familiar with the Bay during field trips on the water. To facilitate this, copies of the airphotos were printed, mounted on card and covered with clear plastic sheet. As the boat captain navigated around the Bay features in the airphotos were annotated on the plastic overlay, to include place names and notes on any locations of particular importance for fishing or other activities. GPS waypoints were saved at key locations to improve the accuracy of mapping and to provide a means of returning to places of interest for further surveying and description of habitats. The information was used to compile thematic maps, using the topographic maps as a base, but in the ongoing process of information exchange the aerial photos were found to be far more effective tool than line-drawn representations of the Bay. People who were not familiar with interpreting either line-drawn maps or aerial views would very easily orient themselves to features in the airphotos despite never previously having had access to such a perspective of their environment. Projected airphotos were used at many of the community meetings during the project, providing a dynamic tool that allowed new information to be added and discussed during the meetings.

The *People and the Sea* project included four experiments, with GIS tools being especially useful in planning and conducting two of them. The first was a study of how increased awareness of, and access to, information on the status, causes, and potential impacts of a water pollution could contribute to a change in behaviour, and to identify the processes by which these changes occur. It was commonly believed in the community that water quality in the Bay had been declining for a number of years, but there were no data available to support this belief. The results of a survey of people's perceptions of the nature and significance of this decline were discussed in community meetings, with projected maps and airphotos used to identify specific locations of concern, to plan an appropriate monitoring activity to generate the necessary data, and to review the data as they became available. The indicators selected for monitoring were the levels of faecal coliform bacteria and benthic community composition.

Coliform levels were determined at stations in the ravines and gullies draining into the Bay, along the shoreline, and on reefs approximately 500 m from shore, using methods consistent with World Health Organisation specifications for detection of faecal coliform bacteria (Robens Institute 1993), as an indicator of sewage pollution.

Benthic community composition was assessed at a number of reef sites using the Reef Check protocol (Reef Check Foundation 2003). The method includes 10 categories of benthos, but public discussion focused on relative cover of live coral and macroalgae. Figure 2 shows results for four reef sites. The increase in live coral and decrease in macrolagal cover with distance from shore, together with the algal species composition at inshore sites, supported the belief that land-based sources of nutrients were affecting the condition of reefs in the Bay. Linking data and underwater photographs to reefs in the GIS aided in discussing the results at community meetings.

The second experiment that benefited from the GIS tools was the investigation of institutional options for the management of the harvest of the edible white spined sea urchin, *Tripneustes vestricosus*, locally known as the sea egg, or *chadon* in Creole. A national management programme was implemented in

Saint Lucia by the Department of Fisheries in 1986, in response to overexploitation and declining stocks (George and Joseph 1994). This was a co-management arrangement based on regular monitoring of stocks and participation of resource users in decisions concerning the annual harvest. This functioned well for a number of years until stocks declined severely in the mid-1990s. The harvest was closed by the Department of Fisheries to allow for stock recovery and was still closed at the time the project began. The annotated airphotos were used in public meetings to identify sites of past importance, to identify suitable locations for monitoring, to record current information and perceptions of the status of stocks, and to discuss the findings with regard to the possibility of resuming the harvest.

RESULTS

The mapping exercise demonstrated that reefs and other features in Laborie Bay (Figure 1) are identified by local names that have been established over a long period of time. They come from a variety of sources, such as the names of fishermen who live nearby, the type of fish caught in the area, or particular wave formations. This information has not previously been documented but proved to be indispensable in any public discussions that needed to refer to specific locations.

The ability to link data from a range of sources to specific reefs greatly enhanced discussion and interpretation during public consultations. This was particularly true of the results from the study of water quality (Figure 2), which would have been less readily understood and accepted without the advantage of GIS tools. The use of projected airphotos of the Bay displaying the distribution of bacterial pollution was a very effective means of sharing the results of monitoring. One indication of this effectiveness was the fact that while the results supported many of the popular perceptions, including the belief that sewage pollution was the main problem, they contradicted the belief that only one part of the village was responsible when results showed the source to be much broader. Access to information and a better understanding of the nature and extent of pollution in the Bay have resulted in local initiatives to reduce sewage pollution through the improvement and expansion of public facilities, and to collaborate with appropriate Government departments in identifying suitable systems for new housing construction in the village.

The ability to gather and redistribute information on the status of the sea urchin stocks in public fora was a critical element in the participatory process of monitoring, redistributing results, and discussing management options before each harvest season. Based on this information, and an agreement on specific conditions, including duration and size limits, the harvest was opened in October 2002. This consultative process has continued under the leadership of the Laborie Fishers and Consumers Cooperative which facilitates data gathering and the communication of management recommendations from the community to the Department of Fisheries.

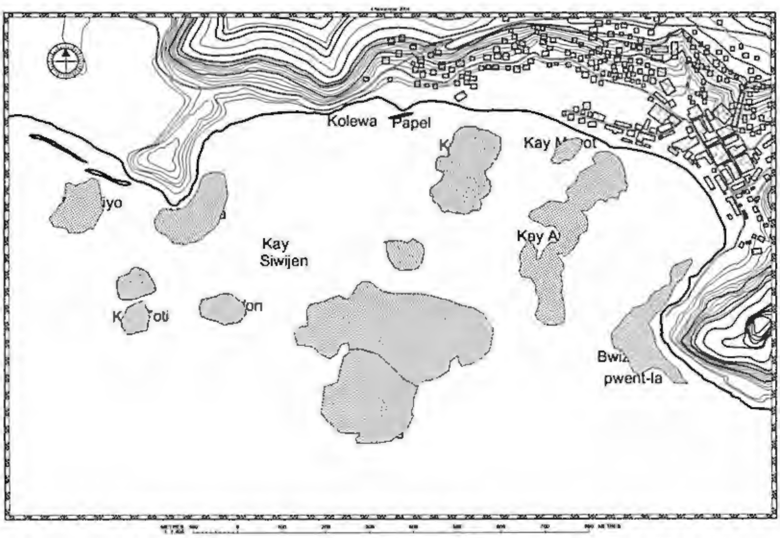


Figure 1. Distribution and names of reefs in Laborie Bay

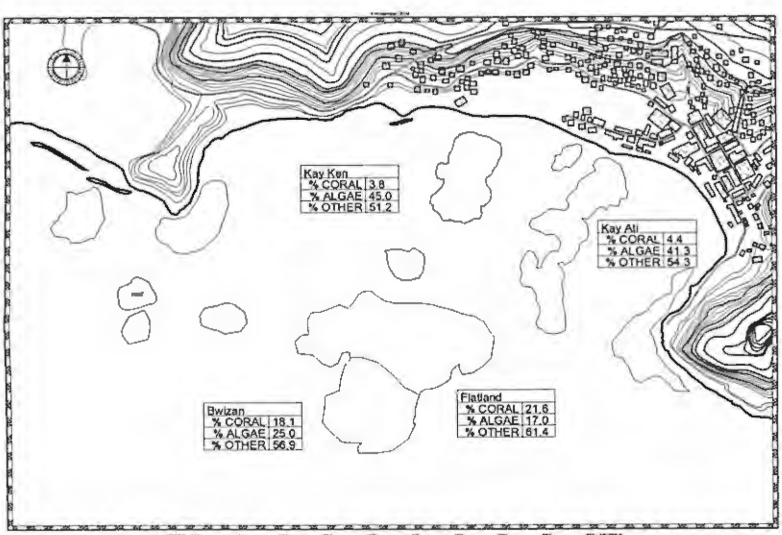


Figure 2. Cover of live coral and macroalgae on two inshore and two offshore reefs in Laborie Bay.

The value of the GIS component of the *People and the Sea* project to ongoing community development has been recognised by local organisations. The Laborie Village Council has provided space for the computer equipment donated to the community by the *People and the Sea* project, and the Laborie Development Foundation has initiated a training programme for teachers and students in mapping and information management in support of a range of planned community development projects.

DISCUSSION

The experience of the People and the Sea project has illustrated a number of issues regarding the use of GIS tools in participatory research projects:

i) The use of GIS tools is appropriate if it adds to the participatory process, and is based on the priority of collecting and disseminating information for collective decision-making.

ii) Ownership of information collected through a participatory process, including both popular and scientific information may be an important issue. Individuals have the option of not revealing information when it may not be in their own interest, but information gathered collectively may need a collective decision about how it is to be used. Local residents had identified sewage pollution as a primary concern and as a priority for research, and it was initially planned that the results of water quality analysis from Laborie Bay would be widely disseminated. However, it was soon realised that the results could be wrongly interpreted to mean that the condition is unusually severe and specific to Laborie. It was decided by community members that a plan of action to investigate options for reducing sewage pollution should first be developed. The dissemination of information on pollution could then indicate the steps being taken by the community to address a situation that no doubt affects all coastal communities on the island.

iii) The appropriate GIS tools have great potential to support community initiatives in resource management that typically do not benefit from the centralised GIS systems that exist in most islands. At the same time, the development of local GIS should be compatible with national systems to ensure that information not available elsewhere can be shared and used by centralised systems.

iv) Mapping aimed at facilitating stakeholder participation in management must identify those features and processes recognized by the resource user community. Habitat mapping based on ecological criteria will have much less meaning than maps based on local names and understanding of the area.

This research project has raised some important questions that are being examined by organisations in the community. In cases where information dissemination can be controversial or damaging, it is essential to determine what could and should be done with the information, who should get it, and in what form.

ACKNOWLEDGEMENTS

Assistance was received from the UWI Coastal Management Research Network (COMARE Net), a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID or UWI.

LITERATURE CITED

CANARI. [2003]. The Sea is our Garden: a report on a study of institutional and technical options for improving coastal livelihoods in Laborie, Saint Lucia. CANARI Technical Report No. 322. Unpublished MS. 146 pp.

George, S. and W. Joseph. 1994. A new participatory approach towards sea urchin management in Saint Lucia, West Indies. *Proceedings of the Gulf and Caribbean Fisheries Institute* 46:197-203.

Reef Check Foundation. 2003. Reef Check Survey Instruction Manual. Reef Check Foundation, Department of the Environment, University of California, USA. 21 pp.

Robens Institute. 1993. OXFAM-DELAGUA water test kit – users manual. University of Surrey, United Kingdom. 60 pp.

Integrating GIS with Fishery Survey Historical Data: A Possible Tool for Designing Marine Protected Areas

JILL J. ROWE[1] and GEORGE R. SEDBERRY[2]
[1]*Applied Science Associates, Inc.*
70 Dean Knauss Drive
Narragansett, Rhode Island 02882 USA
[2]*Marine Resources Research Institute*
P.O. Box 12559
Charleston, South Carolina 29412 USA

ABSTRACT

Spatial patterns in the abundance, biomass, and diversity of fishes caught on the continental shelf and upper slope off the southeastern United States Atlantic coast were described from a fishery-independent trawl survey conducted from 1973 - 1980. Geographic Information Systems (GIS) analysis revealed that relative abundance and biomass of fishes caught in depths from 11 - 360 m were significantly higher between coastal and shelf break (11-140 m) waters than in deeper off-shelf zones, and fish abundance was significantly higher off the coast of Charleston, South Carolina than farther south off the coast of Georgia and northern Florida. The highest levels of diversity occurred in shelf-edge and upper slope waters (41 - 120 m), and two diversity indices, Shannon Wiener Index and Margalef's species richness, were positively correlated with the presence of hard bottom habitat and reported reef fish spawning locations. The analyses revealed areas of particularly high fish biomass, abundance, and diversity that should be given consideration as marine protected areas for deep reef species that are not effectively managed by traditional means.

KEY WORDS: Diversity, GIS, MPA

Integracíon de GIS con Datos Históricos de la Pesquería: Un Instrumento Posible para Diseñar Areas Marinas Protegidas

Los patrones espaciales en la abundancia, biomasa, y la diversidad de los peces encontrados en la plataforma continental y la cuesta superior sureste del Atlántico de los Estados Unidos, fueron descritos por una encuesta arrastrada de pesquería independiente conducida desde 1973 hasta 1980. El análisis de los Sistemas de Información Geográfico (GIS) reveló que la abundancia relativa y la biomasa de los peces encontrados en profundidades desde 11 - 360 metros fueron significantemente más altas entre aguas rompientes de plataforma y costeras (11 - 140 metros) que en zonas más profundas fuera de la plataforma, y la abundancia de peces fue significantemente mayor en las afueras de la costa de Charleston, Carolina del Sur que más hacia el sur de la afueras de la costa de Georgia y norte de Florida. Los mayores niveles de diversidad ocurrieron en el borde de plataforma y aguas de cuesta superior (41-

120 metros), y dos índices de diversidad, el Indice de Shannon Wiener y riqueza de especies de Margalef, fueron positivamente correlacionada con la presencia de un hábitat de profundidad duro y reportó localidades de freza (zona de desove) de peces de coral. Los análisis revelaron áreas de particularmente alta de biomasa de peces, abundancia y diversidad, que deben ser dados en consideración como áreas marinas protegidas para especies de corales profundos que no son efectivamente manejados por medios tradicionales.

PALABRAS CLAVES: GIS, áreas marinas protegidas, pesquería

INTRODUCTION

The continental shelf off the southeastern United States from Cape Hatteras to Cape Canaveral out to the edge of the Exclusive Economic Zone (EEZ), also referred to as the South Atlantic Bight in published fisheries research (Govoni and Hare 2001), provides habitat for a highly diverse marine fauna, including many species that are important in recreational and commercial reef fisheries (Coleman et al. 2000). The marine fauna of the region receives contributions from northern waters via intrusions of Labrador Current waters around Cape Hatteras (Briggs 1974), and from the Caribbean via transport of southerly fauna in the Florida Current and Gulf Stream (Schwartz 1989). Rocky outcrops and other reef features also contribute to the diversity of the marine fauna by providing habitat complexity over portions of the sandy continental shelf (Miller and Richards 1980). These rocky reef habitats support a higher abundance, biomass and diversity of fishes and invertebrates than adjacent areas of open, sandy-bottom shelf (Wenner et al. 1983, Sedberry and Van Dolah 1984), and are heavily fished (Coleman et al. 2000).

Struhsaker (1969) divided the continental shelf and upper slope waters between Cape Hatteras, North Carolina and the southern tip of Florida into five bottom habitat types based on species composition of trawl catches:

i) Coastal areas (0 - 18 m depth) - mostly smooth sandy bottom;
ii) Open shelf (18 - 55 m) - sandy bottom with relatively stable hydrographic conditions in areas >30m depth due to the influence of the Gulf Stream (Wenner 1983);
iii) Live bottom (19 - 44 m);
iv) Shelf edge (45 - 110 m) - smooth to highly broken bottom, and
v) Lower shelf (110 - 200 m) and upper shelf (>200m) - smooth muddy bottom with some rocky outcrops and mounds.

Oceanographers have divided the open shelf into the middle shelf (21-40m) and outer shelf (41 - 60 m; Barnard et al. 1997), while the shelf edge includes the outer shelf (41 - 60 m) and shelf break (55 - 75 m).

Interest in the distribution of reef habitat has grown due to 1) concerns about the ability of the southeastern U.S. continental shelf to support reef fish populations facing intense fishing pressure (Coleman et al. 2000), and 2) mandates in essential fish habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act that spatial relationships between fishery species and habitats need to be included in fishery management plans

(Rubec et al. 1999). While the definition of habitat quality is difficult to interpret as linkages between fish and their habitats are complex and often dynamic (Able 1999), species distributions based on trawl survey data can be used as proxies for the distribution of seafloor habitats (Auster et al. 2001).

Huntsman and Manooch (1978) reported that no more than 10% (9,064 km^2) of the bottom morphology of the southeastern U.S. continental shelf is reef. On the other hand, Parker et al. (1983) estimated the total amount of reef habitat between Cape Hatteras and Cape Canaveral to be 22.8% (57,159 km^2) of the total bottom area. The considerable difference between these reported estimates shows the lack of, and uncertainty about, these data. Nonetheless, only a portion of the shelf is available to sustain reef fish populations. A geographic information system (GIS) database has been developed that provides reef habitat locations on the continental shelf and upper slope (to 200m depth) of the southeastern U.S. Atlantic coast (SEAMAP-SA 2001), and supports previous reports of hard bottom habitats being relatively scarce. Over 40% of the records in the SEAMAP database indicate the presence of hard bottom, although effort concentrated on data that could indicate hard bottom (SEAMAP-SA 2001).

In addition to limited habitat availability, reef fishes possess life history characteristics making them particularly susceptible to overfishing (Coleman et al. 2000). As the intensity of fishing pressure has increased off the southeastern U.S., there is greater need for conservation measures such as marine protected areas or MPAs (PDT 1990). MPAs have been defined by The World Conservation Union as "any area of intertidal or subtidal terrain, together with overlying water and associated flora, fauna, historical and cultural features, which have been reserved by law or other effective means to protect part or all of the enclosed environment" (IUCN 1988).

The South Atlantic Fisheries Management Council (SAFMC), which has jurisdiction in the southeastern U.S., is considering two types of MPAs for management of reef fishes: 1) complete no-take areas where no harvest is allowed, and 2) areas where only bottom fishing is prohibited. The purpose of these MPAs would be to restore reef fish stocks, especially those subject to fishing (e.g., snapper and grouper), particularly at depths where traditional management does not work due to release mortality.

It is critical to obtain a better understanding of the distribution of habitat, fishes, fishing effort and ocean circulation patterns, in order to site MPAs and ultimately reach the goal of maintaining sustainable fishery populations (Murray et al. 1999). Siting MPAs in areas of historically low fish biomass is not likely to be effective in conservation of significant fish productivity. Siting MPAs in areas with low historical biodiversity is not likely to include reef habitats that are high in fish diversity and biomass (Sedberry and Van Dolah 1984). Examination of historical fishery survey databases with recently developed analysis tools can help locate areas of traditionally high biomass and diversity for MPA consideration. In this article, we provide an example of such an application by examining a large historical database for patterns in fish abundance, biomass, diversity and distribution using GIS. The purpose of our analysis was to determine sites that are likely to support reef fish populations, as indicated by high diversity of catches. We also looked for areas of high biomass, abundance or diversity that the SAFMC were not considering as additional potential MPAs.

METHODS

Analyses were based on a groundfish trawl survey conducted by the National Marine Fisheries Service and the South Carolina Department of Natural Resources from 1973 - 1980. Trawl surveys were conducted at least once annually (Table 1). The survey from 1973-winter of 1977 consisted of a stratified random sampling design (see Wenner et al. 1979 for details of trawl sampling) that sampled 738 stations distributed within specified depth (11-366m) and latitudinal zones (Table 1, Figure 1). The Groundfish Survey from summer 1977-1980 consisted of a systematic sampling plan along seven transects, resulting in an additional 282 trawl collections. Transects were spaced fairly equidistant along the coast and perpendicular to the coastline from 11 - 183 m depth. For the Groundfish Survey, tow duration was thirty minutes, and distance varied slightly but was not measured.

Table 1. Summary of all cruises and sampling effort for the MARMAP Groundfish Survey (1973-1980). Effort refers to the number of trawls conducted per cruise. (Survey type: Random = stratified random, Transect = systematic transect sampling; see text for explanation.)

Year	Months	Effort	Survey Type
1973	Oct-Nov	87	Random
1974	Apr-May	116	Random
1974	Aug-Sep	88	Random
1975	Jan-Apr	92	Random
1975	Aug-Sep	87	Random
1976	Jan-Feb	86	Random
1976	Aug-Sep	89	Random
1977	Jan-Mar	93	Random
1977	Aug-Sep	50	Transect
1978	Jan	52	Transect
1978	Sep	60	Transect
1979	Aug	58	Transect
1980	Jul	62	Transect

Total number of trawls (or stations) = 1,020

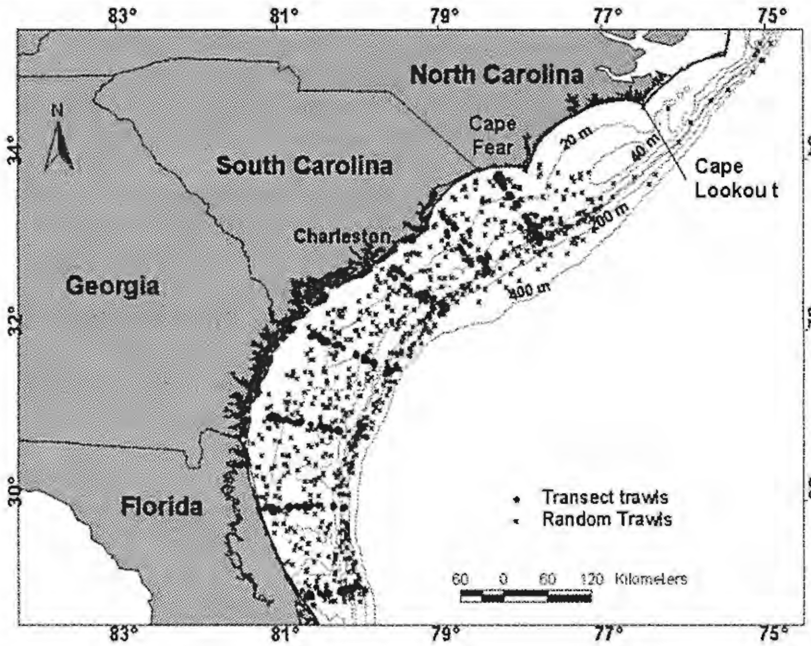


Figure 1. Locations of all trawl stations sampled during fishery surveys from 1973 - 1980. n = 1,020.

Analyses were conducted on total fish abundance and biomass using trawl data from summer months (July-September) only, which helped to reduce seasonal effects on catch variability. However, trawls from all seasons were used in diversity analyses to capture seasonal influx of species. Initial analysis of the trawl data showed that the variance in number of individuals and weight per tow far exceeded the mean and approximated a negative binomial distribution. Therefore, all catch per tow data were log-transformed [$\ln(x + 1)$] before statistical analysis to standardize the variance and approximate a normal distribution (Taylor 1953).

GIS (ArcView Version 3.1; ESRI 1998) was utilized for visualization and spatial data analysis and to elucidate geographic patterns in distribution of abundance, biomass, and diversity that were subject to further statistical analyses. For visualization purposes, catch per trawl was mapped and interpolated to a grid surface of 1.5-minute latitude x 1.5-minute longitude cells. These interpolated surfaces were created using the inverse distance weighted (IDW) procedure (ESRI 1998), which converts the point data to grids, and assumes that each input point has a local influence that diminishes with distance. Therefore, points closer to the processing cell are weighted greater than those farther away. Points within a fixed radius of 29.39km were used in these interpolations to create the specified 1.5-minute latitude x 1.5-minute longitude cell size. Further details of the GIS analysis can be found in Jennings (2001).

Following visualization and spatial analysis of the trawl data using GIS, log-transformed relative abundance and biomass data were statistically compared using nonparametric Kruskal Wallis tests (Sokal and Rohlf 1995). Tukey-Kramer multiple comparison tests (Sokal and Rohlf 1995) were used *a posteriori* to compare among means of unequal sample sizes for specific differences in equally-divided latitudinal regions and depth ranges of 20m increments.

To determine whether a relationship between bottom type, fish abundance and fish biomass existed, bottom type data, complied from SEAMAP Hard Bottom Mapping Project (Van Dolah et al. 1994), were pooled into 10-minute grids using GIS. For each 10-minute grid, a derived index of bottom type was calculated based on the average score of all collections within that grid. These scores range from 0 (no hard bottom) to 1 (possible hard bottom) to 2 (hard bottom). Pearson correlations (Sokal and Rohlf 1995) were used to compare transformed indices of relative abundance and biomass data of species caught by trawl to derived bottom type scores.

All fishes caught during the groundfish trawl survey were pooled into 10-minute latitude x 10-minute longitude grids (ArcView Spatial Analyst) to calculate three diversity indices: Margalef's (1958) species richness (D), Shannon-Wiener Index (H') (Shannon and Weaver 1949), and Pielou's (1975) Evenness Measure (J'), using a SAS biodiversity program (SAS Institute Inc. 1997). Diversity indices were then mapped and interpolated to a 1.5-minute latitude x 1.5-minute longitude cell surface following the same procedure described previously.

Following visualization and spatial analysis of the trawl data using GIS, the same statistical comparisons were performed on the pooled diversity data as were done with the relative abundance and biomass data. Likewise, applying the same procedure as was used to determine whether relationships existed between bottom type and relative abundance and biomass, Pearson correlations (Sokal and Rohlf 1995) were performed to compare diversity data of species caught by trawl to derived bottom type scores for each 10-minute grid.

RESULTS

A total of 785,088 fishes were sampled by trawl from 1973-1980 (Table 2). However, over 70% of the individuals sampled were represented only by 12 species, regardless of seasonality. Mean number of fishes and their biomass per trawl differed significantly among depth ranges (Table 3, Figure 2). Mean number caught per tow was higher in shallow water (11 - 40 m) than elsewhere in the survey area, however, abundance was significantly higher on the continental shelf (11 - 140 m) than upper slope (141 - 340 m) (Table 3, Figure 2). Mean biomass per tow was higher in shallow and outer shelf waters (11 - 80 m) than elsewhere in the survey area, and was significantly higher on the shelf (11 - 40 m and 61 - 80 m) than on the deeper shelf edge and upper slope (81 - 100 m, 121 - 160 m and 241 - 300 m; Table 3, Figure 2). Relative abundance of fish varied by latitude as well as depth. The mean number of individuals per tow was higher in latitude zone 2 off the coast of Charleston, SC than latitude zone 4 off the coast of Georgia and northern Florida (Table 3,

Figure 3). Areas of particularly high fish abundance were noted between Cape Lookout and Cape Fear off North Carolina (Onslow Bay). There was no significant difference in the relative biomass of all fishes caught among latitudinal ranges, but there were scattered areas of high fish biomass throughout the region at mid-shelf depths (Table 3, Figure 2).

Table 2. Most abundant species caught during all months of the groundfish trawl surveys from 1973 to 1980 (n = 1,020 trawls). This reflects the most abundant species living on or near the bottom of the continental shelf and upper slope off the southeastern United States Atlantic coast.

Scientific name	Common name	Total abundance	% of total individuals
Stenotomus chrysops	scup	166,293	21.2
Decapterus punctatus	round scad	70,442	9.0
Anchoa cubana	Cuban anchovy	59,690	7.6
Sardinella aurita	Spanish sardine	51,533	6.6
Etrumeus teres	round herring	49,158	6.3
Anchoa lyolepis	dusky anchovy	40,676	5.2
Peprilus tricanthus	butterfish	39,685	5.1
Haemulon aurolineatum	tomtate	21,833	2.8
Monacanthus hispidus	planehead filefish	18,632	2.4
Urophycis regia	spotted hake	12,146	1.6
Chloroscombrus chrysurus	Atlantic bumper	10,877	1.4
Anchoa hepsetus	striped anchovy	10,106	1.3
	Sum of above	551,071	
	Total of all species caught by trawl	785,088	70.2

Areas of high fish abundance and biomass coincided with concentrations of hard bottom (Table 3, Figure 4), and included the shallow waters just north of Long Bay, NC (< 20 m), the waters just offshore Long Bay (15 - 40 m), and the waters off Charleston, SC (15 - 25 m). When using the derived score in bottom type per grid, there was a significant positive correlation between bottom type and the relative abundance and biomass of fishes (Table 3).

Significant differences were found in the three diversity indices among depth ranges. Mean values of Shannon-Wiener index (H'), which varied from 0.18 - 4.78, were significantly lower in coastal and mid-shelf depths (11 - 40 m) than deeper, off-shelf zones (41 - 120 m, 141 - 160 m and 221 - 280 m; Table 3, Figure 5). Similarly, the coastal and mid-shelf depths (11 - 40 m) had significantly lower mean values of Pielou's species evenness (J'), which varied from 0.05 - 1.0, than deeper zones (41 - 60 m, 81 - 100 m and 261 - 280 m; Table 3, Figure 5). Outer shelf to lower shelf depths (41 - 120 m and 141 - 160 m) had higher means in species richness, which varied from 0.62 - 13.05, than coastal, mid-shelf, deeper lower shelf, and off-shelf depths (11 - 40 m and 181 - 320 m; Table 3, Figure 5). Coastal depths (11 - 20 m) also had significantly lower species richness than mid-shelf depths (21 - 40 m).

Table 3. Summary of statistical analyses done on the abundance, biomass and diversity of fishes caught per trawl (1973-1980). Statistical comparisons among means for depth and latitudinal ranges were made using Kruskal Wallis tests and Tukey Kramer multiple comparison tests ($p < 0.05$). Pearson correlation analysis was used between the abundance, biomass and diversity of fish and bottom type per 10-minute grid. (NS = no significant difference).

	Depth Range	Latitudinal Range	Correlation with Bottom Type
Biomass	p<0.0001	NS	r = 0.136, p = 0.000
Abundance	p<0.0001	p = 0.0222	r = 0.134, p = 0.000
Diversity Indices			
Shannon Wiener	p<0.0001	p = 0.0111	r = 0.061, p = 0.039
Species Evenness	p<0.0001	p = 0.0048	r = -0.161, p = 0.000
Species Richness	p<0.0001	p <0.0001	r = 0.367, p = 0.000

All three diversity indices were significantly different among the six equal latitudinal ranges (Table 3, Figure 6). Significantly higher H' occurred in latitude zone 6 off the coast of Cape Canaveral, FL than in latitude zone 4 off the coast of Georgia and northern Florida. Species evenness was significantly higher off the coast of Cape Canaveral, FL in zone 6 than in latitudinal zone 2 off the coast of Charleston, SC. Significantly higher species richness occurred in latitudinal zones 6 and 2 than in the other survey areas (zones 1, 3, 4 and 5).

GIS and statistical analysis of diversity values indicated localized areas of high fish diversity along the shelf break (40-100 m, Figure 7). High diversity measures correlated with areas of hard bottom (Table 3), particularly along the shelf edge, indicating areas where the presence of hard bottom, deep water and proximity to the Gulf Stream resulted in high reef diversity.

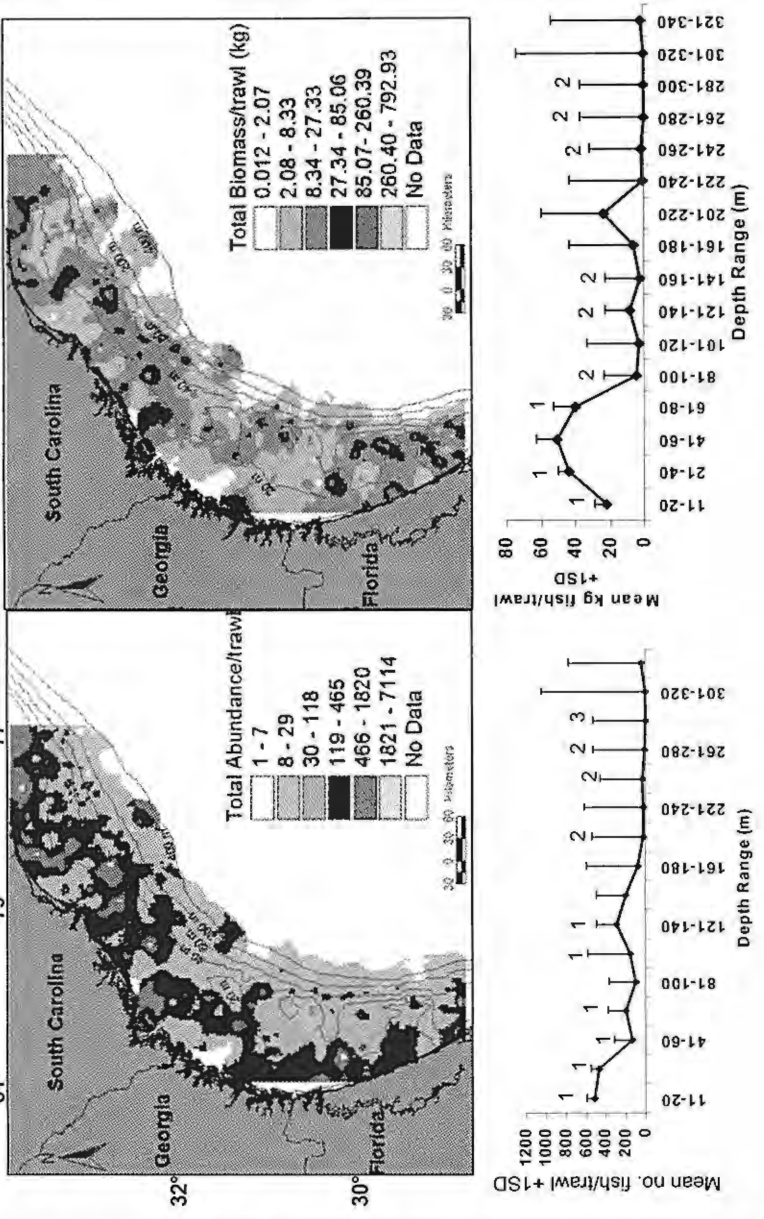


Figure 2. Mean number of individuals per tow and mean biomass per tow of all fishes caught by trawl (n = 487) during the summer months of the groundfish survey (1974-1980) statistically compared between 20 m depth ranges (Kruskal Wallis, $p < 0.0001$ for each). The graphs illustrate Tukey-Kramer test results, with significantly different ($p < 0.05$) means indicated by different numbers. Means with the same number are not significantly different from each other.

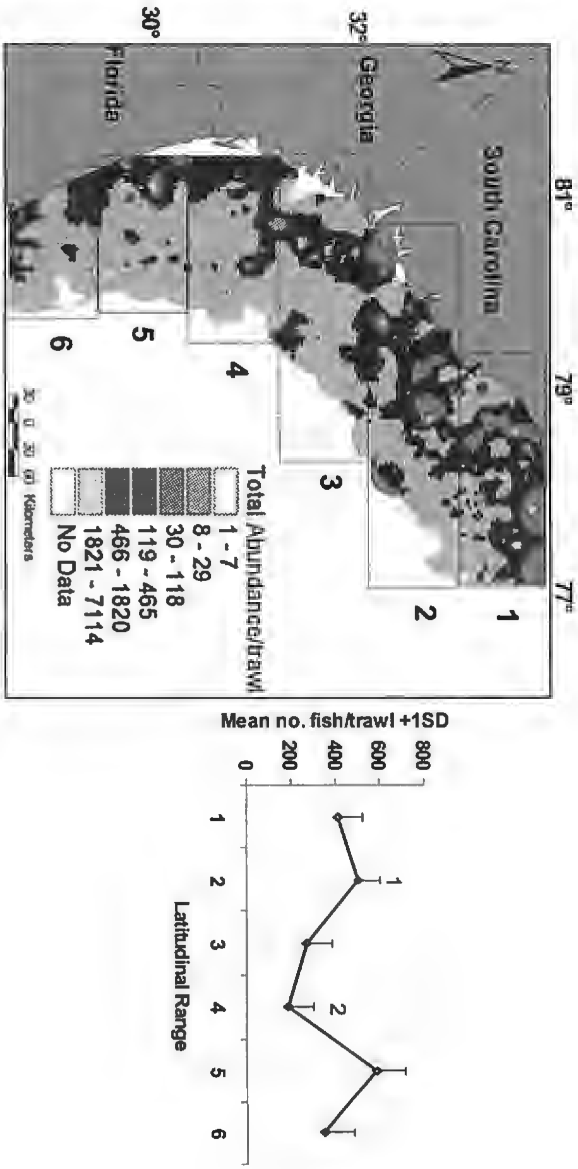


Figure 3. Mean number of individuals per tow for all fishes caught by trawl (n = 487) during the summer months of the groundfish survey (1974-1980) statistically compared between six equal latitudinal ranges (Kruskal Wallis, $p = 0.0222$). The graphs illustrate Tukey-Kramer test results, with significantly different ($p < 0.05$) means indicated by different numbers. Means with the same number are not significantly different from each other.

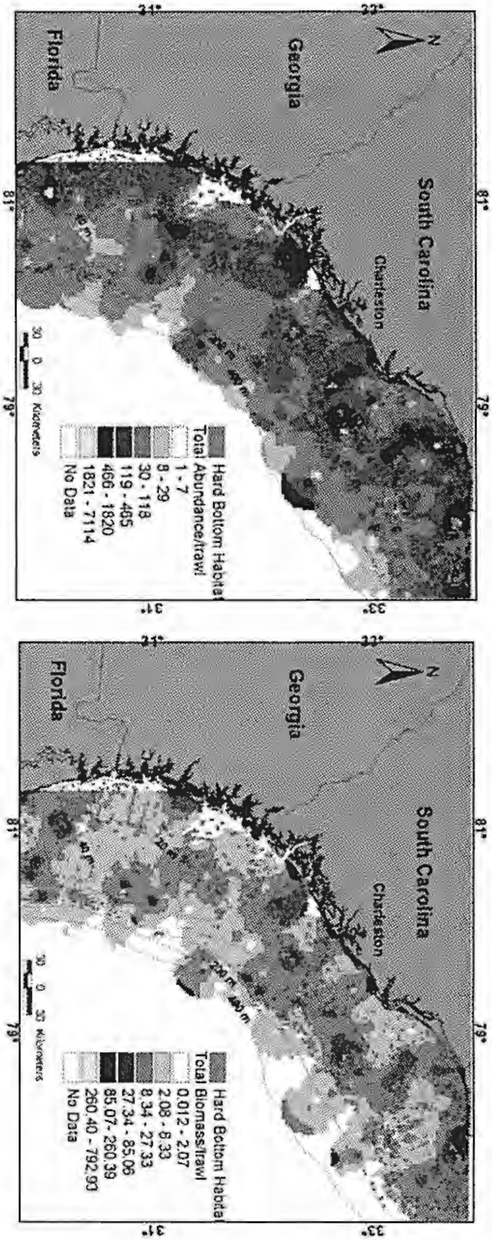


Figure 4. SEAMAP hard bottom grids (one minute *one minute) mapped on the interpolated surface of fish abundance and biomass from summer trawls (n = 487) during the groundfish survey (1974-1980).

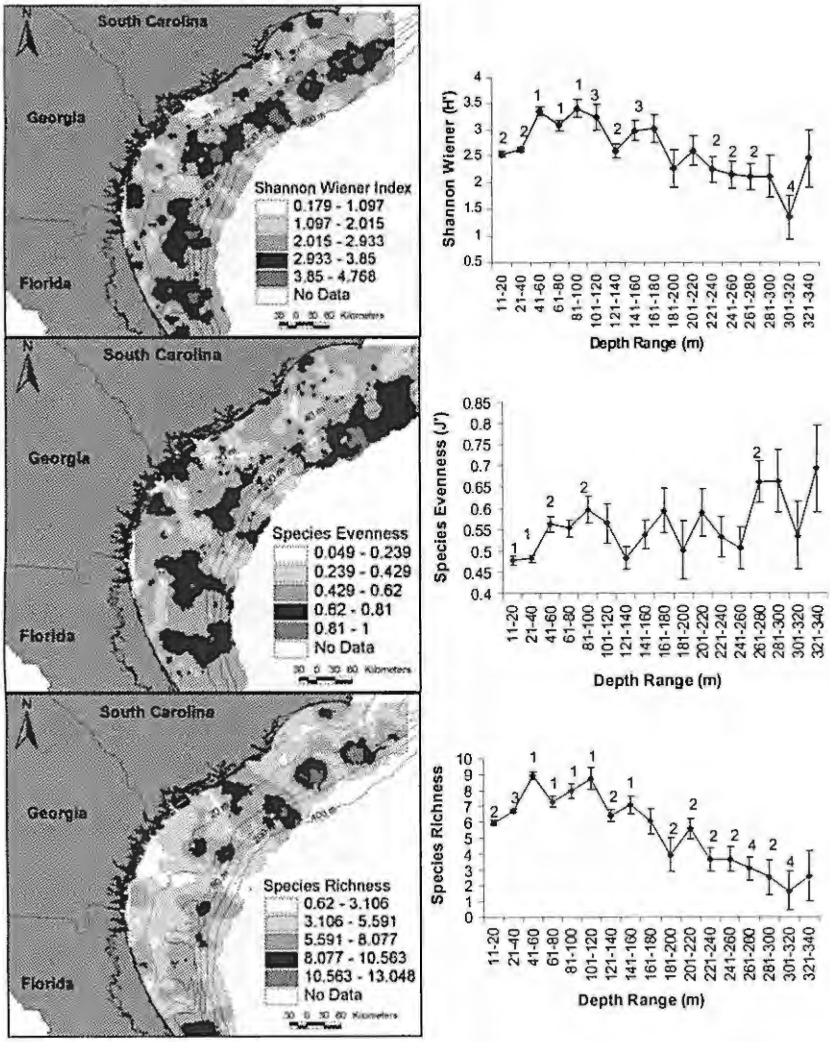


Figure 5. Statistical comparisons between 20-m depth ranges and Shannon-Wiener diversity index (H'), species evenness, and Margalef's species richness based on pooled samples of all species caught by trawl (n = 1,020) during all months of the groundfish survey (1973-1980). The graphs illustrate Tukey-Kramer test results, with significantly different ($p < 0.05$) means indicated by different numbers. Means with the same number are not significantly different from each other.

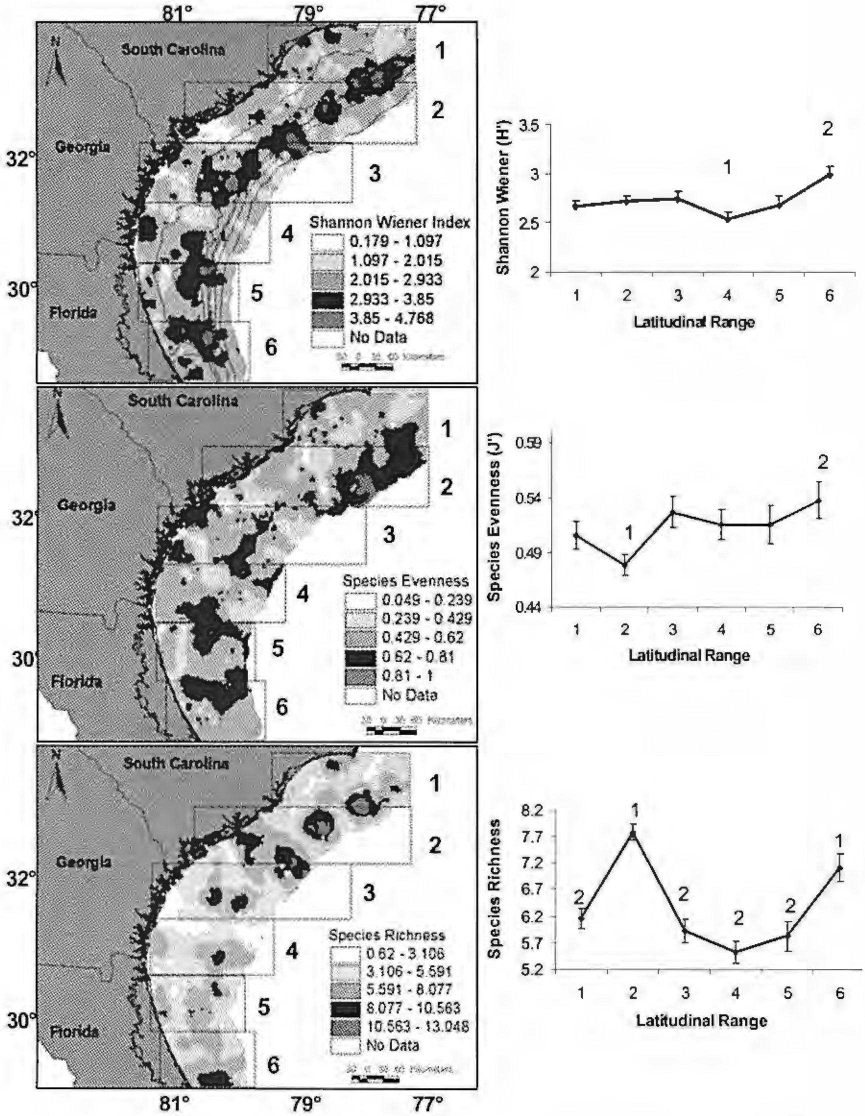


Figure 6. Statistical comparisons between six equal latitudinal ranges and Shannon-Wiener diversity index (H'), species evenness, and Margalef's species richness based on pooled samples of all species caught by trawl (n = 1,020) during all months of the groundfish survey (1973-1980). The graphs illustrate Tukey-Kramer test results, with significantly different ($p < 0.05$) means indicated by different numbers. Means with the same number are not significantly different from each other.

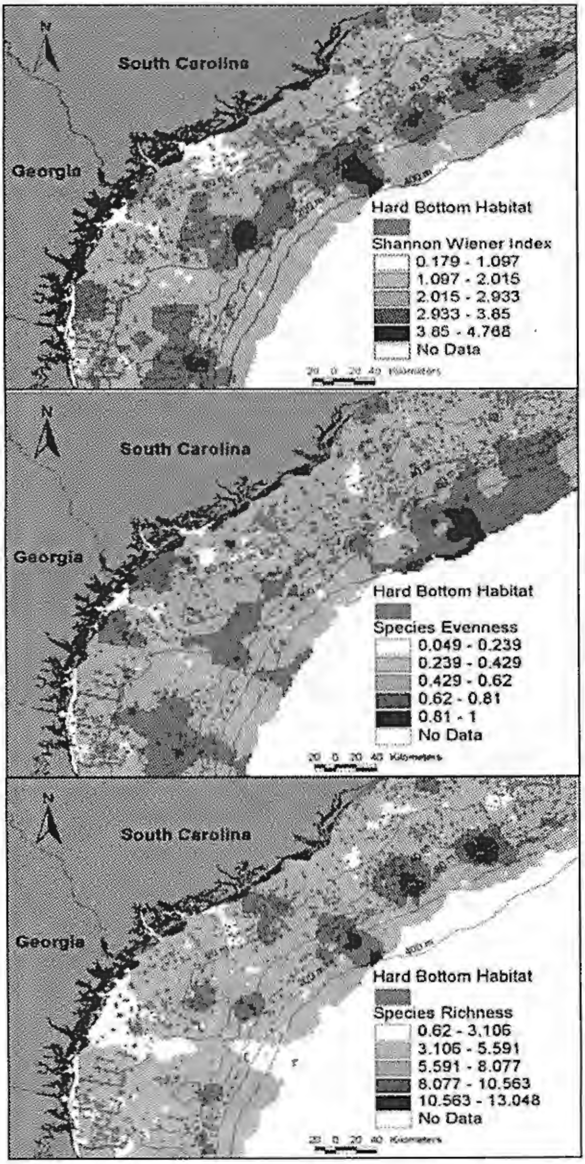


Figure 7. SEAMAP hard bottom grids (one minute *one minute) mapped on the interpolated surface of Shannon Wiener index (H'), species evenness and Margalef's species richness from all trawls (n = 1,020) during the groundfish survey (1973-1980).

DISCUSSION

The highest relative abundance and biomass occurred on the shelf (11 - 140 m) versus off the upper slope (> 140 m). Higher fish abundance and biomass in coastal and mid-shelf depths than in deeper areas probably resulted from factors such as more stable temperatures and the presence of moderate relief hard bottom at these depths (Sedberry and Van Dolah 1984). High abundance and biomass of fishes was also noted on the outer shelf off North Carolina, between Cape Fear and Cape Lookout (Figure 2). The shelf edge between these capes is an area of cross-shelf transport of nutrients upwelled at the shelf edge, and of increased productivity (Lee et al. 1991). The localized, yet persistent, oceanographic phenomena that cause this productivity support very localized high abundance and biomass of fishes. Such systems, in which productive oceanographic conditions coincide with suitable bottom habitat for fishery species (i.e. hard bottom reef), are relatively rare on the southeastern continental shelf, and may warrant special protection as producers and possible exporters of fish biomass in the region.

Although there have been reports of higher estimates of fish biomass from specific hard bottom areas of the South Atlantic Bight compared to nearby sandy bottoms (Wenner 1983), this phenomenon could not be easily examined in the current analysis, since bottom type was not confirmed visually as in Wenner (1983). Nonetheless, the abundance and biomass of fishes collected during the groundfish survey showed positive correlations with the derived bottom-type scores from the SEAMAP-SA (2001) hard bottom mapping project. It is apparent from fishery landings and fishery-independent surveys that hard bottom reefs support the greatest fish biomass and constitute the primary bottom fishery habitats off the southeast coast (Wenner 1983).

A latitudinal variation in the amount of hard bottom could explain the higher abundance in trawl catches off Charleston, SC than farther south, off Georgia and northern Florida. The SEAMAP bottom type analysis is supported by previous geological surveys showing the greatest amount of high relief habitat at the shelf edge off the Carolinas and in a small area off northern Florida (Barans and Henry 1984). The combination of increased hard bottom composition and oceanographic features on the continental shelf off North Carolina and northern South Carolina results in higher fish abundance relative to the shelf off Georgia and northern Florida.

Sedberry and Van Dolah (1984) found diversity (H') values ranging from 0.80 - 3.21 in hard bottom areas of the South Atlantic Bight, while in the current study the H' values from trawl collections pooled by cell ranged from 0.18 - 4.78, with the elevated values similar to those found in some tropical systems (Sedberry et al. 1999). It has been suggested the normal scale for H' results spans from 1.50 - 3.50, and rarely surpasses 4.50 (Magurran 1988). Species evenness (J') estimates in this study were within the range reported previously for the continental shelf of the southeastern U.S. and tropical areas (Sedberry and Van Dolah 1984; Sedberry and Carter 1993). The range of species richness estimates in this analysis, however, far exceeded those reported previously for this region. The occasional high species richness value helps to explain higher than normal H' estimates (Magurran 1988). Species richness values for this study ranged from 0.62 - 13.05, while ranging from either 3.54 - 5.51 on mid-shelf, live bottom reefs of the southeastern shelf (Sedberry and Van Dolah 1984) or 2.5 - 5.5 in Belize (Sedberry and Carter 1993). High species richness estimates resulted from a much broader range of depths, latitude and seasonal temperature variation than that covered in other trawl surveys.

Levels of diversity in this study were significantly higher between the outer shelf (41 - 60 m) and lower shelf (110 - 120 m and 141 - 160 m), as compared to shallower and deeper areas. Small areas of high H' diversity and species richness were positively correlated with hard bottom habitat. These pockets of high diversity were discontinuous, apparently coinciding with rocky outcrops at the shelf edge (Grimes et al. 1982). While discontinuous, these features are connected by the Gulf Stream flow, which may disperse pelagic eggs and larvae of tropical and subtropical fishes and other marine organisms, from one patch of outcrop to the next (Olney and Sedberry 1983). Such influx of larvae from tropical and subtropical locations upstream helps maintain a high diversity in fishes and invertebrates.

While high H' diversity and species richness coincided with shelf edge reefs, species evenness was negatively correlated with the presence of hard bottom. Low evenness appears to be associated with hard bottom on the shelf, which could indicate low evenness with high niche diversity. This low species evenness may be caused by the capture of large schools of pelagic schooling forage fishes, such as round scad. Dominance of the catch by one species makes for low evenness. Schools of scad are more abundant on reefs than on sand (Hales 1987), therefore lowering evenness in reef trawls, as round scad are such a dominant species.

Shelf-edge reefs, along the western edge of the Gulf Stream, were areas of particularly high diversity, connected by persistent warm-water currents. Protecting a series of these shelf edge reefs could help conserve high biodiversity of organisms along the shelf edge and replenish reef areas downstream in the Gulf Stream flow. An MPA network, along the shelf edge, could ultimately protect larval sources (Dayton et al. 2000), nurseries for targeted fish species (Sala et al. 2002), and may ensure the connectivity and persistence of reef fish populations through protection of sources of larvae and their settlement habitats (Palumbi 2001).

A trend towards increasing H' diversity and species richness was apparent with decreasing latitude. Some of the highest fish diversity in the trawl dataset occurred in the waters off northern Florida. These results are similar to previous observations showing higher diversity in the lower latitudes, which are more thermally stable than higher latitudes (Sala et al. 2002).

Spatial analysis of historical fishery survey data elucidated areas where high relative abundance, biomass, and diversity of fishes have occurred based on data collected prior to rapid expansion of the reef fish fishery in the southeastern U.S. in the late 1970s (Huntsman and Manooch 1978). Such historical databases are invaluable in locating areas where high fish production and diversity may have existed prior to heavy fishing pressure. For example, high fish abundance, biomass and diversity existed in mid-shelf (21 - 40 m), shelf edge (55 - 75 m), and upper slope (> 200 m) collections east of Long

Bay, NC (approximately 33°18'N-32°29.4'N). Historically, there have also been high levels of diversity in the shelf edge areas off the entire coast of South Carolina, off the border of Georgia and Florida, and slightly north of Cape Canaveral, FL. Such sites deserve special consideration for protection, as they have unique conditions that support concentrations or diverse assemblages of fishes. Because of recent overfishing of fish stocks off the southeastern U.S. and worldwide, examination of historical databases might be one way to determine areas that possess combinations of oceanographic and habitat conditions that are conducive to high fish abundance, biomass and diversity. Examination of such databases should be an essential part of MPA design and placement.

A chain of MPAs along the shelf edge reef of the southeastern U.S., in addition to protecting diverse fish assemblages, may help in protecting stocks of valuable reef fishes such as gag (*Mycteroperca microlepis*) that spawn at shelf edge reefs (McGovern et al. 1998). Such an MPA network should include all known spawning aggregations of vulnerable reef fishes (Sala et al. 2002). Protection afforded by a reserve network that targets spawning areas of commercial species will also ensure sufficient larval production for diverse assemblages of non-threatened species (Sala et al. 2002). An added benefit of setting aside some shelf edge reefs as MPAs is the protection of deep reef species that do not survive traditional management measures such as minimum sizes and bag limits. Survival of reef fishes released at shelf edge depths is significantly lower than fishes released at shallower depths (Collins et al. 1999).

The results of this GIS analysis were compared to potential MPA sites (no bottom fishing) being considered by the South Atlantic Fishery Management Council (SAFMC) for management and restoration of overfished stocks of hard-bottom reef fishes. The SAFMC criteria for MPA establishment included overfished status and emphasis on deep reef species that have very high release mortality. The SAFMC approach has been toward establishment of no-take MPAs for bottom fish that encompass habitat, but which are directed at specific fishery species. In this sense, the MPA criteria under which the SAFMC is operating are not much different than individual species management plans. A more desirable approach might be to take an ecosystem perspective and protect areas that have high fish abundance and biomass, or which support diverse assemblages of reef fishes.

Spatial analysis of potential MPA sites off South Carolina, Georgia and northern Florida indicate that two of the MPAs under consideration by the SAFMC (North Florida option 1 and South Carolina B option 2) coincide with areas of high fish diversity, however, lower fish abundance (Figure 8). The South Carolina A, option 3 proposed site is the only one that historically has had high H' diversity and fish abundance. Fish abundance is lower at deeper shelf edge reefs than on the continental shelf (Sedberry and Van Dolah 1984), so it is not too surprising that the trawl survey indicates lower fish abundance at shelf-edge reefs. However, the high diversity of these areas indicate this is reef habitat and should support populations of large reef fishes that are not as vulnerable to trawls as are smaller reef fish (Wenner 1983). Such sites contain a high diversity of reef fishes, such as snappers and groupers, that do not survive release under traditional management methods, and these areas are good candidates for no-take protected areas.

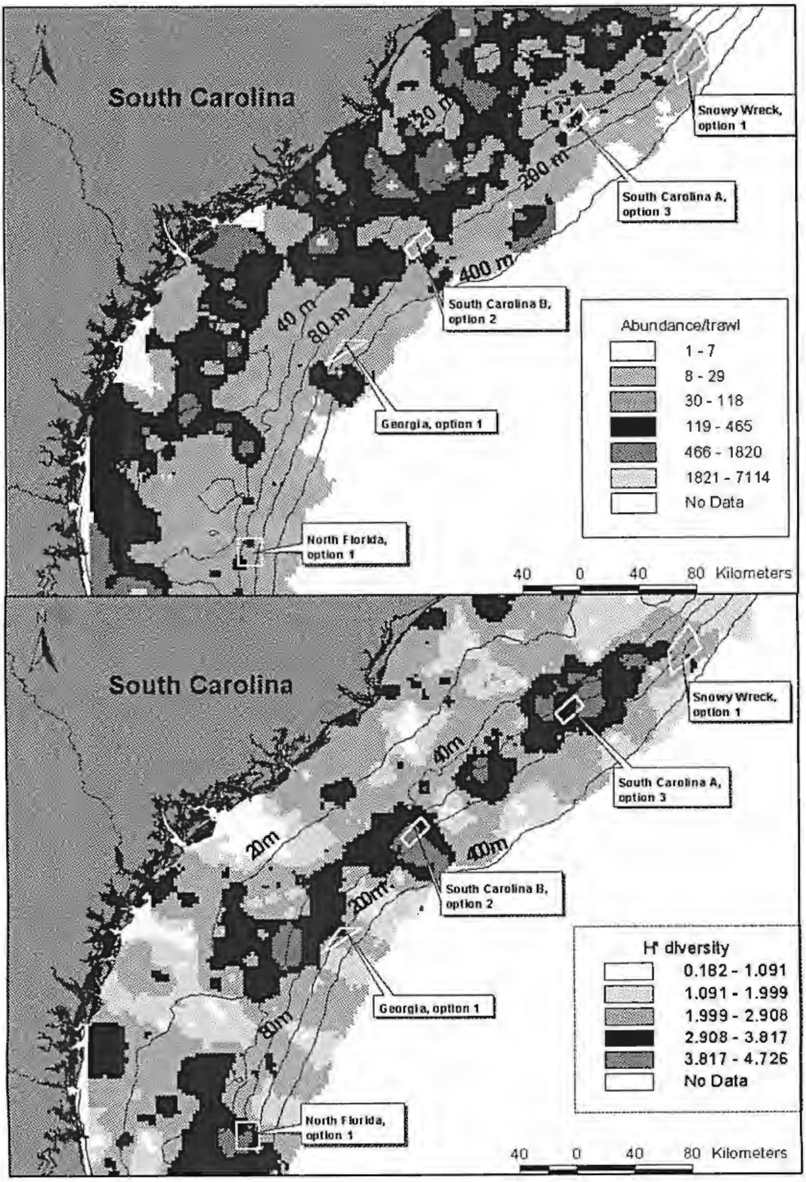


Figure 8. Sites being considered by the SAFMC in January 2002 as MPAs to protect stocks of deepwater reef fishes, in relation to the mean catch per tow from the summer trawls (n = 487) of the groundfish survey (1974 - 1980) and diversity (H') of fishes caught during all trawls (n = 1,020) of the groundfish survey (1973-1980).

Our analyses demonstrated that, although existing databases are useful in evaluating MPA sites selected using other criteria besides evaluation of fishery surveys, the data and analyses can, and should, be used prior to site selection, to look at areas that are particularly productive. At the least, the analysis points out areas of particularly high fish abundance, biomass and diversity that warrant additional research and consideration as MPAs. The method can also point out where additional analyses or surveys are needed to detect locations and habitats important to particular life history stages, such as juvenile nursery habitats and spawning locations for adults. Preliminary work has mapped locations that are important spawning grounds for some species (e.g., Burgos 2001).

More recent community studies of the fish in the South Atlantic Bight are needed in order to determine whether shallow and mid-shelf areas are still areas of high fish abundance after years of overfishing of key predator species, and thus might be candidates for further protection. This could be completed by performing another trawl survey or through non-removal visual census, to compare historic and current conditions. More detailed study in these areas will increase the value of the historical dataset, and provide further valuable insight into the condition of all fish populations in the continental shelf waters of the southeastern United States.

ACKNOWLEDGMENTS

We thank C.A. Barans, L.M. Kracker and C.J. Plante for their review of early drafts of this manuscript. T. Snoots (SCDNR) and L. Balthis (NOAA) provided assistance with data processing. This work was supported by MARMAP Grant 50-WCNF-0-06002 from the National Marine Fisheries Service to the SCDNR (J.C. McGovern and G.R. Sedberry, principal investigators). This is Contribution Number 552 from the South Carolina Marine Resources Center, and Contribution Number 266 of the Grice Marine Laboratory, College of Charleston (South Carolina).

LITERATURE CITED

Able, K.W. 1999. Measures of juvenile fish habitat quality: examples from a national estuarine research reserve. *American Fisheries Society Symposium* 22:134-197.

Auster, P.J., K. Joy, and P.C. Valentine. 2001. Fish species and community distributions as proxies for seafloor habitat distributions: the Stellwagen Bank National Marine Sanctuary example (NW Atlantic, Gulf of Maine). *Environmental Biology of Fishes* 60:331-346.

Barans, C.A., and V.J. Henry, Jr. 1984. A description of the shelf edge groundfish habitat along the southeastern United States. *Northeast Gulf Science* 7:77-96.

Barnard, A.H., P.M. Stegmann, and J.A. Yoder. 1997. Seasonal surface ocean variability in the South Atlantic Bight derived from CZCS and AVHRR imagery. *Continental Shelf Research* 17:1181-1206.

Briggs, J.C. 1974. *Marine Zoogeography.* McGraw-Hill Book Company, New York, New York USA. 475 pp.

Burgos, J.M. 2001. Life history of the red grouper (*Epinephelus morio*) off the North Carolina and South Carolina coast. M.S. Thesis, University of Charleston, Charleston, South Carolina USA.

Coleman, F.C., C.C. Koenig, G.R. Huntsman, J.A. Musick, A.M. Eklund, J.C. McGovern, R.W. Chapman, G.R. Sedberry, and C.B. Grimes. 2000. Long-lived reef fishes: The grouper-snapper complex. *Fisheries* **25**(3):14-21.

Collins, M.R., J.C. McGovern, G.R. Sedberry, H.S. Meister, and R. Pardick. 1999. Removing gas from the distended bladder of reef fish: does it really increase post-release survival? *North American Journal of Fisheries Management* **19**:828-832.

Dayton, P.K., E. Sala, M.J. Tegner, and S. Thrush. 2000. Marine reserves: parks, baselines, and fishery enhancement. *Bulletin of Marine Science* **66**:617-634.

ESRI (Environmental Systems Research Institute, Inc.). 1998. *Getting to Know ArcView GIS.* ESRI, Redlands, California USA.

Govoni, J.J. and J.A. Hare. 2001. The Charleston Gyre as a spawning and larval nursery habitat for fishes. Pages 123-136 in: G.R. Sedberry (ed.). *Island in the stream: oceanography and fisheries of the Charleston Bump. American Fisheries Society Symp*osium **25**, Bethesda, Maryland USA.

Grimes, C.B., C.S. Manooch, and G.R. Huntsman. 1982. Reef and rock outcropping fishes of the outer continental shelf of North Carolina and South Carolina, and ecological notes on the red porgy and vermilion snapper. *Bulletin of Marine Science* **32**:277-289.

Hales, L.S., Jr. 1987. Distribution, abundance, reproduction, food habits, age, and growth of round scad, *Decapterus punctatus*, in the South Atlantic Bight. *Fisheries Bulletin* **85**:251-268.

Huntsman, G.R., and C.S. Manooch III. 1978. Coastal pelagic and reef fishes in the South Atlantic Bight. Pages 97-106 in: H. Clepper (ed.). *Proceedings of the Second Annual Marine Recreational Fisheries Symposium.* Sport Fishing Institute, Washington, D.C. USA.

IUCN (The World Conservation Union). 1988. *Resolution 17.38 of the 17th General Assembly of the IUCN.* Gland, Switzerland and Cambridge, UK.

Jennings, J.A. 2001. Distribution, diversity and habitats of fishes on the continental shelf and upper slope of the southeastern Atlantic coast of the U.S. M.S. Thesis, University of Charleston, Charleston, South Carolina USA.

Lee, T.N., J.A. Yoder, and L.P. Atkinson. 1991. Gulf Stream frontal eddy influence on productivity of the southeast U.S. continental shelf. *Journal of Geophysical Res* **96**:22191-22205.

Magurran, A.E. 1988. *Ecological Diversity and Its Measurement.* Princeton University Press, Princeton, New Jersey USA.

Margalef, D.R. 1958. Information theory in ecology. *General Systems* **3**:36-71.

McGovern, J.C., D.M. Wyanski, O. Pashuk, C.S. Manooch II, and G.R. Sedberry. 1998. Changes in the sex ratio and size at maturity of gag, *Mycteroperca microlepis*, from the Atlantic coast of the southeastern

United States during 1976-1995. *Fisheries Bulletin* **96**:797-807.

Miller, G.C. and W.J. Richards. 1980. Reef fish habitat, faunal assemblages and factors determining distributions in the South Atlantic Bight. *Proceedings of the Gulf and Caribbean Fisheries Institute* **32**:114-130.

Murray, S.N., and 18 co-authors. 1999. No-take reserve networks: sustaining fishery populations and marine ecosystems. *Fisheries* **24**:11-25.

Olney, J.E., and G.R. Sedberry. 1983. Dragonet larvae (Teleostei, Callionymidae) in continental shelf waters off the eastern United States. *Biological Oceanography* 3:103-122.

Palumbi, S.R. 2001. The ecology of marine protected areas. Pages 509-530 in: M.D. Bertness, S.M. Gaines, and M.E. Hixon (eds.). *Marine Community Ecology*. Sinauer Associates, Sunderland, Massachusetts USA .

Parker, R.O., Jr., D.R. Colby, and T.D. Willis. 1983. Estimated amount of reef habitat on U.S. South Atlantic and Gulf of Mexico continental shelf. *Bulletin of Marine Science* **33**:935-940.

PDT (Plan Development Team). 1990. The potential of marine fishery reserves for reef fish management in the U.S. southern Atlantic. *NOAA Tech. Mem. NMFS-SEFC-216*.

Pielou, E.C. 1975. *Ecological Diversity*. John Wiley & Sons, New York, New York USA..

Rubec, P.J., J.C. Bexley, H. Norris, M.S. Coyne, M.E. Monaco, S.G. Smith, and J.S. Ault. 1999. Suitability modeling to delineate habitat essential to sustainable fisheries. Pages 108-133 in: L.R. Benaka, (ed.). *Fish Habitat: Essential Fish Habitat and Rehabilitation. American Fisheries Society Symposim* **22**, Bethesda, Maryland USA.

Sala, E., O. Aburto-Oropeza, G. Paredes, I. Parra, J.C. Barrera, and P.K. Dayton. 2002. A general model for designing networks of marine reserves. *Science* **298**:1991-1993.

SAS Institute Inc. 1997. *Statistical Analysis System*. Cary, North Carolina USA.

Schwartz, F.J. 1989. Zoogeography and ecology of fishes inhabiting North Carolina's marine waters to depths of 600 m. Pages 335-374 in: R.Y. George and A.W. Hulbert (eds.). *Carolina Coastal Oceanography. National Undersea Research Program Research Report* **89**. NOAA NURP, Silver Spring, Maryland USA.

Sedberry, G.R. and J. Carter. 1993. The fish community of a shallow tropical lagoon in Belize, Central America. *Estuaries* **16**:198-215.

Sedberry, G.R., J. Carter, and P.A. Barrick. 1999. A comparison of fish communities between protected and unprotected areas of the Belize reef ecosystem: implications for conservation and management. *Proceedings of the Gulf and Caribbean Fisheries Institute* **45**:95-127.

Sedberry, G.R. and R.F. Van Dolah. 1984. Demersal fish assemblages associated with hard bottom habitat in the South Atlantic Bight of the USA. *Environmental Biology of Fishes* **11**:241-258.

Shannon, C.E. and W. Weaver. 1949. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, Illinois USA.

Sokal, R.R., and F.J. Rohlf. 1995. *Biometry. Third Edition*. W.H. Freeman, San Francisco, California USA.

Southeast Area Monitoring and Assessment Program–South Atlantic (SEAMAP-SA). 2001. Distribution of bottom habitats on the continental shelf from North Carolina through the Florida Keys. *Southeast Area Monitoring and Assessment Program–South Atlantic Bottom Mapping Workgroup*, Atlantic States Marine Fisheries Commission, Washington D.C. USA.

Struhsaker, P. 1969. Demersal fish resources: composition, distribution and commercial potential of the continental shelf stocks off the south-eastern United States. *Fisheries Industry Research* 4:261-300.

Taylor, C.C. 1953. Nature of variability in trawl catches. *Fisheries Bulletin* 54:145-166.

Van Dolah, R.F., P.P. Maier, G.R. Sedberry, C.A. Barans, F.M. Idris, and V.J. Henry. 1994. Distribution of bottom habitats on the continental shelf off South Carolina and Georgia. *Final Report to SEAMAP South Atlantic Committee, NOAA Award NA27FS0050.*

Wenner, C.A. 1983. Species associations and day-night variability of trawl-caught fishes from the inshore sponge-coral habitat, South Atlantic Bight. *Fisheries Bulletin* 81:537-552.

Wenner, C.A., C.A. Barans, B.W. Stender, and F.H. Berry. 1979. Results of MARMAP otter trawl investigations in the South Atlantic Bight I: Fall 1973. *Technical Report No. 33*, South Carlina Marine Resources Center, Charleston, South Carolina USA.

Wenner, E.L., D.M. Knott, R.F. Van Dolah, and V.G. Burrell, Jr. 1983. Invertebrate communities associated with hard bottom habitats in the South Atlantic Bight. *East Coast Shelf Science* 17:143-158.

Utilization of GIS Mapping in the Measurement of the Spatial Distribution of Queen Conch (*Strombus gigas*) in Puerto Rico

ANTHONY R. MARSHAK, RICHARD S. APPELDOORN,
and NILDA JIMENEZ
Department of Marine Sciences
University of Puerto Rico
Mayagüez, Puerto Rico 00681-9013

ABSTRACT

Measurement of the spatial distribution of queen conch (*Strombus gigas*) through fisheries-independent underwater surveys was carried out along the west coast of Puerto Rico during 2001 - 2002. Sixty transects were performed from which densities per depth, age class, and habitat were calculated. Transects from this survey were plotted within a Geographic Information System (GIS) in which areas of habitat surveyed were calculated, and exact conch locations along the west coast were estimated. The highest densities of juveniles (26.101 - 27.391 conch/ha) and adults (9.667 – 10.145 conch/ha) were found within shallow seagrass beds. Densities of older conch, although low in value (0.822 – 0.885 conch/ha), were highest within *Syringodium* habitats. Juveniles were the most frequently encountered conch stage (59.7%; n = 89).

Spatial analyses of this survey data, and of newly plotted data from previously published stock surveys, were performed in order to evaluate the distribution of the Puerto Rican queen conch population at various scales. These analyses revealed that two distinct large groups of individuals surveyed could be identified along the western insular shelf, both of which contained smaller sized juveniles, but varied in depth, habitat, and geographic location. As no significant relation was found between conch size and depth, it is suggested that conch are settling and aggregating into both shallow seagrass and deep algal sand habitats, but higher proportions and densities may be found within shallower seagrasses.

KEY WORDS: Geographic Information System, Puerto Rico, stock abundance surveys, *Strombus gigas*, queen conch

La Utilización de GIS en la Medida de la Distribución Espacial del Caracol de Reina (*Strombus gigas*) en Puerto Rico

La medida espacial de la distribución del caracol de reina (*Strombus gigas*) con censos subacuáticos independientes de la pesquería, fue realizada a lo largo de la costa del oeste de Puerto Rico durante 2001 - 2002. 60 transectos fueron realizados de los cuales las densidades por profundidad, grupo de edad, y habitat eran calculadas. Transectos de este estudio fueron trazados dentro de una Sistema de Información Geográfico (GIS) en el cual las áreas del habitat examinadas eran calculadas, y las localizaciones exactas del caracol a lo largo de la costa del oeste eran estimadas. Las densidades más altas de de los juveniles (26.101 - 27.391 caracol/ha) y adultos (9.667 – 10.145 caracol/ha) fueron encontrados dentro de las yerbas marinas. Las densidades de caracoles viejos, aunque punto bajo en valor (0.822 – 0.885 caracol/ha), eran las más altas dentro de habitats de *Syringodium*. Juveniles era la etapa lo más con frecuencia posible encontrada del (59.7%; n = 89), mientras que encontraron a los adultos y caracoles más viejos en números más pequeños.

Los análisis espaciales de los datos de este estudio, y de datos nuevamente trazados de censos cuales eran previamente publicadas, fueron realizados para evaluar la distribución de la población del caracol de reina de Puerto Rico en las varias escalas. Estos análisis revelaron que dos grupos distintos de individuos examinados podrían ser identificados a lo largo de la plataforma insular occidental, que contuvieron juveniles clasificados más pequeños, pero variado en profundidad, habitat, y la localización geográfica. Pues no se encontró ninguna relación significativa entre el tamaño del caracol y profundidad, se sugiere que el caracol está colocando en las yerbas marinas someras y los habitats profundos de la arena con algas, pero se puede encontrar proporciones y densidades elevadas dentro de las yerbas marinas.

PALABRAS CLAVES: Sistema de Información Geográfico, Puerto Rico, censos de la abundancia, *Strombus gigas*, caracol de reina

INTRODUCTION

The queen conch (*Strombus gigas*) is one of the most important fished species in the Caribbean (Randall 1964, Brownell and Stevely 1981, Appeldoorn 1994), with distribution ranging from Bermuda and southern Florida to the Lesser Antilles and the Caribbean coasts of Central and South America (Warmke and Abbott 1961). Economically, it has been listed as "the second most valuable Caribbean fishery resource after the spiny lobster" (Brownell and Stevely 1981) at an estimated $40 million per year (Appeldoorn 1994). However, due to intense overfishing of this species, Caribbean stocks have shown significant declines over the past 30 years (Hesse 1979, Appeldoorn 1987, Berg and Olsen 1989). Similar trends of overfishing have been documented in Puerto Rico's queen conch populations as well (Appeldoorn 1992).

Historically, Puerto Rico has had a large artisanal fishery for queen conch, with most landings concentrated in the southern and western coasts. Because conchs have been historically depleted from inshore seagrass beds, transition of fishing to deeper habitats has occurred. Deeper water animals collected by using SCUBA gear have comprised the majority of landings (Appeldoorn, 1991). Appeldoorn (1994) reported that total estimated landings of queen conch in Puerto Rico peaked in 1983 at 325 metric tons (mt), but steadily fell to 79 mt by 1990. A recent survey of Puerto Rico's small-scale fisheries has indicated that queen conch landings averaged about 123 mt during 1998 - 2001, and comprised 8% of total reported landings of fish and shellfish during that period (Matos-Caraballo 2004), suggesting small recent recovery of the stock.

While some management initiatives have been applied in Puerto Rico, adequate information on stock status and specific species distribution has not been historically available (Ballantine and Appeldoorn 1983, Mateo-Rabelo 1997). However, increased monitoring of Puerto Rico stocks through fisheries independent stock abundance surveys may aid in better management decisions. Surveys may inform about locations of high concentrations, variations in distribution during life history, population age and size structure, and habitat use by the stock. Pre-stratification of stock abundance surveys by sampling in known areas of historically higher concentrations and landings, may narrow confidence limits of estimated abundance (Mateo-Rabelo 1997).

Two previous surveys of queen conch have been conducted within Puerto Rico. Torres-Rosado (1987) surveyed both queen conch and milk conch (*Strombus costatus*) along the southwestern shelf from 1985 - 1986 to study the distribution and association between the two species using transects. Mateo-Rabelo (1997) surveyed queen conch stocks of both the west and east coasts of Puerto Rico. Sixty-seven stations were sampled along the southwest coast, whereas 29 stations were sampled along the east coast. Based upon historical fishing patterns, sampling sites were stratified along both coasts, and visual surveys in random strip transects were performed using underwater scooters. As Mateo's study provided preliminary information regarding stock abundance per coast and habitat, his methodology was repeated in this survey.

Stock abundance surveys in addition to calculating overall abundance, permit the estimation of average densities per habitat or depth and the mapping of spatial distributions. With modern technological advances of Global Positioning Systems (GPS) and Geographic Information Systems (GIS), it is possible to pinpoint the exact location and aerial coverage of queen conch aggregations and associated habitats. The growing availability of detailed regional spatial benthic habitat information has greatly aided in the stratification of queen conch stock surveys (Delgado et al. 1998), in the identification of potential nursery grounds and Essential Fish Habitat (EFH) (Jones and Stoner 1997, Glazer and Kidney 2004), and has shed light upon large-scale conch spatial distribution patterns and their influences (Stoner et al. 1996, Jones and Stoner 1997).

Through analysis and mapping of stock abundance survey data, this study will attempt to reassess the status and shelf-wide distribution of queen conch along the west coast of Puerto Rico.

METHODS AND MATERIALS

Sixty stations along the west coast of Puerto Rico were surveyed by visual transects of a fixed width of 8 meters, but of varying lengths, during August 2001 to May 2002 (Figure 1). Surveys were performed using underwater scooters for a minimum of 15 minutes per transect. Paired divers were trained in the visual estimation of conch size and stage based upon Appeldoorn's classification (1995). Transect start and endpoints were recorded with GPS. Transects were run at a random fixed compass reading with transect length and duration dependent upon no-decompression time limits per depths not exceeding 33 meters. Time of start, end, change in habitat and depth, and encounter with conch were recorded along with conch stage and shell length to the nearest centimeter.

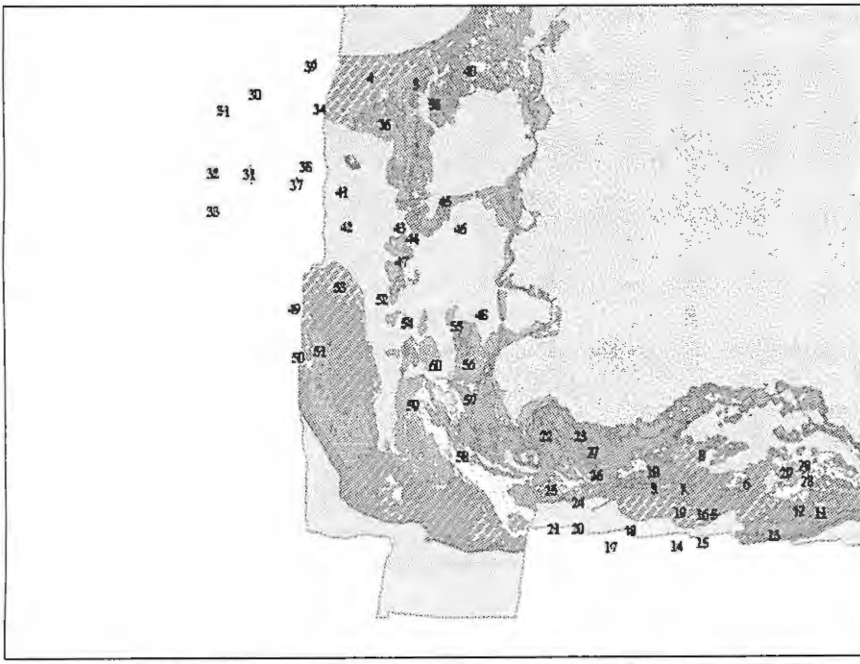


Figure 1. Survey transects along the west coast of Puerto Rico

Using GPS start and endpoints, distances for each transect were calculated with Arc-View GIS software. Transect start and endpoints, in addition to inferred conch location and habitat boundaries, were plotted. Area of coverage per habitat was calculated by multiplying the speed of the entire transect by the time spent over a given habitat, and the transect width. Of the 60 transects, were without a recorded endpoint. Lengths of these transects were estimated using the average speed and 95% confidence interval calculated from the known 52 transects, where average speed was 30.69 +/- 4.08 meters per minute. Transect speeds were calculated by dividing the length of each transect by its time of coverage. Estimated transect lengths were calculated by multiplying the average speed value by the time of each unknown transect.

Densities per transect were calculated as the number of conch observed per transect divided by the area of the entire transect. Total habitat area was found by adding all areas per habitat over all 60 transects. Densities per habitat were calculated as the total conch found within the sum of each habitat component of the 60 transects, divided by the total surveyed area of each habitat. Densities per depth were recorded at 10 foot (3.03 m) intervals as the total number of conch encountered within the total surveyed area comprising the depth range.

Conch and transect locations were overlain upon NOAA-National Ocean Service benthic habitat maps of Puerto Rico (Kendall et al. 2001) as a reference point for shelf locations and for possible correlation with mapped larger scale habitat information. Variables of habitat encountered, depth, size, and stage of each conch were incorporated into the accompanying data plotted in GIS. This enabled the representation of particular depths and habitats per conch location and transect in reference to the west coast of Puerto Rico. Using the Arc-View Spatial Analyst density calculator, overall shelf-wide distribution and large-scale aggregation strategies of conch were determined. Areas which were high in conch density at a 5,000 meter radius were identified. Densities within these areas were calculated as the quotient of all conch and total transect area which intersected with these identified regions. Data collected by Mateo-Rabelo (1997) were also plotted and analyzed in this manner for comparison.

RESULTS

One hundred and forty nine (149) queen conch were reported within 60 transects, consisting of 23.5 +/- 0.4 hectares of surveyed habitat, at an overall density of 6.208 - 6.431 conch/ha for the west coast of Puerto Rico. The most frequently surveyed habitat (Table 1) was sand, consisting of 7.7 +/- 0.05 hectares (31.989 – 32.718% of the total area surveyed). Number of conch observed per transect ranged from 0-40. Density of conch was highest (35.768 – 37.536 conch/ha) in *Thalassia* habitat (Table 2). Overall, seagrass habitats held highest densities. Densities per depth (Table 3) were highest (13.967 – 15.048 conch/ha) at the 9.091 to 12.121 meter range. This was due in part to the dominance of seagrasses and juveniles within the 3.030 –12.121 meter range. Densities in shallower depths were much higher than those found in deeper depths.

Juveniles were the most frequently encountered conch stage (59.7%, n = 89). Ten old conch were encountered, while only two very old conch were discovered, both in the same transect. Juvenile and adult densities were highest within *Thalassia* habitats, while older conch were most dense within *Syringodium* habitats. Juvenile density was highest (8.869 conch/ha) between 12.121 – 15.152 m, while adults were found at highest densities (6.984 – 7.524 conch/ha) within 9.091 – 12.121 m. Older conch were found at highest densities from 9.091-12.121 m, however the largest proportion was found in deeper sand. No significant correlation was found between size and depth (r^2 = 0.0293). Conch within 0 – 13.636 m, the depth range of surveyed seagrass beds, were overwhelmingly found within seagrass beds (91.6%, n = 98). Within deeper waters surveyed (13.636 – 33.333 m), individuals of all stages were most frequently observed in sand habitats, with higher proportions of juveniles (56%, n = 14) in these areas.

Spatial analysis of mapped conch points revealed specific geographic areas along the west coast of Puerto Rico where conch were aggregated in comparatively high densities. When all conch were plotted together (Figure 2), and analyzed at a 5,000 m radius, five distinct groups were identified, with most conch concentrated within west (Groups 2 and 3) and southwest coast seagrass habitats (Group 5). A large aggregation (Group 4, n = 40) of juveniles and some adults, encountered in one transect, was separated from other groups at this scale. Small proportions of individuals along the southwestern coast were found in deeper, sand habitat within Group 5, where juveniles were the most frequently encountered stage (n = 9). A distinctly separate group (Group 1) along the deep northwestern insular platform was identified within more barren terrain, with conch densities highest within hardbottom and algal sand (Table 4). However, proportions of conch were highest within deeper sand habitats (47.1%, n = 8). Nearly equal proportions of adults (52.9%) and juveniles (47.1%) were surveyed within this area.

Table 1. Total area (m^2) surveyed per habitat along the west coast of Puerto Rico from August, 2001 to May, 2002.

Habitat	Area	% Area
Sand	75704.71 - 76679.27	31.99 - 32.72
Coral	29133.15 - 31472.09	12.59 - 13.13
Hardbottom	20968.96 - 21163.87	8.83 - 9.06
Thalassia	19714.27 - 20688.83	8.52 - 8.63
Algae	19417.82	8.10 – 8.39
Sand with Algae	18063.58 - 19038.14	7.81 - 7.94
Sand with Gorgonians	16525.09 - 17824.5	7.14 - 7.43
Sand with *Syringodium*	6363.64	2.65 – 2.75
Sand with *Halophila*	4913.97	2.05 – 2.12
Gorgonians with Hardbottom	4748.85	1.98 – 2.05
Algae with *Halophila* and *Syringodium*	3403.13 - 4442.66	1.47 - 1.85
Syringodium	4265.34	1.78 – 1.84
Hardbottom with Sand	3832.59	1.60 – 1.65
Sand with *Thalassia*	1701.89 - 2221.33	0.74 - 0.93
Gorgonians	1143.62	0.48 – 0.49
Hardbottom with Coral	781.29	0.33 – 0.34
Thalassia with *Syringodium*	370.73	0.15 – 0.16
Sand with Coral	336.27	0.14 – 0.15

When data from Mateo-Rabelo (1997) were plotted and analyzed (Figure 3), five groups were found. The majority of juveniles and adults were located within shallower seagrass beds along the southwest coast (Group 5), while smaller groups along the shallow to moderately deep northern shelf were identified within seagrass beds (Groups 2 and 3). Densities of adults were higher than those of juveniles within the deeper, more barren regions of Group 5 (Table 5). Mateo-Rabelo's survey data also revealed a deep algal sand cluster (Group 1), in which juveniles made up 51.9% of the individuals surveyed. As Mateo-Rabelo's survey was stratified with higher emphasis within reef and hardbottom habitats, its data revealed the presence of a cluster of individuals (Group 4) within moderately deep reef habitats, where adults were found in higher numbers (82.8%, n = 9) and densities than juveniles.

Table 2. Density (conch/ha) of queen conch per habitat along the west coast of Puerto Rico

Habitat	Conch	Juveniles	Adults	Old	Very old
Algae	2.060	0.515	0.515	1.030	0
Algae with *Halophila* and *Syringodium*	20.258 - 26.466	15.756 - 20.569	4.502 - 5.877	0	0
Coral	0.318 - 0.343			0.318 - 0.343	0
Gorgonians	0	0	0	0	0
Gorgonians with Hardbottom	0	0	0	0	0
Hardbottom	4.725 - 4.769	1.890 - 1.908	1.890 - 1.908	0.945 - 0.954	0
Hardbottom with Coral	0	0	0	0	0
Hardbottom with Sand	0	0	0	0	0
Sand	3.912 - 3.963	2.347 - 2.378	1.174 - 1.189	0.391 - 0.396	0
Sand with Algae	3.152 - 3.322		1.576 - 1.661	0.525 - 0.554	1.051 - 1.107
Sand with Coral	0	0	0	0	0
Sand with Gorgonians	0	0	0	0	0
Sand with *Halophila*	0	0	0	0	0
Sand with *Syringodium*	0	0	0	0	0
Sand with *Thalassia*	13.505 - 17.627	4.502 - 5.876	9.004 - 11.752	0	0
Syringodium	25.789	7.033	16.411	2.344	0
Thalassia	35.768 - 37.536	26.101 - 27.391	9.667 - 10.145	0	0
Thalassia with *Syringodium*	26.974	26.974	0	0	0

Table 3. Density (conch/ha) of queen conch per depth stratum (meters) along the west coast of Puerto Rico

Depth (m)	Conch	Juveniles	Adults	Old	Very Old
3.030 to 6.061	5.655 - 6.559	4.241 - 4.919	1.414 - 1.640	0	0
6.061 to 9.091	8.934 - 9.769	6.552 - 7.164	2.382 - 2.605	0	0
9.091 to 12.121	13.967 - 15.048	6.162 - 6.639	6.984 - 7.524	0.822 - 0.885	0
12.121 to 15.152	12.861	8.869	3.326	0.665	0
15.151 to 18.181	0.629 - 0.671	0.629 - 0.671	0	0	0
18.181 to 21.212	2.745 - 2.763	1.497 - 1.507	0.998 - 1.005	0.250 - 0.251	0
21.212 to 24.242	2.925 - 2.996	1.219 - 1.248	0.731 - 0.749	0.487 - 0.499	0.487 - 0.499
24.242 to 27.272	4.541 - 4.715	2.271 - 2.358	1.514 - 1.572	0.757 - 0.786	0

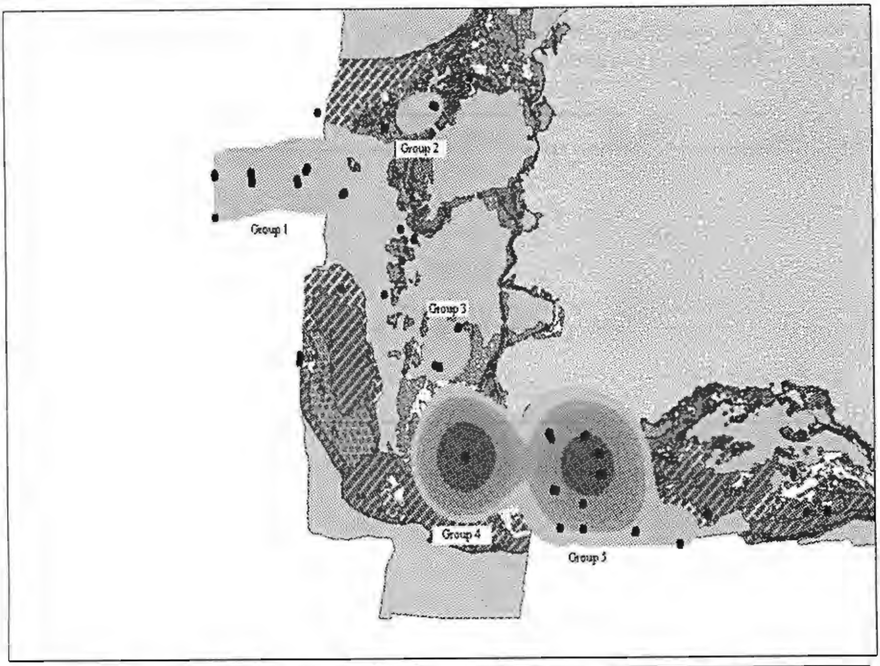


Figure 2. Identified clusters of queen conch along the west coast of Puerto Rico at a 5000 meter radius scale.

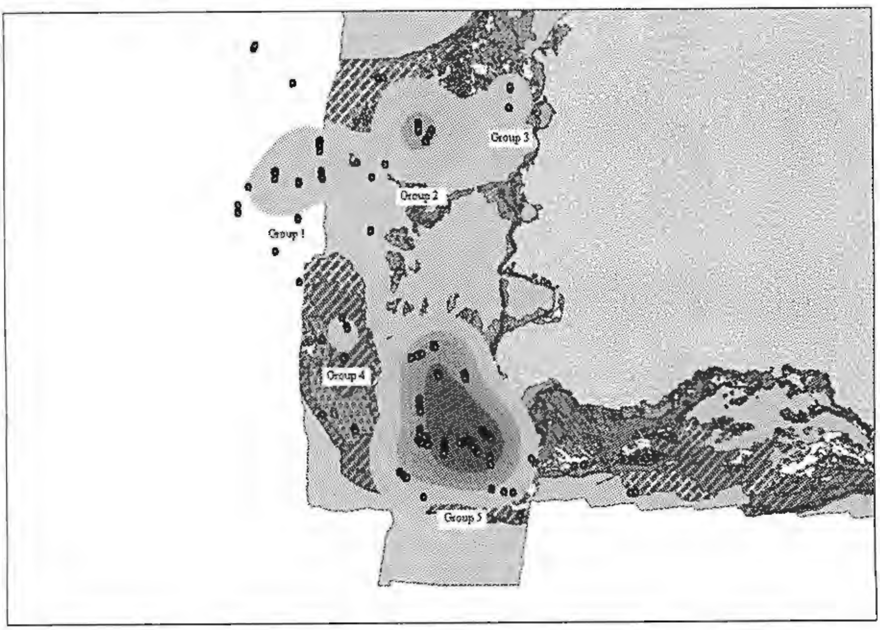


Figure 3. Identified clusters of queen conch along the west coast of Puerto Rico at a 5000 meter radius scale from Mateo, 1998 survey data.

Table 4. Densities of queen conch per identified cluster and its associated surveyed depths and habitats along the west coast of Puerto Rico

Totals

Group	Conch	Juveniles	Adults	Old
1	5.804	2.731	2.39	0.683
2	4.539 - 5.246	2.594 - 2.998	1.945 - 2.248	0
3	14.61	10.435	4.174	0
4	215.482	188.547	26.935	0
5	10.705 - 11.330	6.091 - 6.446	4.245 - 4.493	0.369 - 0.391

Depths

Group	Depth Range	Conch	Juveniles	Adults	Old
1	18.182 - 21.212	6.249	2.5	2.5	1.25
	21.212 - 24.242	6.538	4.67	1.868	0
	24.242 - 27.272	4.725	0.945	2.835	0.945
2	3.030 - 6.060	4.937 - 6.445	2.468 - 3.222	2.468 - 3.222	0
	6.060 - 9.090	14.949 - 19.503	0	14.949 - 19.503	0
	9.090 - 12.121	9.604 - 12.537	7.203 - 9.403	2.401 - 3.134	0
3	9.090 - 12.121	23.684	15.79	7.895	0
	12.121 - 15.151	11.761	8.821	2.94	0
4	12.121 - 15.151	215.482	188.547	26.935	0
5	6.060 - 9.090	15.942 - 16.879	12.526 - 13.262	3.416 - 3.617	0
	9.090 - 12.121	26.619 - 31.787	12.777 - 15.258	13.842 - 16.529	0
	12.121 - 15.151	8.841	1.965	5.894	0.982
	18.182 - 21.212	3.291	3.291	0	0
	24.242 - 27.272	8.397 - 9.509	5.998 - 6.792	1.200 - 1.358	1.200 - 1.358

Table 4. Densities of queen conch per identified cluster and its associated surveyed depths and habitats along the west coast of Puerto Rico (continued).

Habitats

Group	Habitat	Conch	Juveniles	Adults	Old
1	Algae	3.172	1.586	1.586	0
	Hardbottom	10.208	4.083	4.083	2.042
	Sand	4.94	3.087	1.235	0.617
	Sand with Algae	10.574	0	10.574	0
2	Sand with *Thalassia*	13.505 - 17.631	4.502 - 5.877	9.004 - 11.754	0
	Thalassia	9.604 - 12.537	7.203 - 9.403	2.401 - 3.134	0
3	*Thalassia* with *Syringodium*	26.974	26.974	0	0
	Syringodium	26.974	13.487	13.487	0
	Sand	11.761	8.821	2.94	0
4	*Thalassia*	512.371	448.325	64.046	0
5	Algae with *Halophila* with *Syringodium*	20.258 - 26.446	15.756 - 20.569	4.502 - 5.877	0
	Sand	12.484 - 13.586	11.236 - 12.227	0	1.248 - 1.359
	Sand with Algae	2.163	0	2.163	0
	Syringodium	25.54	5.676	17.027	2.838
	Thalassia	30.573	15.813	14.759	0

Table 5. Densities of queen conch per identified cluster and its associated surveyed depths and habitats, from Mateo-Rabelo (1997) data, along the west coast of Puerto Rico.

Totals

Group	Conch	Juveniles	Adults	Old
1	3.846	1.994	0.997	0.855
2	5.884	4.771	0.954	0.159
3	7.169	7.169	0	0
4	3.025	0.550	1.375	1.100
5	11.459	8.533	2.072	0.853

Depths

Group	Depth Range	Conch	Juveniles	Adults	Old
1	18.181 - 21.212	3.959	0	0	3.959
	21.212 - 24.242	4.963	3.436	0.764	0.764
	24.242 - 27.273	3.221	1.171	1.171	0.878
	27.273 - 30.303	18.107	9.054	9.054	0
2	0 - 3.030	18.832	18.832	0	0
	3.030 - 6.060	18.701	14.961	2.992	0.748
	9.090 - 12.121	1.533	0.511	1.022	0
	18.181 - 21.212	2.953	2.953	0.000	0
3	3.030 - 6.060	73.742	73.742	0	0
	6.060 - 9.090	2.838	2.838	0	0
	12.121 - 15.151	14.353	14.353	0	0
4	12.121 - 15.151	4.122	0.515	2.576	1.030
	15.151 - 18.181	1.769	0.590	0	1.180
5	6.060 - 9.090	8.141	8.141	0	0
	9.090 - 12.121	18.670	16.276	2.394	0
	12.121 - 15.151	10.956	8.764	1.517	0.674
	15.151 - 18.181	9.547	3.038	5.641	0.868
	18.181 - 21.212	4.852	1.386	0.693	2.773

Table 5. Densities of queen conch per identified cluster and its associated surveyed depths and habitats, from Mateo-Rabelo (1997) data, along the west coast of Puerto Rico (continued).

Habitats

Group	Habitat	Conch	Juveniles	Adults	Old
1	Algae-*Halimeda*	3.464	2.771	0	0.693
	Algae	3.919	2.613	0.653	0.653
	Halophila	3.959	3.167	0	0.792
	Hardbottom with Sand and Algae	4.931	0	3.698	1.233
	Rubble	5.362	2.681	0	2.681
	Sand	3.749	0.750	2.249	0.750
2	Algae-*Halimeda*	2.870	2.870	0	0
	Algae	2.533	2.533	0	0
	Hardbottom with Gorgonians	0.926	0.309	0.617	0
	Thalassia	16.544	8.272	4.136	4.136
	Thalassia with *Syringodium*	19.758	17.563	2.195	0
3	Mud with *Halophila*	17.520	17.520	0	0
	Sand	11.154	11.154	0	0
	Thalassia with *Syringodium*	106.516	106.516	0	0
4	Coral	0.601	0.601	0	0
	Sand with Coral	5.067	0.507	2.533	2.027
5	Algae	2.800	1.866	0.933	0
	Algae-*Halimeda*	33.204	30.650	2.554	0
	Algae with Sand	14.632	1.126	2.251	11.255
	Halophila	1.791	0	1.791	0
	Hardbottom with Gorgonians	1.172	0.586	0.586	0
	Rubble	14.333	12.900	1.433	0
	Sand	4.332	4.332	0.000	0
	Syringodium	17.340	12.283	4.094	0.963
	Thalassia	50.370	43.024	7.346	0
	Thalassia with *Syringodium*	38.435	32.367	6.069	0

DISCUSSION

Queen conch were found in highest abundance within shallow seagrass beds along the west coast, with major concentrations within the southwestern part of Puerto Rico. When data were assessed without the addition of GIS mapping, it was possible to conclude that conch were mostly restricted to shallow vegetated areas, while others were found in smaller numbers within inshore or deeper algal sand habitats. Findings from other studies lead one to expect that higher concentrations of conch would be found within these key habitats (Stoner and Waite 1990, Frielander et al. 1994, Mateo-Rabelo 1997, Posada et al.. 2000). However, with the addition of GIS mapping, large-scale high-density areas encompassing several habitats and depths throughout the shelf were identified. In Puerto Rico, the identification of large-scale key conch areas through use of fisheries independent surveys is a new approach. If the information gathered on the stock through surveys is to be used to enable proper management of the resource, the addition of descriptive key locations of conch aggregations and size and stage distributions must be considered. Currently, many GIS studies involving queen conch have been assessing their relationship with well mapped habitats, and in areas where key aggregations have been identified and monitored over time (Stoner et al. 1996, Jones and Stoner 1997, Glazer and Kidney 2004). As much habitat still has yet to be mapped and quantified, and key regions and habitats used by commercially important species are still being identified in Puerto Rico, the identification of these large-scale conch areas in this study is noteworthy.

When comparing data from this survey to that of Mateo-Rabelo's survey, it is interesting to note that although a larger area was sampled in his earlier survey, and that more conch were reported, similar key areas were identified at varying densities. This could suggest that the identified clusters are permanent, and that these are true key sites which reflect an accurate clumped distribution of queen conch along the western shelf of Puerto Rico. Studies within the Bahamas have illustrated that "most juveniles are concentrated in large aggregations in relatively few locations" (Stoner and Ray 1993). As juveniles and adults of varying sizes were found scattered throughout the shelf within large clusters which were not stage-specific and at varying depths, one may question whether the vertical stratification by size that has been observed in the Bahamas (Stoner and Ray-Culp 2000) and Venezuela (Weil and Laughlin 1984) is applicable to the Puerto Rico stock along an expansive shelf. While conch are known to migrate into deeper waters with age, and conch of all stages have been observed migrating along the shelf into shallower habitats at key times (Hesse 1979, Stoner et al. 1988, Stoner and Sandt 1992), it is likely that physical factors such as current patterns and the size of the Puerto Rico shelf are contributing to the pattern of intermixed groups of juveniles and adults at varying depths. Both surveys found similar results regarding the distribution of conch stages within groups. However, Mateo's survey revealed the presence of more clustered adults in deeper southwest reef habitat. It is possible that juveniles are settling into deeper algal habitats as well as shallower seagrasses. However, these surveys represent only a snapshot of the resource at a given time.

The question as to whether these findings are the result of overfishing influencing the natural distribution of conch cannot be ignored. Within the Bahamas there is prohibition of harvesting conch with SCUBA gear, which can result in substantial size stratification by depth within that population. As the majority of larger conch are being taken from deeper waters in Puerto Rico, it is possible that nearly equal densities of juveniles in deeper algal sand habitats is a result of this fishing practice. However, it may be possible that older conch are opting to stay with younger conspecifics in shallower protected habitats or within deeper regions similar to those identified along the northwest coast. As fishing is taking place throughout the entire shelf, all regions are still subject to exploitation.

Although collected data informed greatly about the abundances of conch per habitat, depth, and location, it also showed low densities of conch in all areas covered, which suggests that the fishery has not recovered. While the Caribbean Fisheries Management Council (CFMC) enacted management restrictions upon the fishery in 1996, these data suggest the fishery, as of these surveys, was still in poor state. Overall density for the entire shelf was low in comparison to other Caribbean nations (Mateo-Rabelo 1997), and the west coast value reported by Mateo-Rabelo's survey (9.20 conch/ha). Stoner and Ray-Culp (2000) warn of Allee effects in populations at low densities where spawning has been observed to cease at densities lower than 48 conch/ha. Older conch could be within territories of juvenile conch due to the inability to successfully find mates within other regions. While juveniles were found in higher concentrations than adults and older conch, their numbers were still relatively low in both surveys. Given the lower densities and low numbers of older conch encountered, it is likely that the population is still experiencing effects of overfishing. In order to enable more detailed conclusions about the permanency of these identified groupings, the status of the fishery, and the relationships between habitat, depth and conch stage, surveys should be continued and mapped throughout the year.

ACKNOWLEDGEMENTS

This study was performed as a component of the SouthEast Area Monitoring and Assessment Program (SEAMAP). Financial support for this study was provided by the Department of Natural and Environmental Resources (DNER) of Puerto Rico. Comments from Dr. David L. Ballantine greatly improved the manuscript.

LITERATURE CITED

Appeldoorn, R.S. 1987. Practical considerations in the assessment of queen conch fisheries and population dynamics. *Proceedings of the Gulf and Caribbean Fisheries Institute* **38**:314-331.

Appeldoorn, R.S. 1991. History and recent status of the Puerto Rican conch fishery. *Proceedings of the Gulf and Caribbean Fisheries Institute* **40**:267-282.

Appeldoorn, R.S. 1992. Preliminary calculations of sustainable yield for queen conch (*Strombus gigas*) in Puerto Rico and the U.S. Virgin Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* 41:95-105.

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

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.

Ballantine, D.L. and R.S. Appeldoorn. 1983. Queen conch culture and future prospects in Puerto Rico. *Proceedings of the Gulf and Caribbean Fisheries Institute* 35:57-63.

Berg, C.J., Jr. and D.A. Olsen. 1989. Conservation and management of queen conch (*Strombus gigas*) fisheries in the Caribbean. Pages 421-442 in: J.F. Caddy (ed.). *Marine Invertebrate Fisheries: Their Assessment and Management.* John Wiley and Sons, New York, New York USA.

Brownell, W.N. and J.M. Stevely. 1981. The biology, fisheries, and management of the queen conch, *Strombus gigas*. *Marine Fisheries Review* 43 (7):1-12.

Delgado, G.A, Chiappone, M., Geraldes, F.X., Pugibet, E., Sullivan, K.M., Torres, R.E., and M. Vega. 1998. Abundance and size frequency of queen conch in relation to benthic community structure in Parque Nacional del Este, Dominican Republic. *Proceedings of the Gulf and Caribbean Fisheries Institute* 50:1-29.

Frielander, A., Appeldoorn, R.S., and J. Beets. 1994. Spatial and temporal variations in stock abundance of queen conch, *Strombus gigas*, in the US Virgin Islands. Pages 51-60 in: R.S. Appeldoorn and B. Rodriguez (eds.). *Queen Conch Biology, Fisheries and Mariculture.* Fund. Cientif. Los Roques, Caracas, Venezuela.

Glazer, R.A. and J.A. Kidney. 2004. Habitat associations of adult queen conch (*Strombus gigas* L.) in an unfished Florida Keys back-reef: applications to Essential Fish Habitat. *Bulletin of Marine Science* 75(2):205-224.

Hesse, K.O. 1979. Movement and migration of the queen conch, *Strombus gigas*, in the Turks and Caicos Islands. *Bulletin of Marine Science* 29:303-311.

Jones, R.L. and A.W. Stoner. 1997. The integration of GIS and remote sensing in an ecological study of queen conch, *Strombus gigas*, nursery habitats. *Proceedings of the Gulf and Caribbean Fisheries Institute* 49:523-530.

Kendall, M.S., Monaco, M.E., Bjua, K.R., Christensen, J.D., Kruer, C.R., Finkbeiner, M.R, and R.A. Warner. 2001. (On-line). Methods Used to Map the Benthic Habitats of Puerto Rico and the U.S. Virgin Islands URL: http://biogeo.nos.noaa.gov/projects/mapping/caribbean/startup.htm. Also available on U.S. National Oceanic and Atmospheric Administration. National Ocean Service, National Centers for Coastal Ocean Science Biogeography Program. 2001. (CD-ROM). Benthic habitats of Puerto Rico and the U.S. Virgin Islands. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Mateo-Rabelo, 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. Univ. Puerto Rico, Mayaguez, Puerto Rico. 75 pp.

Matos-Caraballo, D. 2004. Overview of Puerto Rico's Small-Scale Fisheries Statistics: 1998-2001. *Proceedings of the Gulf and Caribbean Fisheries Institute* **55**:103-118.

Posada, J.M., Mateo, I.R., and M. Nemeth. 2000. Distribution and abundance of queen conch, *Strombus gigas*, (Gastropoda: Strombidae) on the shallow waters of the Jaragua National Park, Dominican Republic. *Proceedings of the Gulf and Caribbean Fisheries Institute* **51**:1-15.

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

Stoner, A.W., Lipcius, R.N., Marshall, L.S., and A.T. Bardales. 1988. Synchronous emergence and mass migration in juvenile queen conch. *Marine Ecology Progress Series* **49**:51-55.

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 M. Ray. 1993. Aggregation dynamics in juvenile queen conch (*Strombus gigas*): population structure, mortality, growth, and migration. *Marine Biology* **116**:571-582.

Stoner, A.W. and M. Ray-Culp. 2000. Evidence for Allee effects in an over-harvested marine gastropod: density dependent mating and egg production. *Marine Ecology Progress Series* **202**:297-302.

Stoner, A.W. and V.J. Sandt. 1992. Population structure, seasonal movements and feeding of queen conch, *Strombus gigas*, in deep-water habitats of the Bahamas. *Bulletin of Marine Science* **51**(3):287-300.

Stoner, A.W. and J.M. Waite. 1990. Distribution and behavior of queen conch *Strombus gigas* relative to seagrass standing crop. *Fisheries Bulletin* **88**:573-585.

Torres-Rosado, Z.A. 1987. Distribution of two mesogastropods, *Strombus gigas* Linneaus, and the milk conch, *Strombus costatus* Gmelin, in La Parguera, Lajas, Puerto Rico. M.S. Thesis. Univ. Puerto Rico, Mayaguez, Puerto Rico. 37 pp.

Warmke, G.L. and R.T. Abbott. 1961. *Caribbean Seashells*. Livingston Publishing Company, Narbeth, Pennsylvania USA. 348 pp.

Weil M., E., and R. Laughlin G. 1984. Biology, population dynamics, and reproduction of the queen conch, *Strombus gigas* Linne, in the Archipelago de Los Rogues National Park. *Journal of Shellfish Research* **4**:45-62.

BLANK PAGE

The Use of a Coral Reef Conservation Management Value Rating to Aid in the Management of an Artisanal Fishery

RYAN C.J. WALKER, DANIEL J. PONCE-TAYLOR, JAMES COMLEY, and PETER S. RAINES
Coral Cay Conservation
The Tower, 13th Floor, 125 High Street
London SW19 2JG, United Kingdom

ABSTRACT

Selected marine protected areas (MPAs) within coral reef environments have been shown to increase local fisheries yields. The UK based NGO Coral Cay Conservation (CCC), carried out baseline biological surveys across twelve patch reefs within Ascension Bay, UNESCO Sian Ka'an Biosphere Reserve, Yucatan, Mexico. The Bay is managed and exploited by Pescadores de Vigia Chico (PVC), an exemplary managed community-based fishing cooperative, targeting spiny lobsters (*Panulirus argus*). Results from the baseline surveys were analysed using a method developed to assess an area of reef and assigned a simple relative conservation management value rating, designed to be used and interpreted at the community level. Each of the twelve sites was assigned a "high", "medium", or "low" relative conservation management value rating dependent on six variables, such as coral and fish species richness and diversity. Two sites recording "high" were recommended to PVC to be managed as small community managed MPAs, with results and recommendations disseminated through a series of workshops and presentations within the community, and to other stakeholders.

KEY WORDS: Coral reefs, baseline survey, Mexico

Aplicación del Ranking 'Valor de Conservación del Arrecife' para Ayudar en el Manejo de una Pesquería Tradicional, Reserva de la Biosfera UNESCO de Sian Ka'an, México

Determinadas áreas marinas protegidas (AMPs) en medioambientes arrecifales han demostrado un incremento en las capturas de las pesquerías locales. La ONG Británica Coral Cay Conservation (CCC) realizó una serie de estudios biológicos de línea de base en doce arrecifes parcheados de la Bahía de la Ascensión, Reserva de la Biosfera UNESCO de Sian Ka'an, México. La Bahía está manejada y explota por la *Cooperativa de Pescadores de Vigía Chico* (PVC), una cooperativa pesquera local manejada ejemplarmente, y que pesca principalmente langosta espinosa (*Panulirus argus*). Los resultados de los estudios de línea de base fueron analizados utilizando un método desarrollado para valorar áreas del arrecife y asignar un simple valor relativo de conservación, diseñado para ser utilizado e interpretado a nivel local. A cada uno de los doce sitios se le asignó un valor relativo de conservación "alto", "medio" o "bajo", dependiendo de seis variables, como por ejemplo riqueza y diversidad de especies de peces y coral, valores que fueron aplicados a un simple SIG. Dos de los sitios obtuvieron la clasificación de "alto", y fue recomendado a PVC que estos sitios se manejasen como pequeñas AMPs dirigidas administradas localmente. Los resultados y las recomendaciones del estudio fueron diseminadas mediante una serie de talleres y presentaciones para la comunidad y para los administradores del parque.

PALABRAS CLAVES: Valor relativo de conservación, Reserva de la Biosfera UNESCO de Sian Ka'an, Áreas Marinas Protegidas, pesquerías tradicionales de langosta, *Panulirus argus*

INTRODUCTION

Location of most marine reserves has depended more on social criteria and opportunism than on scientific study (Roberts 2000). Establishing permanent "no take" marine reserves where fishing and all other extractive activities are prohibited is an attractive but under-utilised tool for fisheries management (Bohnsack 1998). Ideally, the most biologically diverse and productive habitats within a reef system need to be considered for protection if conservation and fisheries activity are to coexist. Biodiversity levels have been widely used an indicators of conservation value (Margules and Usher 1981, and Magurran 1983). Moreover, biodiversity is known to influence ecosystem functioning for terrestrial systems (Naeem et al. 1994, Tilman et al. 1997, Schmid et al. 2001) and is now similarly under investigation for aquatic systems (Giller, et al. 2004).

The economic valuation of an ecosystem's functions and services is also now well established (de Groot et al. 2002, Faber et al. 2002) and is becoming an increasingly more important tool in the designation of protected areas in the both the terrestrial and marine context. Conservation value is a commonly used term in the field of tropical marine conservation and coastal zone management (Done 1995 and Edinger and Risk 2000). Coral reef conservation value has been related to fisheries potential (Jennings et al. 1995), the biodiversity of corals, invertebrates and reef fish (Edgar et al. 1997), and the habitat available for rare or endangered species. Other conservation related values cited for coral reefs include aesthetic value (Birkeland 1997), naturalness, uniqueness, accessibility, and representativeness (Alder et al. 1994).

A number of studies have used estimates of coral reef conservation value to decide both the areas that require protection and the degree of zoning needed (Done 1995, Edinger and Risk 2000, and Edgar et al. 1997). The latter study emphasised that measures of coral reef conservation should not be taxonomically based at the species level, in this case, hard corals, as many managers do not have much if any expertise in taxonomy. This leads to the suggestion that there is a need for clear and simple tools to define conservation value from the baseline data collected on coral reefs. Edinger and Risk (2000) based their conservation values on coral morphology. In this paper we present a conservation management rating (CMR) that is based on coral reef flora and fauna biodiversity and abundance but is expressed as a simple scale to highlight areas that are recommended for proposition as Marine Protected Areas (MPA's). The CMR is easy to understand and can be combined with GIS data to accurately show the areas earmarked for conservation. A worked example is presented using data collected by Coral Cay Conservation (CCC) volunteers from the Sian Ka'an UNESCO Biosphere Reserve (UNESCO-SKBR).

Site Profile

UNESCO-SKBR lies on the Yucatan Peninsular of southern Mexico within Quintana Roo, located between 19°05'20-20°06'N and 87°30'-87° 58'W. The site was declared a Biosphere Reserve in 1986 and inscribed as a World Heritage Site in 1987 (Salvat et al. 2002). The reserve covers approximately 6,808 km^2 and is Mexico's third largest protected area. Sian Ka'an is described as the largest effective nature reserve in Mexico and protects one of the most pristine expanses of wetland in Mesoamerica (Salvat et al. 2002).

Approximately 1,000 people live in the reserve either in small family ranches along the coast or in the reserve's two fishing settlements, Punta Allen and Punta Herrero. At present the main economic activities is fishing predominantly for lobster (*Panulirus argus*) and occasionally finfish, which is regulated by a local fisheries co-operative, Pescadores de Vigia Chico (PVC). The lucrative lobster fishery within the reserve has so far been extremely successfully managed by the PVC with current regulations maintaining a seemingly sustainable fishery (Alvarez 2003). Jordan-Dahlgren et al. (1994) distinguish two main coral community types within the coastal environment of the reserve: a shallow water community colonizing raised features dominated by scleractinians; and a deeper water community colonizing raised features. It is the shallow water patch reefs of Ascension Bay that are exploited by PVC for *P. argus*. At present the bay is split into 85 "fields" or zones by PVC, each of the 78 fishers within the cooperative are responsible for management of their respective fields, or in some cases fields (Borges Arceo 1999). The fields encompass a mixture of reef habitats including seagrass beds and shallow patch reefs. Concrete lobster aggregating devices (sombras) measuring approximately 1m x 1m are left on areas of flat substrate within each field. Lobsters are harvested from under the aggregating devices using snorkelling gear. A great sense of pride and responsibility is upheld within the cooperative and management techniques are respected by the fishing community (Walker et al 2004, Borges Arceo 1999), with strict minimum size limits on harvested animals, closed seasons and other management techniques strictly adhered to by the fishers.

METHODS

Survey Methods

Surveys were conducted over a three-month period from September to November 2003 using underwater visual census with SCUBA gear, by a team of rigorously trained non specialist volunteers, and two marine biologists (Walker et al. 2004). A total of 12 survey sites were selected within the shallow reefal habitats of Ascension Bay based on discussion with La Comisión Nacional de Áreas Naturales Protegidas, (CONANP) who hold responsibility for the management of the reserve (Figure 1). These sites measured approximately 100 m x 100 m. The local names of the survey sites were maintained to aid with familiarity when the results were presented to the fishing community. Two baseline surveys were conducted using methods adapted from the Meso-American Barrier Reef System Synoptic Monitoring Program (MBRS SMP) (Almada-Villela et al. 2003) and described in detail in Walker et al. (2004). Method 1 adopted a 30 m long point transect technique to measure the percentage cover of substrate at each site. Eight transects were deployed randomly, running perpendicular to the reef slope at each of the 12 sites. The nature of the substrate or organism directly below each transect was recorded every 25 cm using six different classification groups: coralline algae, turf algae, macro algae, sponges and gorgonians to life form level and stony corals to species level. The health of all stony corals was noted. Bleaching and disease were recorded, noting the extent and type of disease using nine categories taken from the Caribbean Coastal Marine Productivity Program (CARICOMP).

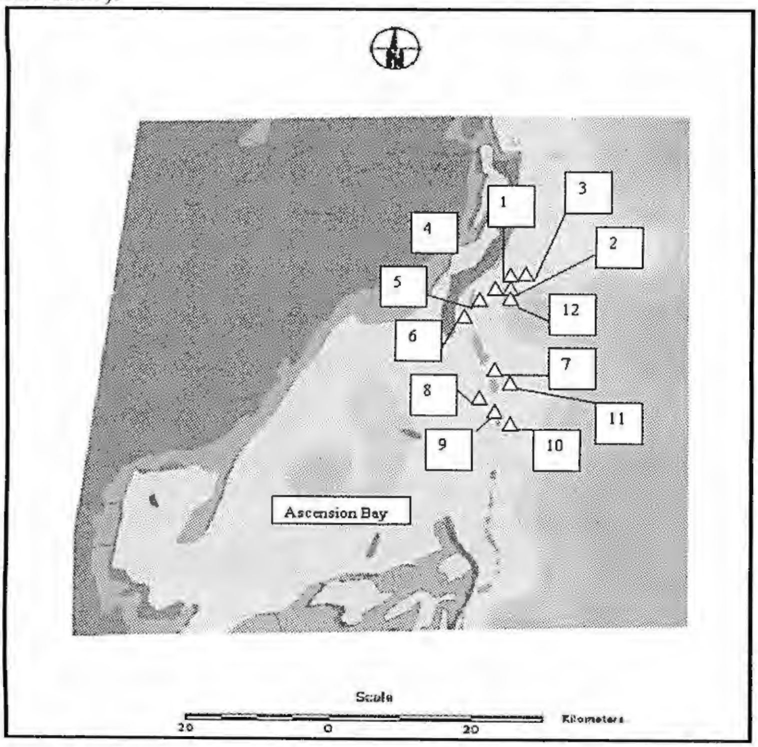


Figure 1. Ascension Bay showing the 12 survy sites: 1= Sol, 2= Chenchomac, 3 = Chenchomac 2, 4= La Colonia, 5= Punta Allen, 6= Mikes Reef, 7= Dani's Buoy, 8= Niccehabim, 9= El Faro, 10= El Barco, 11= Dani's Buoy 2, 12= Mike's Reef 2.

Method 2 consisted of a 30 m belt transect census of commercially important species of reef fish or those considered biological indicator species, as described by Almada-Villela et al. (2003). Six transects were undertaken at each of the 12 sites visually censuring all species within the families Acanthuridae, Chaetodontidae, Haemulidae, Serranidae, Balistidae, and the species *Aluterus scriptus, Catherhines pulles, C. macrocerus, Bodianus rufus, Lachnolaimus maximus, Caranx rubber, Microspathodon chrysurus, Sphyreane barracuda.*

Data Analysis

The establishment of a MPA is based on the need for environmental stability and the socio-economic demands placed upon the local natural resources. Ideally MPA sites should represent the richest and most ecologically important areas present. The definition of a healthy coral reef community is a complex one and one that relies on a number of variables. In this case study, the relative condition and therefore the relative management potential of each surveyed area is defined using a range of univariate indicators (Harding et al. 2003). Each of these indicators was calculated for the 12 survey sites within Ascension Bay. The factors used for each site were:

i) mean percentage hard coral cover,
ii) Marglef species richness and Shannon-Weiner Diversity Index of benthic species or life forms (except algae) associated with the site,
iii) Marglef species richness and Shannon-Weiner Diversity Index of fish associated with the site, and
iv) Mean hard coral cover mortality.

Hard coral cover has been used as a general indicator of reef condition in the Caribbean for a number of years (Gardener et al. 2003) but does have some limitations (Edinger and Risk 2000). The Shannon-Weiner index considers species proportionality and equitability, and is a widely used technique to measure biodiversity. For coral reef studies see Hawkins and Roberts (1997), Reigl and Reigl (1995) and Hawkins et al. (1997). Hard coral mortality due to disease and bleaching can give an indication of stress within a reef environment.

Sites were then assessed in turn to determine how many of the calculated reef health variables were above the survey mean. Each site was then given a rating using the number of univariate reef health indicators for which it scored above average. To facilitate easy interpretation of these values, the following classification scale was used: overall rating > 4 = high management potential, 3-4 = moderate management potential and < 3 = low management potential.

RESULTS

The relative conservation management values of the 12 sites were assessed using the method developed by Harding et al. (2003). Table 1 gives the calculated values for the six univariate 'reef health' indices for the 12 sites as well as the survey means and gives each site a 'score' in terms of the number of occasions a site's biological attributes exceed the survey means (where disease/bleaching values less than the survey mean are scored).

Table 1. Calculated values for six reef health indicators and CMR for the 12 survey sites. Values in bold exceed the survey mean for that variable (except for the case of disease /bleaching where values <average are scored and indicated in bold).

	Live Substrate			Fish			
Site	**% Hard coral cover**	**Disease/ bleaching mean abundance / 100m^2**	**Marglef species richness**	**Log$_e$ Shannon-Weiner index**	**Marglef species richness**	**Log$_e$ Shannon-Weiner index**	**Variables >average**	**Conservation management value**
Sol	**17.51**	0.80	1.60	1.55	2.51	1.66	1	Low
Chenchomac	**26.46**	**0.11**	**3.01**	**2.19**	**3.33**	**2.29**	6	High
Chenchomac 2	8.13	**0.25**	1.28	1.31	2.01	1.72	1	Low
La Colonia	**17.89**	**0.11**	**3.21**	**2.19**	2.31	1.67	4	Medium
Punta Allen	5.05	**0.15**	1.95	1.65	1.99	1.51	1	Low
Mike's Reef	11.42	0.85	**2.43**	**1.96**	**2.74**	**1.98**	4	Medium
Dani's Buoy	5.77	**0.05**	1.65	1.43	1.68	1.40	1	Low
Niccehabim	**12.28**	0.54	2.10	**1.85**	**2.73**	**1.88**	4	Medium
El Faro	10.69	**0.02**	**2.54**	**2.01**	**3.31**	**2.13**	5	High
El Barco	6.18	**0.23**	1.94	1.76	2.35	1.70	1	Low
Dani's Buoy 2	11.98	**0.07**	**3.23**	**2.05**	**2.88**	**2.09**	5	High
Mike's Reef 2	11.74	**0.13**	**2.87**	**2.02**	**2.64**	**1.92**	5	High
Survey Mean	***12.12***	***0.29***	***2.27***	***1.81***	***2.53***	***1.82***		

Using this scoring system, four sites (Chenchomac, El Faro, Dani's Buoy 2 and Mike's Reef 2) had five or six reef indicators greater than the calculated averages across all sites, with Chenchomac having all six indicators greater than the combined averages calculated (Figure 2). Hard coral cover was the highest at Chenchomac at 26.46%. Chenchomac 2, Sol, Punta Allen, Dani's Buoy and El Baco all scored low in this management-rating scheme. These results are represented in a simple colour coded geographical Information System (GIS) (Figure 2).

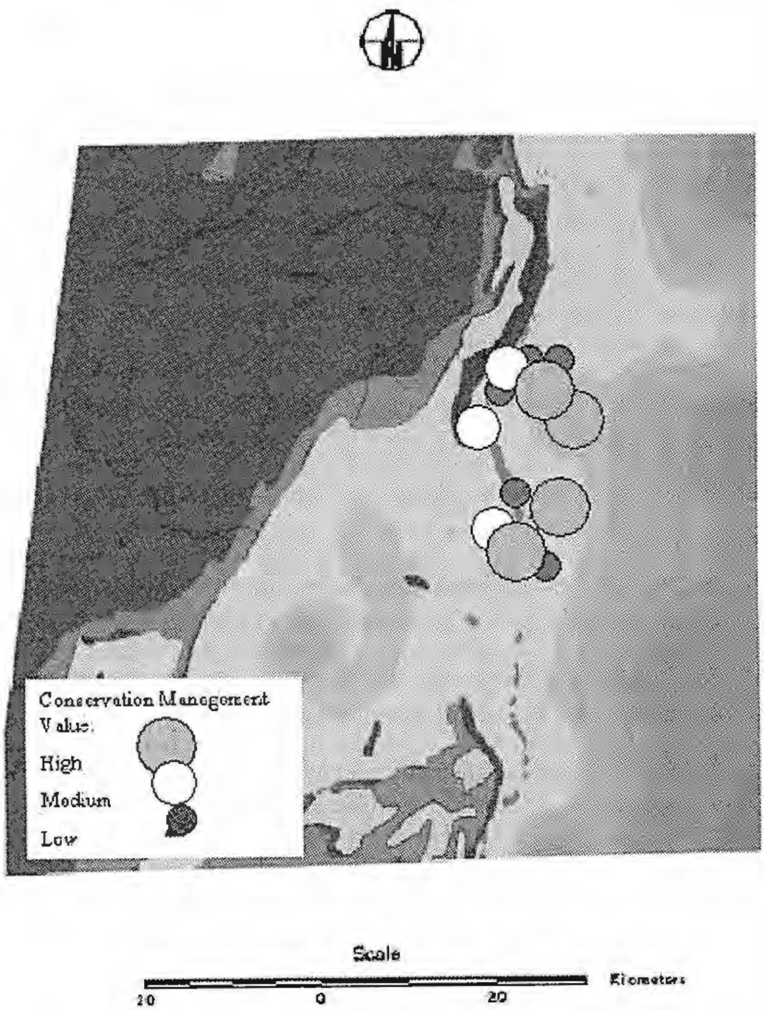


Figure 2. Ascension Bay showing the 12 survey sites with the high, medium or low CMR values assigned.

DISCUSSION

The results of these surveys therefore indicate that four of the 12 sites surveyed within Ascension Bay are of high relative conservation management value, with a further three of medium value and five of low value. The results of the three month survey was formally presented to PVC, CONANP, and other interested stakeholder groups, through a series of presentations, workshops and a report (Walker et al. 2004), all in both English and Spanish. The authors recommended that the sites Chenchomoc and Mikes reef 2 be gazetted as "no take" areas on account of their high CMR. It was suggested to CONANP that the boundaries of the MPAs be marked with buoys. An environmental education program was carried out over three months in conjunction with the survey program within the community of Punta Allen, this program introduced the idea of MPAs and their benefits as a tool for fisheries management. Environmental awareness is generally high within the local fishing community, due to the lucrative nature of the fishery enabling many members of the cooperative to educate them selves to degree level.

Even though the protected area is relatively small (two sites of 10,000 m^2), Roberts and Hawkins (1997) report that for coral reefs almost no MPA is too small to benefit from no-take as a result of research in St Lucia. Marine species have very open populations, with local replenishment often depending on reproduction else where. Consequently, populations in small MPAs cannot be self sustaining. In the case of the reefs of Ascension Bay, low population pressure and sound fishery management suggest the reefs are in reasonably healthy condition by wider Caribbean standards. Mean hard coral cover was recorded at 12.1% across the 12 survey sites, higher than observations for the wider Caribbean, where hard coral cover is reported to have decreased by as much as 80% over the last three decades to just 10% cover (Gardner et al. 2003). Key biological indicator species such as triton (*Charonia variegata*) lobster (*P. argus*), and Chaetodontidae occurred in higher abundances (Walker et al. 2004) than regional means for the wider Caribbean (Hodgson and Liebeler 2002). The two small community based MPAs suggested by the authors have a very good chance of success due to the responsible nature of the local resource users, and the generally healthy reefs within Sian Ka'an.

The strengths of the CMR for MPA selection are that the data can be represented in its simplest form as in the case of Figure 2, and interpreted by decision makers more readily than complicated habitat maps for example. The GIS can also be interpreted very easily at the community level, with fishers and local resource users being able to easily interpret the data, thus play a key role in local costal zone management decision making. The very people all too often disenfranchised in such processes (Roberts 2000).

One noticeable draw back of the CMR technique is that the method does not take into consideration the conservation importance of seagrass environments that are generally of low biodiversity compared to reefs but play and important role in fisheries recruitment as breeding and nursery grounds for many reef associated species. Additionally, the CMR data presented graphically here were single points on a geo-referenced image (Figure 2). Further use of remote sensing tools have enabled the production of thematic CMR

Roberts, C.M. 2000. Selecting marine reserves locations: optimality versus opportunism. *Bulletin of Marine Science* 66(3):581-592.

Salvat, B., J. Haapylä, and M. Schrimm. 2002. *Coral reef protected areas in international instruments*. World Heritage Convention, World Network of Biosphere reserves, Ramsar Convention, CRIOBE-EPHE, Moorea, Polynésie Française.

Schmid B., J. Joshi, and F. Schlapfer. 2001. Empirical evidence for biodiversity-ecosystem functioning relationships. Pages 120-150 in: A.P. Kinzig, S.W. Pacala, and D. Tilman (eds.). *The Functional Consequences of Biodiversity*. Princeton University Press, Princeton, New Jersey USA.

Tilman D, J.M.H. Knops, and D. Wedin. 1997. The influence of functional diversity and composition on ecosystem processes. *Science* 277:1300-1302.

Walker, R.C.J., J. Taylor, H. Waska, D Ponce-Taylor, B. Vause, J. Comley, and P. Raines. [2004]. *The Sian Ka'an Coral Reef Conservation Project: Final Report – Mexico 2003*. Report submitted to La Comisión Nacional de Áreas Naturales Protegidas. 94 pp.

BLANK PAGE

Relating Changes in Freshwater Inflow to Species Distributions in Rookery Bay, Florida, via Habitat Suitability Modeling and Mapping

PETER J. RUBEC[1], JESSE M. LEWIS[1], MICHAEL A. SHIRLEY[2], PATRICK O'DONNELL[2], and STANLEY D. LOCKER[3]

[1]*Florida Fish and Wildlife Conservation Commission*
Fish and Wildlife Research Institute
100 Eighth Ave. S.E.
St. Petersburg, Florida 33701 USA

[2]*Florida Department of Environmental Protection*
Rookery Bay National Estuarine Research Reserve
300 Tower Road
Naples, Florida 34113 USA

[3]*College Of Marine Science, University of South Florida*
140 7th Ave. S.
St. Petersburg, Florida 33701 USA

ABSTRACT

We conducted this study to assess the influence of changes in freshwater inflow on the distribution and relative abundance of estuarine species in Rookery Bay, Florida. Originally, freshwater entered the bay via sheet-flow. In the 1960s, the creation of a canal system, which funnels water through a weir situated on Henderson Creek, altered inflows. To assess the effect of these changes, we initiated monitoring in Rookery Bay and Fakahatchee Bay. The latter estuary served as a control, because it still has natural sheet-flow.

Bottom types and bathymetry in Rookery Bay were mapped using side-scan and QTC View sonar systems. Bottom types were verified via analyses of bottom-grab and core samples. Salinity, temperature, and dissolved oxygen data collected seasonally in the two estuaries were interpolated to map water-column habitats.

When this study was initiated, no long-term fisheries-independent monitoring (FIM) had been conducted in Rookery Bay. Consequently, we analyzed FIM data collected in Charlotte Harbor to determine habitat affinities for 22 life stages of 11 species of fish and macroinvertebrates. Suitability functions were derived by fitting splines to catch rates (CPUEs) across environmental gradients and by calculating mean CPUEs within bottom-type categories. Abundance indices transferred from Charlotte Harbor were applied to Rookery Bay habitat layers so that we could conduct raster-based habitat suitability modeling (HSM) for a dry season (spring) and a wet season (summer) in Rookery Bay with differing freshwater inflows. Predicted HSM maps depict suitability zones (low to optimum) across the estuary. The models were validated by calculating mean observed CPUEs (from monthly trawl sampling) within the predicted zones. Increasing mean observed CPUEs across the zones indicated that the models adequately predicted the spatial distributions of the species' life stages.

KEY WORDS: Fish habitat, GIS modeling, mapping, Rookery Bay

Modela y Traza la Relaciona de los Cambios an la Afluencia de Agua Dulce a Distribuciones de Especias en Rookery Bay, Florida

La Oportunidad del habitat que Modela y Traza la Relaciona de los Cambios En la Afluencia de Agua Dulce A Distribuciones de Especias en Rookery Bay, Florida. Realizamos este estudio para valorar la influencia de cambios en la afluencia de agua dulce en distribuciones y abundancia relativa de especias estuarinas en la Bahía de Rookery, Florida. Originalmente, agua dulce entró la bahía vía el sheet-flow. En la década de los 60, la creación de un sistema de canales, que encauza riega por un vertedero situado en Henderson Creek, y altero afluencias. Para valorar el impacto de estos cambios, nosotros iniciamos un muestreo en Rookery y Fakahatchee Bay, Florida. Fakahatchee Bay sirvió como un control, porque todavía tiene el sheet-flow natural.

Tipos de fondo y bathymetry en Rookery Bay fueron trazado utilizando side-scan y QTC View sistemas de sonar. Tipos de fondo fueron verificados por análisis de muestras inferioras de agarro y centro. Datos de salinidad, temperatura, y niveles disueltos de oxígeno se collecionaron durante differentes temporadas en los dos esteros y fueron interpolados para trazar los habitates de las columnas de agua.

Porque no hay muestro consistente de pescados en Rookery Bay a largo plazo, nosotros analizamos los datos de pescados colleccionados en Charlotte Harbor para determinar las afinidades del habitat para 22 etapas de vida de 11 especies de pescado y macro-invertibrados. Las funciones de la oportunidad fueron derivadas por tiras para agarrar los datos de la tasa (CPUE) a través de declives ambientales, y calculando las unidades de procesamiento centrales malas dentro de categorías de tipo fondo. Los índices de la abundancia transferidos de Charlotte Harbor fueron aplicados a capas de habitat de Rookery Bay para realizar la oportunidad trama-basado del habitat modelando (HSM) durante una temporada (primavera) seca y una temporada (verano) mojada en Rookery Bay. Los mapas predichos de HSM representan la oportunidad las zonas (bajo a óptimo) a través del estero. Los modelos fueron verificados calculando medio las unidades de procesamiento centrales observadas (de rastreo mensual que prueba) dentro de las zonas predichas. Creciente significa observó que las unidades de procesamiento centrales a través de las zonas indicaron los modelos predijeron correctamente las distribuciones espaciales de la especie' las etapas de la vida.

PALABRAS CLAVES: Habitat modelando, distribuciones espaciales, mapas predichos Rookery Bay

INTRODUCTION

Watersheds in South Florida have been extensively altered by the canalization of streams and by water diversions through canals. The effects of these changes on aquatic communities are not well understood (Sklar and Browder 1998). A number of studies in Florida clearly demonstrate the need to manage freshwater inflow into estuaries in order to protect marine resources (Browder and Moore 1981, Browder 1985 1991, Livingston et al. 1997 2000, Browder et al. 2002).

Starting in the 1920s, the Big Cypress Swamp near Naples was altered with the creation of U.S. Highway 41 (Gardner 1988). The creation of the Southern Golden Gate Estates Canal system and the Faka Union-Remuda Ranch Canal system, to drain agricultural and residential areas during the 1960s, and the construction of major highways have altered the quantity, quality, and timing of freshwater entering the Rookery Bay system and other estuaries in the Ten Thousand Islands region. The canal systems, combined with deforestation and increasing urbanization, have reduced the amount of upland swamps, lowered the water table, and reduced regional rainfall, which in turn affected freshwater inflows to the estuaries (Carter et al. 1973, Browder and Moore 1981, Colby et al. 1985). Consequently, the Big Cypress Basin Board of the South Florida Water Management District (SFWMD) funded the present study to provide information to help manage freshwater inflows into Rookery Bay in order to protect the integrity of estuarine habitats and to conserve estuarine fish and macro-invertebrate species present in the estuary.

The Florida Fish and Wildlife Conservation Commission's (FWC) Fish and Wildlife Research Institute (FWRI) has developed habitat suitability models (HSM) using geographic information systems (GIS) to predict spatial distributions and relative abundance of estuarine species (Rubec et al. 1998, 1999, 2001, 2003a,b). One of the main strengths of using GIS is its ability to integrate data from a wide variety of sources. By transferring abundance relationships from estuaries with fisheries-independent monitoring (FIM) programs, the HSM can allow the prediction of species distributions in estuaries that lack long-term FIM programs.

The FWRI, Florida Department of Environmental Protection (FDEP) and the University of South Florida (USF) College of Marine Science collaborated to map habitats and model species distributions in relation to changes in environmental conditions in the Rookery Bay system. Data were collected across Rookery Bay and Fakahatchee Bay (control estuary). The environmental data points were interpolated to create habitat layers for use with the HSM model. Habitat affinities for key species were derived from FIM data previously gathered by FWRI in Charlotte Harbor. The predicted HSM maps determined changes in habitat suitability associated with salinity patterns related to different freshwater inflows. The study was conducted to provide water managers with information to help manage water flow through the weir situated at the head of Henderson Creek, which regulates inflow from the Henderson Creek canal to the Rookery Bay system. It demonstrates the use of HSM to assess the effects of changes in freshwater inflow on estuarine species.

METHODS

Study Area

The Rookery Bay National Estuarine Research Reserve (RBNERR), situated south of Naples, encompasses an area of 445 km^2. It includes the Rookery Bay system (424.4 hectares) and estuaries in the Ten Thousand Islands. Rookery Bay is surrounded by mangroves and has islands with bird rookeries, sand and mud substrates, oyster beds, and some areas with submerged aquatic vegetation (SAV). Most of Rookery Bay is quite shallow (< 2 m). The bay's high turbidity prevented us from using aerial photography to map SAV distributions in Rookery Bay.

Gear Standardization

One of the main goals of the present study was to map geographic distributions of marine fish and macro-invertebrate species by young-of-year (YOY), juvenile (Juv), and adult life stages during spring and summer seasons in Rookery Bay. The HSM requires as input indices of relative abundance across environmental gradients for each species' life stage. Ideally, these indices would be obtained from FIM in Rookery Bay. Although trawl sampling (4 - 5 samples per month) has been conducted since 2000, there was insufficient long-term FIM sampling in the bay. Consequently, we used the larger FIM datasets (600 to 1500 samples per season) obtained in Charlotte Harbor from 1989 to 1997 to create suitability functions (Rubec et al. 2003b).

To use all survey data in a comprehensive analysis, sample CPUEs were standardized across gear types to create gear-correction factors by species' life stages by using a modification of Robson's (1966) "fishing power" estimation method (Ault and Smith 2000). Gear-corrected CPUE data sets for Charlotte Harbor were created for the following species life stages: YOY (10 - 119 mm standard length-SL), Juv (120 - 199 mm SL), and adult (^{3} 200 mm SL) spotted seatrout (*Cynoscion nebulosus*); Juv (10 - 99 mm SL) and adult (^{3} 100 mm SL) pinfish (*Lagodon rhomboides*); Juv (15 - 29 mm SL) and adult (^{3} 30 mm SL) bay anchovy (*Anchoa mitchilli*); YOY (10 - 139 mm SL) Juv (140-239 mm SL) and adult (^{3} 240 mm SL) sheepshead (*Archosargus probatocephalus*); *duorarum*); and Juv (10 - 299 mm SL) red drum (*Sciaenops ocellatus*).adult (^{3} 110 mm SL) hardhead catfish (*Arius felis*); Juv (150 - 279 mm SL) and adult (^{3} 280 mm SL) common snook (*Centropomis undecimalis*); Juv (10-149 mm SL) and adult (^{3} 150 mm SL) sand seatrout (*Cynoscion arenarius*); YOY (10 - 149 mm SL) and Juv (150 - 199 mm SL) spot (*Leiostomus xanthurus*);
YOY (10 - 119 mm SL) and adult (^{3} 180 mm SL) southern kingfish (*Menticirrhus americanus*); Juv (5 - 17 mm carapace length-CL) and adult (^{3}18 mm CL) pink shrimp (*Farfantepenaeus*

Suitability Functions

Habitat affinities for 11 species of fish and macroinvertebrates were determined from 8.5 years of FIM data gathered in Charlotte Harbor from 1989 to mid-1997. The analyses involved development of suitability functions by fitting splines across environmental gradients to mean gear-corrected catch rates (CPUEs) for each species' life stage (Rubec et al. 2003b). First, mean CPUEs were computed within each season for each environmental variable. Then, splines (variable lambda) were fitted to mean CPUEs across gradients of salinity, temperature, dissolved oxygen, and depth using JMP software (SAS 2002). Mean CPUEs were computed by 1 g/L (‰) salinity, 1°C temperature, 1-mg/L dissolved oxygen (DO), and 1 meter depth intervals. Seasonal-mean CPUEs were also computed by Sand, Mud, and SAV bottom-type classes. The mean CPUE values across each gradient were placed in look-up tables within a GIS to facilitate HSM analyses. We then transferred the suitability functions derived from Charlotte Harbor monitoring to Rookery Bay.

Habitat Mapping

The mapping of water-column and benthic habitats in Rookery Bay, required data collection, data integration, and the use of GIS-based software to interpolate raw data points. Bottom type and bathymetry were determined from data gathered by USF using sidescan and Quester Tangent QTC View sonar systems (Locker and Wright 2003). Salinity, temperature, and dissolved oxygen data were gathered seasonally in the two estuaries using a Hydrolab MiniSonde Model 4a data logger.

A skiff with the data logger mounted to the boat's gunnel, a differential global positioning system (DGPS), and a Furuno LS-6000 depth sounder linked to a Furuno 520ST–PWD transducer were wired to a rugged Argonaut laptop computer to gather environmental data. The data were merged on the computer using software developed for the project (Rubec et al. 2003b).

The boat cris-crossed Rookery and Fakahatchee bays during separate days to gather data believed to be representative of five seasonal time periods (June to August 2002, September to November 2002, December 2002 to February 2003, March to May 2003, and June to August 2003). The data logger was used to collect salinity, temperature, and dissolved oxygen data in Rookery Bay on August 22, 2002; October 30, 2002; February 20, 2003; May 2, 2003; and July 10, 2003. Data were collected in Fakahatchee Bay on August 23, 2003; October 31, 2003; February 21, 2003; May 1, 2003; and July 11, 2003.

The GeoStatistical Analyst module associated with ArcGIS 8.3 was used to interpolate the environmental data points in an iterative manner using simple punctual kriging (Johnston et al. 2001). Semivariograms were used to choose the most optimal interpolation for each environmental variable. Raster-based grids were created representing seasonal habitat layers for salinity, temperature, and dissolved oxygen in the two estuaries, as well as grids for bathymetry (depth) and bottom type in Rookery Bay derived from data gathered by USF.

Habitat Suitability Modeling

We used the Spatial Analyst extension in ArcMap associated with ArcGIS 8.3 to relate abundance indices from Charlotte Harbor, for the spring (March-May) and summer (June - August) seasons, with the habitat layers in Rookery Bay to conduct HSM analyses for Rookery Bay. The HSM analyses were conducted to spatially compare the effects of several inflow conditions on species' life stages at two time periods during the summer and at one period during the spring.

The geometric mean algorithm was used to compute composite suitability values in order to create predicted seasonal HSM maps for Rookery Bay. Composite HSM values within each 18.5 m^2 cell were computed as the geometric mean of the suitability values associated with the habitat layers for *n* environmental factors. Predicted HSM values were derived from abundance indices associated with five habitat layers, as follows:

$$HSM = (\Pi \, CPUE_i)^{1/n} \quad .$$

Separate HSM analyses were conducted for each time period to model species distributions by each species' life stage in Rookery Bay. The CPUEs in predicted HSM grids were scaled from 0 to 10. The predicted HSM grids were classified into equal CPUE ranges to create four suitability zones (Low, Moderate, High, and Optimum). This allowed us to compare the effects of changes in freshwater inflow into Rookery Bay. Percent changes in total area of Rookery Bay for the four HSM zones were used to determine whether the changes in salinity were beneficial or not for various estuarine species' life stages.

Three tables were associated with each HSM map depicted on the CD-ROM (Rubec et al. 2003b). The first table presented the observed densities (no./m^2) within predicted HSM zones and minimum and maximum CPUEs and the standard deviation for each zone. Provided there were observed data in the first table, a histogram was created as part of the validation analysis. The second table presented predicted densities (no./m^2) for the four HSM zones. The third table presented the areas, expressed in hectares, for each of the predicted HSM zones and percentages of the total area for each of the suitability zones in the estuary. Hence, the predicted suitability zones were summarized both in terms of their area and by the proportion of the total area each zone occupied in the Rookery Bay system.

The HSM analyses were conducted for two time periods with different inflow conditions (August 2002, July 2003) during the summer season. Changes in percentages of the total area with High plus Optimal suitability in the estuary were computed to determine whether changes in salinity distributions, associated with changes in freshwater inflow, were "suitable" for various life stages of estuarine species.

Model Validation

The models presented are heuristic and qualitative in nature, thereby precluding any formal statistical testing of model efficacy (Rubec et al. 2001). A simple test was developed to assess the adequacy of the HSM analyses (Rubec et al. 2001, 2003a,b). If histograms of mean CPUE values that fall within the predicted zones increased from "Low" to "Optimum", then model performance was judged to be adequate.

CPUE data obtained by RBNERR staff from trawling on a monthly basis in Rookery Bay (from 2000 to 2003) were used to validate the predicted HSM maps (Rubec et al 2003b). The observed CPUE data (74 samples for spring and 65 samples for summer) were overlaid onto the predicted seasonal HSM maps. Then, mean CPUEs were calculated within the low to optimum suitability zones. Increasing mean observed CPUEs across the HSM zones indicate whether the models adequately predicted habitat suitability for each species' life stage.

RESULTS AND DISCUSSION

Habitat Mapping

The full results of the study are presented on a CD-ROM that accompanied a report to the SFWMD (Rubec et al. 2003b). There were 24 seasonal habitat maps created for salinity, temperature, and dissolved oxygen for Rookery Bay and Fakahatchee Bay, and one map each for bottom type and bathymetry in Rookery Bay.

Water Quality

In the bays proper (excluding tributaries), the ranges in water temperatures between the two estuaries were similar during the spring (26 - 28 °C) and during the summer (29 - 32°C). Dissolved oxygen values ranged from 4 to 8 mg/L in Rookery Bay and 4 to 6 mg/L in Fakahatchee Bay during May 2003, 4 to 7 mg/L in Rookery Bay and 3 to 6 mg/L in Fakahatchee Bay during August 2002, and 1 to 6 mg/L in Rookery Bay and 2 to 5 mg/L in Fakahatchee Bay during July 2003. Low DO values (1 to 2 mg/L) extended out from the Fakahatchee River into the eastern part of Fakahatchee Bay during August 2002. Salinities were similar (30 - 33 g/L) in both estuaries during May 2003 (the dry season). Marked differences in salinity were found between Fakahatchee Bay (8 - 16 g/L) and Rookery Bay (30 - 31 g/L) during August 2002. Inflow data obtained from SFWMD indicates that the higher salinities in Rookery Bay during August 2002 were related to the fact that the weir situated at the head of Henderson Creek kept freshwater from entering Rookery Bay. There was heavy rainfall at the end of June, which lowered salinities in both estuaries during July 2003. Salinities ranged from 26 to 29 g/L in Rookery Bay and 16 to 19 g/L in Fakahatchee Bay during July 2003.

Affinities for Salinity

The ranges of salinities within which various species' life stages had the highest affinity (top 25% of each suitability function) in Charlotte Harbor during the spring are depicted in Figure 1. The following species' life stages had affinities for low salinity (< 10 g/L): YOY spot, Juv sheepshead, Juv sand seatrout, Juv red drum, Juv spotted seatrout, and Juv bay anchovy. Some species' life stages were found to have an affinity for moderate salinities (≥ 10 and < 25 g/L): YOY and adult kingfish, YOY spotted seatrout, and adult bay anchovy. Other species had an affinity for high salinities (≥ 25 g/L): Juv spot, YOY and adult sheepshead, Juv spotted seatrout, Juv and adult pink shrimp, adult hardhead catfish, Juv and adult snook, YOY and adult spotted seatrout, and Juv and adult pinfish. The predominate salinity range (30 - 33 g/L) in Rookery Bay proper and the available salinity range (18 - 33 g/L) in the Rookery Bay system (including both the bay and Henderson Creek) were unsuitable for the species with affinities for low salinity. Those species with moderate salinity affinity were restricted to a relatively small area in Henderson Creek. Only species whose life stages had affinities for higher salinities had ranges that overlapped with the predominate salinity range (30 - 33 g/L) available in Rookery Bay during the spring.

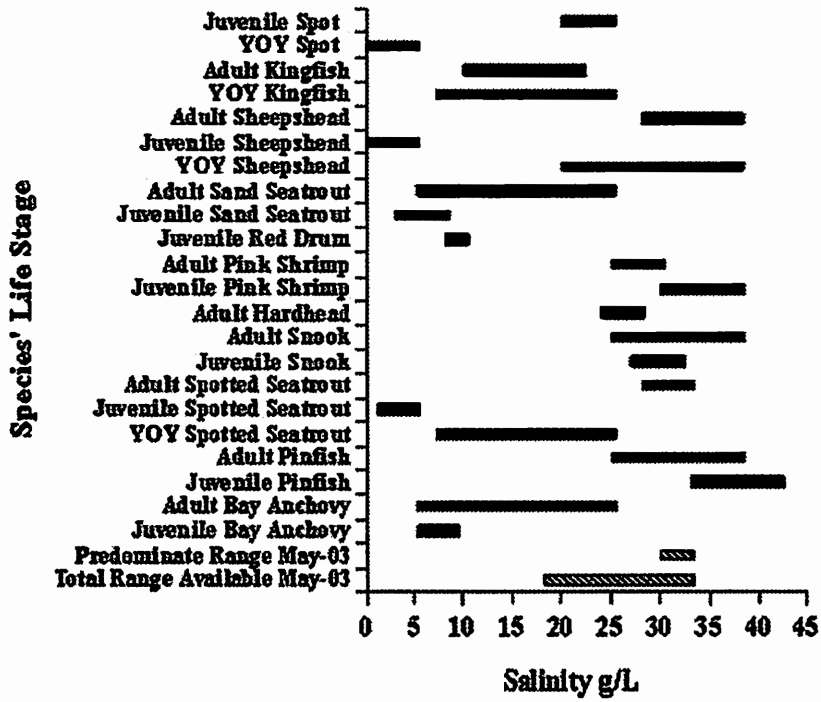


Figure 1. Salinity ranges over which various species' life stages had higher densities (CPUEs) during spring in Charlotte Harbor and the predominate (bay proper) and total salinity ranges (bay plus Henderson Creek) available in Rookery Bay during May 2003.

During the summer, YOY kingfish, Juv sand seatrout, Juv red drum, Juv and adult pink shrimp, and adult hardhead catfish in Charlotte Harbor had affinities for low salinity (Figure 2). Juvenile spot, adult kingfish, adult sand seatrout, Juv pink shrimp, Juv and adult spotted seatrout, Juv and adult bay anchovy had affinities for moderate salinity. Species with affinitiesfor high salinity included YOY, Juv, and adult sheepshead; Juv and adult snook; and Juv and adult pinfish. Examining the predominate salinity range (30 - 33 g/L) and total salinity range (18 - 33 g/L) available during August 2002, it is apparent that salinities in most of Rookery Bay did not match the salinities preferred by the low or moderate salinity species' life stages.

With increasing rainfall during June and July 2003, the predominate salinity range available (26-29 g/L) matched the ranges preferred by the high salinity species (Figure 2). However, the expansion of the total range of salinities (2 - 29 g/L) indicated that there was more area available in Henderson Creek with a salinity range preferred by species' life stages having affinities for low to moderate salinities.

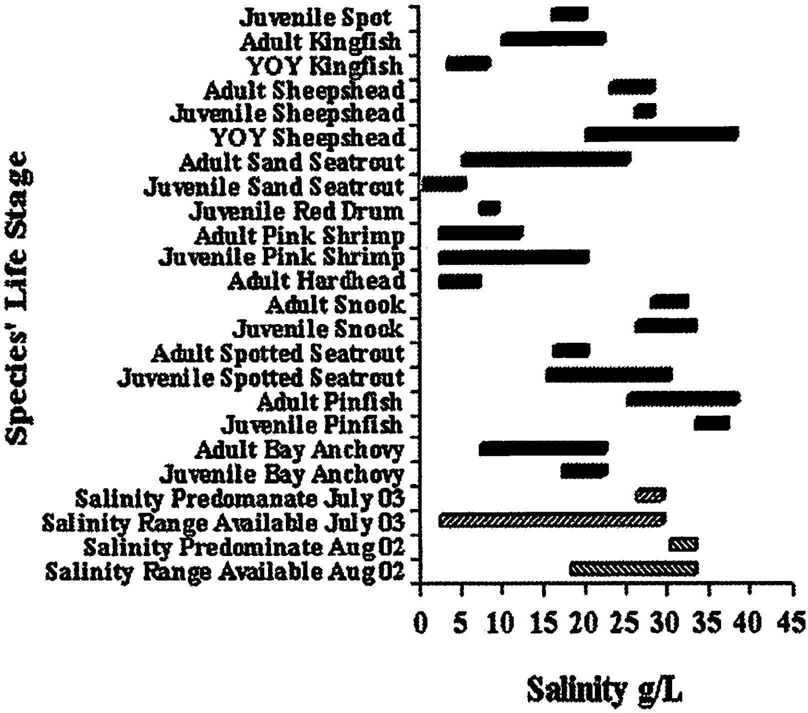


Figure 2. Salinity ranges over which various species' life stages of fish or macroinvertebrates had higher densities (CPUEs) during summer in Charlotte Harbor and with predominate (bay proper) and total salinity ranges (bay plus Henderson Creek) respectively available in Rookery Bay during August 2002 and July 2003.

Percentage of Total Area Suitable for Species' Life Stages

To simplify the interpretation, we summed the areas determined to be High and Optimum from the HSM analyses to determine the proportions of the total areain Rookery Bay that were "suitable" for each species' life stage during the three time periods (Table 1). Although all environmental factors played a role in determining suitability, it is evident that salinity changes between time periods were important in influencing the total area of Rookery Bay predicted to be suitable for various species' life stages. Differences in both water temperature and salinity appear to have been important in influencing the differences in predicted suitability found between the spring and summer time periods.

Table 1. Percentage of the total area determined to be "suitable" for various species' life stages associated with increasing freshwater inflows during three time periods in Rookery Bay.

Species' Life Stage	*Percentage* High + Optimum May-03	*Percentage* High + Optimum Aug-02	*Percentage* High + Optimum July-03
Juvenile Bay Anchovy	21.03	1.61	38.42
Adult Bay Anchovy	99.7	43.37	10.28
Juvenile Pinfish	96.4	99.00	97.8
Adult Pinfish	98.9	98.40	92.9
YOY Spotted Seatrout	97	99.80	87.7
Juvenile Spotted Seatrout	46.3	53.41	23.66
Adult Spotted Seatrout	97.3	44.64	0.31
Juvenile Common Snook	85.1	37.57	30.3
Adult Common Snook	99.7	95.30	97.3
Adult Hardhead Catfish	99.61	18.53	66.8
Juvenile Pink Shrimp	99.8	62.83	99.6
Adult Pink Shrimp	99.9	13.16	38.17
Juvenile Red Drum	58.9	5.46	1.17
Juvenile Sand Seatrout	1.1	6.54	35.99
Adult Sand Seatrout	23.33	39.87	24.49
YOY Sheepshead	99.4	97.60	96.9
Juvenile Sheepshead	92.3	8.77	4.91
Adult Sheepshead	46.4	12.44	16.89
YOY Kingfish	5.17	0.37	2.27
Adult Kingfish	3.19	1.52	2.22
YOY Spot	99.8	95.80	77.63
Juvenile Spot	63.06	3.78	25.49

We consider the two summer time periods (August 2002 and July 2003) to be the most comparable because the same suitability functions were used for the HSM modeling for both time periods. There was little difference in the temperature and dissolved oxygen levels monitored and mapped between the two summer time periods. Hence, we believe that changes in salinity are the most important in explaining the differences in computed habitat suitability between these two periods.

Heavy rainfall that occurred at the end of June 2003 increased the area of lower salinity found on July 10, 2003 in Rookery Bay. The increase in the area predicted to be suitable (Table 1) for Juv bay anchovy (1.61% in August 2002 to 38.42% in July 2003) appears to be related to the reduction in salinity in the estuary. In contrast, the percentage of the area determined to be suitable for adult bay anchovy decreased (43.37% to 10.28%). Some species' life stages with affinities for higher salinity, such as Juv and adult pinfish, adult common snook, and YOY sheepshead did not show marked percent changes in areas estimated to be suitable over the three time periods (the higher salinities present for all time periods were highly suitable). Other species with affinities for higher salinity (Juv and adult spotted seatrout, Juv common snook, Juv sheepshead, and YOY spot) were found to have decreases in the areas predicted to be suitable, associated with the reduction in salinity during July 2003. The HSM analyses predicted increases in areas with suitable habitat during July 2003 for species' life stages (Juv spot, adult hardhead catfish, Juv and adult pink shrimp, Juv sand seatrout, and adult sheepshead) with affinities for low or moderate salinities.

Low percentages of suitable habitat during both summer time periods were predicted for some species such as Juv red drum, Juv sheepshead, and YOY and adult kingfish. The low suitability of the bay during the two summer time periods predicted for Juv and adult kingfish appears to be related to the affinity these fish have for low salinity (lower than what was generally available in Rookery Bay). The low suitability of Rookery Bay predicted for Juv red drum and Juv sheepshead may be related to their high affinity for SAV (the sparse, short-bladed beds of SAV present in Rookery Bay may not provide sufficient cover for larger fish).

Model Validation

We produced 66 HSM maps to predict species distributions in Rookery Bay during the spring (May 2003) and summer (August 2002, July 2003) seasons (Rubec et al. 2003b). Because, the trawl used for monthly sampling in Rookery bay caught only juvenile fish (exceptions were adult bay anchovy and adult hardhead catfish), the validation test was conducted using those species' life stages. The histograms, created by overlaying the observed data from the species caught in Rookery Bay onto the predicted HSM zones, were found to have increasing relations across the zones in 14 of 23 (60.87%) of the cases tested. These results confirmed our ability to adequately predict habitat suitability in Rookery Bay using suitability values transferred from Charlotte Harbor.

CONCLUSIONS

Large differences in salinity were found between Rookery and Fakahatchee bays during the summer and fall wet-seasons (Rubec et al. 2003b). This may be partly related to natural and hydrological differences in rainfall, canal runoff, and the size of the drainage basins for the two estuaries. There was less monthly rainfall recorded near Rookery Bay (Naples) than near Fakahatchee Bay (Copeland) from 1990 to 2003. Based on data published by Carter et al. (1973), the average total annual rainfall at Copeland from 1970 to 1972 was 206.13 cm (n = 3) and the average annual rainfall recorded at Naples over the same time period was 134.53 cm (n = 3). By comparison, the average annual rainfall near Fakahatchee Bay at Copeland from 1990 to 2003 (n = 13) was 155.30 cm (SFWMD reports), and the average annual rainfall at Naples near Rookery Bay over the same time period was 138.38 cm (n = 14) (NOAA National Weather Service on-line data (http://www.dnr.state.sc.us/ water/ climate/sercc/index.html).

Another factor influencing the lower salinities monitored in Fakahatchee Bay in the present study appears to be the high flows of freshwater coming out of the Faka Union Canal system. Salinities lower than those in Rookery Bay were mapped in the northwestern part of Fakahatchee Bay, which adjoins Faka Union Bay, during August 2002, October 2002, and July 2003 (Rubec et al. 2003b).

Differences in the ratios of drainage area to bay area may also help to explain the observed differences in salinity patterns between Rookery and Fakahatchee bays during the wet seasons. Historically, the Belle Meade watershed feeding water to Henderson Creek was similar in size and habitat composition as the Fakahatchee Strand watershed feeding water to Fakahatchee Bay. The creation of the canal system during the 1960s diverted freshwater from the upper part of the Belle Meade watershed through the Golden Gate Canal to Naples Bay (Yokel 1979, Browder and Moore 1981).

Yokel (1979) concluded that excessive freshwater discharges from the Golden Gate Canal through the Gordon River into Naples Bay had caused a rapid decline in salinities to near freshwater conditions from June through September. In the lower part of Naples Bay, the freshwater discharge from the Golden Gate Canal suppressed plankton development, which in turn resulted in a low relative abundance of midwater fish.

In the present study, we conducted HSM modeling to predict spatial distributions and relative abundances of estuarine species' life stages in Rookery Bay over three time periods ordered as they relate to progressively decreasing salinity in the estuary (Rubec et al. 2003b). The modeling found that most of the 22 life stages of the 11 species modeled responded to changes in salinity, related to changes in freshwater inflow. The results demonstrated our ability to predict habitat suitability associated with the changes in salinity in Rookery Bay. It appears that a number of estuarine species' life stages would benefit if the Rookery Bay system received more freshwater inflow during both the dry (winter and spring) and wet seasons (summer and fall). Further research is needed to define the salinity conditions that might be achieved in the Rookery Bay system by water diversions through the canal system in the Belle Meade watershed and by fine-tuning the weir on Henderson Creek.

Based on the large differences in salinity ranges observed between Rookery Bay and Fakahatchee Bay during the wet seasons, it is probably not feasible to augment freshwater inflows to Rookery Bay to exactly match the salinity ranges observed in Fakahatchee Bay. A more realistic management goal would be to use Fakahatchee Bay as a reference site, to help account for the hydrological differences between the two systems, and then set freshwater inflow targets for each season in Rookery Bay. This should broaden the range of salinities, and provide a more natural timing and variation in patterns of freshwater inflow into Henderson Creek, thereby creating more suitable habitats for various species' life stages.

Further studies are needed to develop a circulation model that takes into account monthly freshwater inflows and tidal variation in each estuary. By linking the HSM to both the circulation model and to stream gauging at the upstream weir, it will become possible to predict habitat suitability directly from inflow patterns. We recognize that seasonal patterns of salinity variation (measured by stationary data loggers) are also important (Shirley et al. 2004). Protecting biodiversity in the estuary should also become a management goal, through spatial evaluation of diversity-related indices such as species richness and evenness (Drake et al. 2002). We plan to conduct biodiversity-based HSM analyses to help predict the volumes and timing of freshwater inflows needed in Rookery Bay to mimic freshwater inflow patterns found in Fakahatchee Bay associated with natural sheet-flow.

ACKNOWLEDGMENTS

The participants are grateful for the funding provided to FWC-FWRI though a grant (No C-13253) from the Big Cypress Basin Board of the South Florida Water Management District. Comments by Dr. Joan Browder of NOAA/NMFS in Miami and by two anonymous reviewers, and editing conducted by Dr. Jim Quinn at FWC-FWRI helped to improve the manuscript. Benthic mapping by Dr. Stanley Locker of USF was conducted under subcontract to FWC-FWRI. Software for the capture of field data was developed under subcontract from FWC-FWRI to Sasco Inc., Tampa, Florida.

LITERATURE CITED

Ault, J.S. and S.G. Smith. 2000. *Extensions to Gear Inter-calibration Methods for Fishery-independent Catch-per-unit-effort Data.* University of Miami, Rosenstiel School of Marine and Atmospheric Science, Technical Report to Florida Marine Research Institute, Florida Fish and Wildlife Conservation Commission Contract No. 99020. 67 pp.

Browder, J.A. 1985. Relationship between pink shrimp production on the Tortugas grounds and water flow patterns in the Florida Everglades. *Bulletin of Marine Science* 37(3):839-856.

Browder, J.A. 1991. Watershed management and the importance of freshwater inflow to estuaries. Pages 7-22, in: S.F. Treat and P.A. Clark (eds.). *Proceedings Tampa Bay Scientific Information Symposium 2*, Tampa Bay Regional Planning Council, St. Petersburg, Florida USA.

Browder, J.A. and D. Moore 1981. A new approach to determining the quantitative relationship between fishery production and flow of fresh water to estuaries. Pages 403-430 in: R.D. Cross and D.L. Williams (eds.). *Proceedings of the National Symposium On Freshwater Inflow To Estuaries*. FWS/OBS-81/04. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. USA .

Browder, J.A., Z. Zein-Eldin, M.R. Criales, M.B. Roblee, S.Wong, T.L. Jackson, and D. Johnson. 2002. Dynamics of pink shrimp (*Farfantepenaeus duorarum*) recruitment potential in relation to salinity and temperature in Florida Bay. *Estuaries* 25 (No. 6B): 1355-1371.

Carter, M.R., L.A. Burns, T.R. Cavinder, K. R. Dugger, P.L. Fore, D.B. Hicks, H. Lavon Revells, and T.W. Schmidt. 1973. Ecosystems analysis of the Big Cypress Swamp and estuaries. Atlanta, Georgia: United States Environmental Protection Agency, Region IV; June 1973, EPA 904/9-74-002, Report No. PB 233 070.

Colby, D., G. Thayer, W. Hettler, and D. Peters. 1985. A comparison Of forage fish community in relation to habitat parameters In Faka Union Bay, Florida, and eight collateral bays during the wet season. NOAA Tech. Report NMFS SEFC-162. Southeast Fisheries Center, Beaufort-Laboratory, Beaufort, North Carolina. 87 pp.

Drake, P., A.M. Arias, F. Baldé, J. A. Cuesta, A. Rodríguez, A. Silva-García, I. Sobrino, D. García-Gonzalez, and C. Fernández-Delago. 2002. Spatial and temporal variation of nekton and hyperbenthos from a temperate European estuary with regulated freshwater inflow. *Estuaries* 25(3):451-468.

Gardner, T. 1988. Rookery Bay and Cape Romano-Ten Thousand Islands aquatic preserves management plan. Report prepared by The Florida Department of Natural Resources, Bureau of Aquatic Preservers, Division of State Lands, June 28, 1988. 143 pp.

Johnston, K., J.M. Ver Hoef, K. Krivoruchko, and N. Lucas. 2001. *Using ArcGIS Geostatistical Analyst.* Environmental Systems Institute Inc., Redlands, California USA. 300 pp.

Livingston, R.J., X. Niu, F.G. Lewis, and G.C. Woodsum. 1997. Freshwater input to a Gulf estuary: long term control of trophic organization. *Ecological Applications* 7: 277-299.

Livingston, R.J., F.G. Lewis, G.C. Woodsum, X.-F. Niu, B. Galperin, W. Huang, J.D. Christensen, M.E. Monaco, T.A. Battista, C.J. Klein, R.L. Howell IV, and G.L. Ray. 2000. Modelling oyster population response to variation in freshwater input. *Estuarine, Coastal and Shelf Science* 50:655-672.

Locker, S.D., and A.K. Wright. 2003. Benthic habitat mapping for habitat suitability modeling in Rookery Bay National Estuarine Research Reserve. Final Report submitted by the University of South Florida, College of Marine Science to the Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute under contract No. POS7701617863.

Robson, D.S. 1966. Estimation of the relative fishing power of individual ships. *International Commission Northwest Atlantic Fisheries Research Bulletin* 3:5 - 14.

Rubec, P.J., M.S. Coyne, R. H. McMichael, Jr., and M.E. Monaco. 1998. Methods being developed in Florida to determine essential fish habitat. *Fisheries* 23(7):21 - 25.

Rubec, P.J., C.W. Bexley, H. Norris, M.S. Coyne, M.E. Monaco, S.G. Smith, and J.S. Ault. 1999. Suitability modeling to delineate habitat essential to sustainable fisheries. *American Fisheries Society Symposium* 22:108 - 133.

Rubec, P.J., S.G. Smith, M.S. Coyne, M. White, A. Sullivan, D. Wilder, T. MacDonald, R.H. McMichael, Jr., M.E. Monaco, and J.S. Ault. 2001. Spatial modeling of fish habitat suitability in Florida estuaries. Pages 1-18, in: G.H. Kruse, N. Bez, A. Booth, M.W. Dorn, S. Hills, R.N. Lipcus, D. Pelltier, C. Roy, S.J. Smith, and D. Witherell (eds.). *Spatial Processes and Management of Marine Populations,* Alaska Sea Grant College Program AG-SG-01-02. Fairbanks, Alaska USA.

Rubec, P.J., S.D. Whaley, G.E. Henderson, J. Lewis, M. White, A.M. Sullivan, R.L. Vadas Jr., R. Ruiz-Carus, D.T. Wilder, C. Westergren, and T.M. MacDonald. 2003a. *Development And Evaluation of Methods for Habitat Suitability Modeling In Florida Estuaries*. Report submitted to U.S. Fish and Wildlife Service, Atlanta, Georgia associated with Grant Number F-96 to the Florida Marine Research Institute, 69 pp. + CD-ROM.

Rubec, P.J., M.A. Shirley, J. Lewis, P. O'Donnell, S.D. Locker, G.E. Henderson, T. Mo, and C. Westergren. 2003b. *Spatial Modeling to Determine Optimal Freshwater Inflows into Estuarine Habitats in the Rookery Bay System.* Report submitted by the FWC Florida Marine Research Institute to the Big Cypress Basin, South Florida Water Management District, associated with SFWMD Grant No. C-13253, 83 pp. + CD-ROM.

SAS 2002. *Statistics and Graphics Guide: JMP Statistical Discovery Software.* SAS Institute Inc., Cary, North Carolina USA 707 pp.

Sklar, F.H., and J.A. Browder. 1998. Coastal environmental impacts brought about by alterations to freshwater flow in the Gulf of Mexico. *Environmental Management* 22:547-562.

Shirley, M.A., V. McGee, T. Jones, B. Anderson, and J. Schmid. 2004. Relative abundance estimates of stenohaline and euryhaline oyster reef crab populations as a tool for managing freshwater inflow to estuaries. *Journal of Coastal Research* 45:195-208.

Yokel, B.J. 1979. Section E Biology. Pages E1-E10, in: *The Naples Bay Study*. The Collier County Conservancy, Naples, Florida USA.

BLANK PAGE

Integration of Fisheries into Coastal Management

PATRICK McCONNEY
Centre for Resource Management and Environmental Studies (CERMES)
University of the West Indies, Cave Hill Campus
St. Michael, Barbados

ABSTRACT

Integrated coastal management (ICM) seems to be the obvious choice for small island developing states (SIDS) in the Caribbean that aim for sustainable development. The Code of Conduct for Responsible Fisheries, available globally for voluntary adoption since 1995, is promoted by the Food and Agriculture Organisation of the United Nations (FAO). Article 10 of the Code addresses the integration of fisheries into coastal area management. It deals with institutional frameworks, policy measures, regional cooperation and implementation of ICM. Observations in some of the small islands of the Caribbean suggest that while progress has been made, there is still a long way to go. Some of the challenges include public administration, representation of stakeholders, and issues of power and equity. These are in addition to the technical and scientific challenges surrounding multiple uses of natural resources. The Coastal Management Research Network (COMARE Net) of the University of the West Indies is one of the several recent initiatives that attempt to improve the practice of integrated coastal management in the region.

KEY WORDS: Coastal, fisheries, integrated, management

Integración de Pesquerías en Manejo Eostero

Manejo costero integrado (MCI) parece ser la opción obvia para las pequeñas islas estados en vías de desarrollo del Caribe, que apuntan hacia un desarrollo sostenido. El Código de Conducta para la Pesca Responsable, accesible globalmente para su adopción voluntaria desde 1995, es promovido por la Organización para la Alimentación y Agricultura de las Naciones Unidas (FAO). El articulo 10 del Código trata sobre la integración de pesquerías en manejo de zona costera. Se relaciona así mismo, con marcos institucionales, políticas, implementación y cooperación regional de MCI. Observaciones realizadas en las pequeñas islas del Caribe sugieren que mientras ha habido progreso, aun queda un largo camino por recorrer. Algunos de los retos incluyen la administración publica, representación de accionistas, asuntos de poder y equidad. Todo esto se agrega a los retos técnicos y científicos alrededor de los usos múltiples de los recursos naturales. La Red de Investigación de Manejo Costero (COMARE Net) de la Universidad de West Indies es una de las recientes iniciativas que pretende mejorar la practica de manejo costero dentro de la región.

PALABRAS CLAVES: Costero, pesquería, integrada, manejo

INTRODUCTION

Integrated coastal management (ICM) seems to be an obvious choice for the small island developing states (SIDS) in the Caribbean that aim for sustainable development. An entire island nation may constitute a continuous coastal zone or area because of its small size. Integrated coastal management (and similar terms) have been described as:

> *"...a continuous and dynamic process by which decisions are taken for the sustainable use, development, and protection of coastal and marine areas and resources. ICM acknowledges the interrelationships that exist among coastal and ocean uses and the environments they potentially affect, and is designed to overcome the fragmentation inherent in the sectoral management approach. ICM is multi-purpose oriented, it analyzes and addresses implications of development, conflicting uses, and interrelationships between physical processes and human activities, and it promotes linkages and harmonization among sectoral coastal and ocean activities"* (Cicin-Sain and Knecht 1998).

Fishing is one of the most obvious, and sometimes locally or nationally important, sectoral activities along the coasts of Caribbean countries. It uses space offshore for fish harvesting and onshore for harvest support as well as the postharvest steps leading to domestic seafood consumption or for export. Many user groups from other sectors of the economy and society also place demands on coastal and marine areas. International policy instruments such as Agenda 21 and the Small Island Developing States Plan of Action (SIDS-POA) emphasise the need for ICM.

Among such instruments, however, it is primarily the Code of Conduct for Responsible Fisheries, promoted by the Food and Agriculture Organisation of the United Nations (FAO), and available globally for voluntary adoption since 1995, that specifically addresses how fisheries should be integrated into coastal management. Here the term "management" encompasses both conservation and development. Article 10 (see Appendix for the full text) of the Code of Conduct for Responsible Fisheries (FAO 1995) addresses the integration of fisheries into coastal area management. It deals with institutional frameworks, policy measures, regional cooperation and implementation of ICM.

This paper examines the recommendations set out in the Code. It places the Code in the context of examples of ICM in the Caribbean with a view to learning how integrated coastal management can be improved. I provide perspectives under the headings of Article 10, illustrated with information from recent research. Sharing information on coastal management research, and promoting such research, is a goal of the Coastal Management Research Network (COMARE Net) of the University of the West Indies (UWI). COMARE Net is an outreach initiative of the UWI Office of Research.

INSTITUTIONAL FRAMEWORK

In Article 10 of the Code key points on the institutional framework are:

i) Appropriate policy, legal and institutional framework for social-ecological sustainable utilisation,
ii) Representation of fishing interests in coastal area decision-making,
iii) Retain customary practices, rights of access and use where feasible,
iv) Adopt fishing practices that avoid conflict among all coastal users, and
v) Establish procedures for conflict management within administration.

Social-ecological sustainable utilisation demands that resources are used in a sustainable manner to ensure that ecosystems and social systems thrive. The multidimensional framework required to achieve this should be part of governance arrangements for Caribbean coastal and marine resources (Chakalall, Mahon and McConney 1998). In Barbados, the Coastal Zone Management Act acknowledges the precedence of the Fisheries Act in establishing plans for the management of fishery resources outside of designated marine protected areas (MPAs). The Coastal Zone Management Unit is represented on the policy-level Fisheries Advisory Committee (FAC), the fishery sector's primary consultative comanagement body with multi-stakeholder membership (McConney, Mahon and Oxenford 2003).

Fisheries sector workers, fisheries authority and coastal management authority all serve on the Barbados FAC, but there is no permanent ICM body yet established that includes fishing interests. There is the integration of coastal management into fisheries instead of the reverse. The institutional arrangements for coastal management in Belize, and the Fisheries Advisory Board, are also developed to provide an integrated structure from policy-making to community-level, and fishing interests are represented especially by the fishing cooperatives (McConney et al. 2003).

The beach seine fishery in Grenada provides a case study on retaining customary practices and fishing rules, with recommendations from fishers for incorporating these institutions into the conventional fishery regulations (McConney 2003). Regarding rights of access to coastal areas above the high water mark, fishers in many locations are finding themselves excluded from private properties that were customarily available to them for boat repair and fishing operations. More properties are being developed for local residential or tourism purposes. Beach erosion narrows the area available to fishers even further, strengthening the need for integrating fishing into physical planning. Garaway and Esteban (2003) note that planning needs to be especially comprehensive and participatory for marine protected areas.

In the Grenada beach seine case, fishers were concerned about fishing and boat mooring areas disrupting coastal traffic (McConney 2003). Where disputes arose about the fishing rules, the fisheries authority stepped in to resolve or manage the conflicts. Fishers have proposed that a civil arbitration body be established to handle such incidences in the future when the intervention of the fisheries authority is not sufficient. Coastal conflicts between fishing and tourism feature prominently in the case of fishing and whale-shark encounters competing for space along the barrier reef of Belize (Pomeroy and Goetze 2003). Procedures for conflict management are set out in McConney, Pomeroy, and Mahon (2003).

POLICY MEASURES

In Article 10 of the Code key points concerning policy measures are:

i) Public awareness for conservation and participatory management,
ii) Resource valuation including economic, social, and cultural factors,
iii) Policy decision-making takes risks and uncertainties into account,
iv) Coastal monitoring using physical, chemical, biological, economic, and social parameters, and
v) Multi-disciplinary research on environmental, biological, economic, social, legal and institutional aspects of coastal management.

The Barbados Sea Turtle Project is an example of integrating fishery and coastal management in which public awareness of conservation, and for encouraging participation, is key. Public education has assisted in ensuring a high level of compliance with the regulations that have closed the fishery, and resulted in a high level of participation in conservation efforts by a wide cross-section of the population (http://barbadosseaturtles.uwichill.edu.bb).

Comprehensive coastal and marine resource valuation is recent, and still rare, in the insular Caribbean. The related area that is receiving more attention concerns sustainable livelihoods and pro-poor approaches to coastal research and management (Smith 2001, Smith and Renard 2002, Pantin et al. 2004, Renard et al. 2000). These approaches place resource values in a very practical context integrated with quality of life and well-being, and within a framework of institutional analysis (Garaway and Esteban 2003, Butler 2002).

The trends towards ecosystem-based fishery management and use of social-ecological system concepts are still in their early stages in the region. However, risk and uncertainty are important aspects of these perspectives. Using trade-off analysis, Brown et al. (2001) address coastal decision-making that confronts those engaged in participatory management. Risk and uncertainty require more attention in regional coastal management research. Many coastal development decisions have the potential to marginalise fisheries, often for perceived tourism benefits. They are not easily reversible and there is little physical space for errors.

McConney, Mahon, and Parker (2003) discovered that uncertainty (ecological and institutional) is a factor that hinders co-management of the sea urchin fishery in Barbados. It seems to be less of a factor in St. Lucia in the same fishery (Smith and Koester 2001, Burt 2002). One of the greatest areas of risk and uncertain related to enforcement of fisheries regulations and penalties. Fishers may find it harder to cope with legal-institutional uncertainties concerning power and equity issues.

Coastal monitoring received a boost from the Caribbean Planning for Adaptation to Global Climate Change (CPACC) project. A wide range of monitoring parameters were included, but only in some locations where the coastal authority and fisheries authority were the same or closely linked, did fisheries play a prominent role in the monitoring programme. Other projects, such as by the Caribbean Natural Resources Institute (CANARI), have also paid attention to coastal monitoring (e.g. Hutchinson 2001, Smith 2003).

Recently the Centre for Resource Management and Environmental Studies (CERMES) of the University of the West Indies (UWI) has led an initiative known as SocMon Caribbean (Socioeconomic Monitoring for Coastal Monitoring in the Caribbean) that aims to include all coastal uses within its monitoring regime. Some papers to be presented at this conference use this methodology (e.g. Joseph in Nicaragua and Gibson et al. in Belize). This is a new and growing area of coastal management research.

Multidisciplinary, interdisciplinary or transdisciplinary research is vital for coastal management (Visser 2004). Such research is being undertaken at CERMES and other organisations in the region. However, when compared to research in other regions (e.g. Boissevain and Selwyn 2004) the body of work on Caribbean tourism interactions with fisheries is surprisingly small and focused mainly upon bio-physical aspects or conflicts. It is rare to see research directed at how fisheries can enhance tourism if fully integrated into coastal management (Clauzel and Joyeux 2001).

REGIONAL COOPERATION

In Article 10 of the Code, points concerning regional cooperation are:

i) States with neighbouring coasts should cooperate in management,
ii) Transboundary issues require good communication and consultation, and
iii) Scale of cooperation should be appropriate for most effectiveness.

Several United Nations (UN) agencies have fisheries, coastal and marine programmes and projects in the Caribbean. The Caribbean Environmental Programme (UNEP-CEP) has the potential to integrate fisheries and coastal management, but this has not yet occurred. The English-speaking Caribbean has recently established an indigenous regional fisheries body: the Caribbean Regional Fisheries Mechanism (CRFM). It is located in Belize, along with the Caribbean Community Climate Change Centre (CCCCC). This proximity may foster greater integration. At the sub-regional scale, the Organisation of Eastern Caribbean States Environmental Sustainable Development Unit (OECS-ESDU) houses both the fisheries and coastal management desks. In small countries the close proximity of agencies is important for the creation of critical masses of expertise under conditions of low capacity and inadequate communication.

The regional and international organisations listed above can facilitate transboundary communication and consultation at appropriate scales. However, barriers occur since the fisheries and coastal management stakeholders (both governmental and non-governmental) seldom share the same forums. There is no body set up yet to span the inter-agency divides that prohibit the integration of fisheries into coastal management at a regional scale. The most promising initiative in this regard may be institutional arrangements arising from attempts in the UN to have the Caribbean declared a special area.

However, this does not met the immediate need for integration of fisheries into coastal management.

IMPLEMENTATION

In Article 10 of the Code of Conduct for Responsible Fisheries, the key points concerning implementation are:

i) National coastal authorities involved in planning, development, conservation, and management need to cooperate and coordinate, and
ii) Fisheries sector representatives must have the appropriate technical capacities and financial resources.

The points from the previous section bear repeating here. In addition, it still appears that authorities are reluctant or unable to fully and effectively utilise cost-effective means of electronic communication for conducting business. E-groups, e-mail, e-conferencing, web pages, and the like are not routinely employed to boost interactive productivity at any scale, especially for fisheries and coastal managers to collaborate. Perhaps the enhanced communication efforts of the Gulf and Caribbean Fisheries Institute (GCFI) can assist in improving this situation, but changes in attitudes on data- sharing and pooling, joint problem-solving and the like are also required.

As highlighted in the Small Island Developing States Plan of Action (SIDS-POA), building capacities of coastal and marine management stakeholders is of high priority. For example, fisherfolk organisations in Barbados are eligible to receive small grants from government to acquire technical and financial resources. Technical expertise is offered through organisations such as CERMES and CANARI to build the capacities of NGOs in the region. However, NGOs seldom take full advantage of such opportunities, and governments are not always sufficiently supportive.

DISCUSSION AND CONCLUSIONS

Fisheries management and coastal management are becoming more participatory, comprehensive, and compatible. Recognising social-ecological systems and using ecosystem-based management are features in common. However, the integration of fisheries into coastal management, as promoted by the Code of Conduct for Responsible Fisheries, has not proceeded altogether smoothly in the Caribbean. This is mainly due to structural and institutional barriers in the governance and administration of coastal and marine resources. Change agents are urgently needed.

Coastal management is seen in many places as a part of environmental management while fisheries is seen primarily, in SIDS especially, as one of the "productive sectors" like agriculture and manufacturing. Consequently, despite some similarity in outlooks and approaches at technical level, there is the lingering perception among some fisheries stakeholders that coastal management inevitably means greater regulation of fisheries and marginalisation of fishing in favour of tourism or other types of development. Fisheries stakeholders may consider that as the traditional users of coastal areas they have done more to accommodate the needs of coastal management and development than the reverse.

Recent publications provide insight on how the frameworks for successfully (co-)managing coastal resources may be structured (Brown et al. 2002, McConney et al. 2003). Further research is required to assist the advancement of coastal management in the Caribbean, and the role that fisheries may play in this process. Promoting and disseminating such research is a goal of the Coastal Management Research Network (COMARE Net), an outreach initiative of the University of the West Indies (UWI) Office of Research.

ACKNOWLEDGEMENTS

Assistance was received from the UWI Coastal Management Research Network (COMARE Net), a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID or UWI. I thank the Centre for Resource Management and Environmental Studies (CERMES) of the UWI Cave Hill Campus for additional support.

LITERATURE CITED

Boissevain, J. and T. Selwyn. (eds.) 2004. *Contesting the Foreshore: Tourism, Society and Politics on the Coast.* MARE Publication Series No. 2. Amsterdam University Press, Amsterdam. 320 pp.

Brown, K., E. Tompkins, and N. Adger. 2001. *Trade-off Analysis for Participatory Coastal Zone Decision-making.* Overseas Development Group, University of East Anglia. 109 pp.

Brown, K., E. Tompkins, and N. Adger. 2002. *Making Waves: Integrating Coastal Conservation and Development.* Earthscan Publications, London, United Kingdom. 164 pp.

Burt, M. 2002. A study of the social and economic impacts of sea urchin harvesting in 2002 in Laborie, St. Lucia. CANARI LWI Project Document no. 7. CANARI Technical Report no. 318. Caribbean Natural Resources Institute, Vieux Fort, Saint Lucia.

Butler, C. 2002. Assessing marine resources: institutions and institutional development in Laborie, St. Lucia. CANARI LWI Project Document no. 6. CANARI Technical Report no. 305. Vieux Fort, Saint Lucia: Caribbean Natural Resources Institute.

Cicin-Sain, B. and R.W. Knecht. 1998. *Integrated Coastal and Ocean Management: Concepts and Practices.* Island Press, Washington, DC. USA. 517 pp.

Chakalall, B., R. Mahon, and P. McConney. 1998. Current issues in fisheries governance in the Caribbean Community (CARICOM). *Marine Policy* **22**: 29-44.

Clauzel, S. and Joyeux, G.. 2001. Tourism in Laborie, St. Lucia: baseline study and identification of potential for development. CANARI LWI Project Document no. 3. CANARI Technical Report no. 293. Caribbean Natural Resources Institute, Vieux Fort, Saint Lucia.

FAO. 1995. *Code of Conduct for Responsible Fisheries*. FAO, Rome, Italy. 41 pp.

Garaway, C. and N. Esteban. 2003. *Increasing MPA Effectiveness Through Working with Local Communities: Guidelines for the Caribbean*. MRAG Ltd., London, United Kingdom. 45 pp.

Hutchinson, G. 2001. Water quality in the Laborie Bay. CANARI LWI Project Document no. 5. CANARI Technical Report no. 301. Caribbean Natural Resources Institute, Vieux Fort, Saint Lucia.

McConney, P. 2003. Grenada case study: the legalisation of beach seine traditional rules at Gouyave. Caribbean Coastal Co-management Guidelines Project. Caribbean Conservation Association, Barbados. 70 pp.

McConney, P., R. Mahon, and C. Parker. 2003. Barbados case study: The sea egg fishery. Caribbean Coastal Co-management Guidelines Project. Caribbean Conservation Association, Barbados. 74 pp.

McConney, P., R. Mahon, and H. Oxenford. 2003. Barbados case study: the Fisheries Advisory Committee. Caribbean Coastal Co-management Guidelines Project. Caribbean Conservation Association, Barbados. 77 pp.

McConney, P., R. Mahon and R. Pomeroy. 2003. Belize case study: Fisheries Advisory Board in the context of integrated coastal management. Caribbean Coastal Co-management Guidelines Project. Caribbean Conservation Association, Barbados. 70 pp.

McConney, P., R. Pomeroy, and R. Mahon. 2003. Guidelines for coastal resource co-management in the Caribbean: Communicating the concepts and conditions that favour success. Caribbean Coastal Co-management Guidelines Project. Caribbean Conservation Association, Barbados. 56 pp.

Pantin, D., D. Brown, M. Mycoo, C. Toppin-Allahar, J. Gobin, W. Rennie, and J. Hancock. 2004. Feasibility of alternative sustainable coastal resource-based enhanced livelihood strategies. SEDU, UWI, St. Augustine Campus. 92 pp.

Pomeroy, R.S. and T. Goetze. 2003. Belize case study: Marine protected areas co-managed by Friends of Nature. Caribbean Coastal Co-management Guidelines Project. Caribbean Conservation Association, Barbados. 69 pp.

Renard, Y., A. Smith, and V. Krishnarayan. 2000. Do reefs matter? Coral reef conservation, sustainable livelihoods and poverty reduction in Laborie, St. Lucia. Paper presented at a Regional conference on Managing Space for Sustainable Living in Small Island Developing States, Port of Spain, Trinidad and Tobago, October, 2000. CANARI Communication No. 274:6 pp.

Smith, A.H. 2001. A study of coastal livelihoods in Laborie, St. Lucia – social, human and financial capital. How different resources are used and integrated into household strategies of different stakeholder groups (R7559). Pages 7-12 – 7-13 in: *DFID Natural Resources Systems Programme. Proceedings of the Workshop Improving the poverty focus of NRSP's Research on the Management of Natural Resources*. Rothamsted, Harpenden, UK, November/December 2000.

Smith, A.H. and S. Koester. 2001. A description of the sea urchin fishery in Laborie, St. Lucia. CANARI LWI Project Document no. 4. CANARI Technical Report no. 294. Caribbean Natural Resources Institute, Vieux Fort, Saint Lucia.

Smith, A.H. and Y. Renard. 2002. Seaweed cultivation as a livelihood in Caribbean coastal communities. Paper presented at the ICRI Regional Workshop for the Tropical Americas: Improving Reef Condition Through Strategic Partnerships. Cancun, Mexico, June 2002. CANARI Communication No 309: 8 pp.

Smith, A.H.. 2003. Mapping Laborie Bay, Saint Lucia.. CANARI LWI Project Document no. 8. CANARI Technical Report no. 323. Caribbean Natural Resources Institute, Vieux Fort, Saint Lucia.

Visser, L. (ed.) 2004. *Challenging Coasts: Transdisciplinary Excursions into Integrated Coastal Zone Development*. MARE Publication Series No. 1. Amsterdam University Press, Amsterdam. 245 pp.

BLANK PAGE

Socio-economic Impact of the Closed Season for Lobster in Corn Island. RAAS-Nicaragua

KAREN JOSEPH
CAMP-Lab
CIDC - Bluefields
Pearl lagoon, Nicaragua

ABSTRACT

Nicaraguan water was considered as an open access in which no regulation would comply. The close season mainly for lobster is a regulation that Nicaragua national government began to apply in June 2000.

The Municipality of Corn Island is composed of two islands, Great Corn Island and Little Corn Island; both islands are 100% fishing communities. The islands are situated around 83.3 km east of the city of Bluefields, South Autonomous Atlantic Region (RAAS) of Nicaragua. Great corn Island has an area around 23½ km^2, composed of five neighborhoods.

The spiny lobster, *Panulirus argus*, is one of the principal fisheries resources for exportation captured in the Caribbean sea of Nicaragua, and it is the resource that generates the highest income for the populations of the Corn Islands. Due to the low volume of lobsters captured in the last few years, a closed season for this resource wass implemented.

The objective of this study, is to determine the impact of the closed season, to evaluate what is the effect in the life of the islanders before, during and, after the closed season, and what solution they can propose to do during the closed season to generate income.

This will serve as a guide for decision makers or coastal managers as a previous consultation that can be used to promote the proposals that can emerge during the study.

To obtain this information it was necessary to interview key informants and a focus group, utilize a questionnaire, obtain secondary data, and direct observation.

KEY WORDS: Spiny lobster, close season, socio-economic, Nicaragua

Monitoreo Socio Econ6mico de la Veda en Corn Island RAAS de Nicaragua

Las agues Nicaragüense es considerado como de libre acceso en donde ningún tipo de regulaciones se cumplen. La veda especialmente para ;a Langosta es una normativa que inicio desde Junio 2000 por parte del Gobierno nacional.

El municipio de Corn Island esta compuesto por dos islas , la isla Pequeña del Maiz y la Isla Grande del Maíz, en donde los habitantes de estas islas son meramente pesqueros al 100%. la isla esta situada alrededor de 83.3 km al este de Bluefields cede de la Regi6n Aut6noma del Atlántico Sur de Nicaragua. La

isla grande del maíz tiene una extensión alrededor de 23 ½ km^2 y esta compuesto por cuatro barrios.

La langosta Espinoza Panulirus argus es uno de los recursos pesqueros mas importante de captura y exportación en la Costa Caribe Nicaragüense. Y es uno de los recursos que genera mayor entrada de divisas para los Cornileños. Pero debido al bajo volumen de captura en los últimos años, el sistema de veda para la langosta a sido implementado.

El propósito de este estudio es saber cual ha sido el impacto causado por la veda en la vida de los cornileños antes, durante y después de implementar la veda y que soluciones proponen ellos para generar divisas y para poder sobrevivir durante este periodo.

A la vez esto le serviría como guía para los tomadores de decisiones y manejadores de áreas costeras como una consultoría previa que puede ser usado para promover propuestas de desarrollo que pueden generarse durante el estudio.

Para la obtención de información se vera necesario realizar entrevistas a informante claves y grupos focales. Se ara una lista de preguntas y uso de datos secundarios si están disponibles.

PALABRAS CLAVES: Langosta, la veda, socio-económico, Nicaragua

INTRODUCTION

The fishing grounds around Corn Island, an island located on the Caribbean coast of Nicaragua, form one of the country's most important lobster fishing areas.

During the 1990s the fishery developed tremendously, and the lobsters high unit prices and revenues are of great importance to the poor region that holds few other economic alternatives. The foreign exchange generated by the lobster fishery has been a significance source of revenue for the impoverished government, but it has also lead to over exploitation of the species.

Lobster fishing had always been a very important economic activity for the island but became even more vital after hurricane Joan hit Corn Island in 1988, devastating 95% of all standing structures, and destroying all the palm trees on the island, as well as the copra factory. Currently, the economy of Corn Island primarily depends on the lobster fishery, and all economic activities are somehow related to the lobster fishery. A closed season was established because of the problem of overexploitation of the resource in the area by the Nicaraguan government which included all national and foreign vessels. Nonetheless, management of the Corn Island lobster fishery during the last decade has so far proven unsuccessful, and Nicaragua does not have a fishery management plan for this species..

Initial legislation, submitted in 1961 was approved in February 2004, with the National Assembly approving only Chapter I that has nine articles, related with the administration of the resource.

Objectives

General Objective — To evaluate the social-economic impact on the populations of Great and Little Corn Islands before, during, and after the closed season for lobster in 2003.

Specific objectives —To evaluate the specific impacts on the island fishers after the closed season, and to identify solutions that stakeholders can propose for the future.

METHODOLOGY

Use of *SocMon* Guidelines

In order to examine social and economical aspects, this study surveyed perceptions of fishers in the Corn Islands towards (indicators):

i) Reasons for decline in the fisheries,
ii) Income before, during and after the close season,
iii) Current and potential regulations, and parties responsible for the recuperation of the lobster stock, and
iv) Find new alternative to survive during the close season.

Information was also collected on their socio-cultural background (ethnicity, age, origin, religion, etc.) and fishing technique, and type and size of vessels used in order to enable an analysis of what factors determine different interest groups within the fisher community.

Data collection through secondary sources, data collection through key informants, nearly 100 fishers and household were interviewed with the help of students URACCAN, also data collection through observation was done. Preliminary results of the study were presented to members responsible of Natural Resources of the municipality and members of the Regional council in Bluefields, where the current state of the lobster fisheries and problems with enforcement of management were discussed.

SITUATION OF THE LOBSTER FISHERY:

Lobster Landings

Table 1 shows the total yield report from landings of the spiny lobster obtained from fishery effort within the period of 2000 to 2003.

Along the Caribbean Coast of Nicaragua during the year 2003, the capture and lobster fishing effort of the industrial national fleets registered was 1,234 thousand pound tail; 13 % less than year 2002 with a fishing effort of 13, 566 fishing days using 53 boats with traps, and 4,193 trips, including 24 boats which 10 of them were diving during that year.

Yield from the artisanal fishery was 1,295 thousand pounds, a reduction of 9% compared to 2002.

Table 1. Exportation of spiny lobster from Nicaragua (x 1,000 lb).

Year	2000	2001	2002	2003	Variation %
Lobster tail	4,198	2,684	2,959	2,579	- 13
Lobster (whole)	1,041				
Lobster (meat from tail)	4,4 1				
Lobster (meat from head)	254	190	163	144	

Industrialization

In the year 2003, the processing companies in Nicaragua generated a production of 26,168 thousands pounds (fresh, frozen, and iced product). The Caribbean Coast had a production of 9,690 thousand pounds, with the principal products shrimp and lobster. The Pacific provided 16,478 thousand pounds obtained mainly through shrimp and fish farming.

The processing production of fish on the Caribbean coast increased 2%, from the year 2002. For the lobster fishery, Nicaragua exportation had a reduction of 12 % for the year 2003.

The Study Site

The spiny lobster of the Caribbean (*Panulirus argus*) is distributed from the United States and Bahamas through Brazil, including the Caribbean Islands. (Barnnuty 1998).

The chosen location for the SocMon study was a pair of small inhabited islands on the vast Caribbean coastal shelf of Nicaragua known as the Corn Islands or Las Islas del Maiz (in Spanish). The largest of the two islands, Great Corn Island are situated around 83.3 km east of the city of Bluefields South Autonomous Atlantic Region (RAAS) of Nicaragua. The islands are volcanic in origin and composed by five different neighborhoods.

It has a population of over 6,500 and is just 5 km long from the north to the south, covering an area of 10.3 km^2. Little Corn Island is located 15 km to the northeast of Great Corn Island and is just one half the size with around a tenth of the population. Most of the inhabitants are of Creole origin, and the predominant language in the Corn Islands is Creole English, although Spanish and Miskito are also widely spoken document, Corn Island)

Figure 1. Location of the Corn Islands RAAS-Nicaragua

Until 1988, the main source of income for the islanders was light processing of coconuts and seafood, lobster in particular. However, in 1988 Hurricane Joan struck a devastating blow to the islands, destroying the majority of the coconut trees. Partly as a result of the storm the fishing industry has become the main source of income, and the population is almost entirely depending on the fisheries.

The island is characterized by a wide variety of ecosystems with the presence of wetlands and numerous species of mangroves as well as coral reefs on the northern shore. The climate is humid tropical; the average monthly rainfall is 50 mm, with highest rainfall (150-300 mm) occurring between July and December. The mean annual temperature is 27°C (10°C seasonal range), with prevailing winds from the northeast.

The annual population growth is estimated at 3.9% and significant seasonal population movements. The extensive population growth has already led to increased urbanization on the island, particularly in the Brig Bay area on the western side of the island, where 65% of the population is located. The vast immigration has lead to an ethnically more diverse population (including Mestizo, Miskito, and Creole) which has put further pressure on social stability in the community.

THE SOCIAL – ECONOMIC SITUATION OF CORN ISLAND AND THE LOBSTER FISHERY

Caste and Religious Background

Origin — The fishers of Corn Island do not form a ethnical homogenous group is made up of 40 % Miskito Indians, 30 % mestizo, 30% Creoles. The existence of multiple population groups constitutes a fundamental element of the past and present of the Island. The island has been mainly inhabited by Black Creoles, descendants from African slaves working on the cotton plantations on Corn Island in the 18th century. The African slaves who worked for the European settlers in the 18th century were the founders of modern Creole society on the Coast.

Language — Although Spanish is the official language spoken in Nicaragua, the municipality is run by Creoles and the first language is Creole English or the so call *spanglish*, closely followed by Spanish and Miskito. The mestizos, migrate from the pacific side of Nicaragua, usually only speak Spanish, although the Creoles are bilingual in both English and Spanish. vThe Miskitos are trilingual, speaking Creole English, Miskito and Spanish.

Religion — The Miskitos are almost all members of the Moravian church, the mestizos are mostly Catholic, and the Creoles are distributed over different religions; Moravian, Anglican, Adventist, and Baptists (Corn Island 2002: 10, interviews 2004).

Migration — The population increased from 3,000 Black land-holding Creoles in 1993 to around 6,500 residents in 2000. (CSE 2002). A group of around 1,000 people irregularly migrates to the island (Meltzoff and Schull 1999: 12). The immigrants are mostly Miskito Indians, mestizos from the Pacific, and Black-Creoles from the Atlantic Coast (Bluefields). These people move from their villages on the Atlantic coast to Corn Island in the lobster season, and migrate back to the mainland when the closed season for lobster is declared.

The Lobster Fishery

The spiny lobster is a rather sedentary species, exhibiting well-defined seasonal migratory patterns, and within a geographical limited range. Because of its sedentary nature, management should be easy to facilitated for this resource in comparison with other species.

The lobster fishery is divided into two sectors by the Fisheries Administration of Nicaragua (Moreno 2000: 25): 1. small-scale and 2. industrial' sector.

These two sectors are further defined into five different fleets:

i) Small-scale trappers,
ii) Small-scale divers,
iii) Industrial national divers,
iv) Industrial national trappers, and
v) Industrial international trappers

The first 25 nautical miles around Corn Island are reserved for the small-scale fishers, but the territorial lines consistently lead to conflicts between the industrial and small-scale fishers, since industrial boats have continued fishing in the small-scale fishing area. Small-scale fishers are not able to make a stand against the industrial boats, and governmental institutions cannot enforce these regulations by lack of means.

The different fishing techniques for lobster are trapping and diving. Diving is divided along ethnical lines. Since 1999, the government declared the prohibition of giving fishing license to boats that do diving, but those that had their licenses prior to that date retained the right to do diving. According to an informant, diving for lobster attracted many miskitos to the Island thereby causing a radical demographic change.

In Corn island there are approximately 150 – 200 permanent divers. They go diving one time per day.

Income Activity

The mestizos living on the islands are mostly shopkeepers and the leaders of commerce. The Creoles work in the processing companies (Pacific Seafood of Nicaragua - PASENIC S.A and Central American Fishery - CAF) in the island the Island; women are mainly contracted to do processing, and men go fishing on fishing vessels. The Miskito Indians, however, are divers and compete with the native Creoles for the same lobster resource.

The more wealthy Creole fishers are trappers, able to invest in their gears and boats. Most of the islanders own one or two boats (length: 4 – 7 meters) and out board engine (75 - 150 HP). These owners contract a helper when is time to go to fishing ground, the catch sell and the helper get the 25 % of the profit. If the owner has a son that can go fishing with him, the share of profit is equal.

Miskito divers are poor and unable to invest in trapping gears. Therefore, they depend on the low-capital input diving industry or small scale diving activity by going fishing with someone that's own a boast.

The average incomes for households are represented in the following graph (Figure 2). As it can be appreciated, most of the women in the households do not count as part of the family income; they depend on their husband or someone else in their family to survive. Most of these have low level of education. Those who respond that their income was between 2,000-3,000 cordobas per month are those who are working for the state (Alcaldia, ENEL, ENITEL).

"Ship out" is another alternative for source income in the island. In this case the young generation choose this option. They say that rather than fishing everyday to gain a small amount of money, they would rather go on a ship to the United States where they can make a constant salary, maintain themselves, and send some money to their family to help them survive during the closed lobster season.

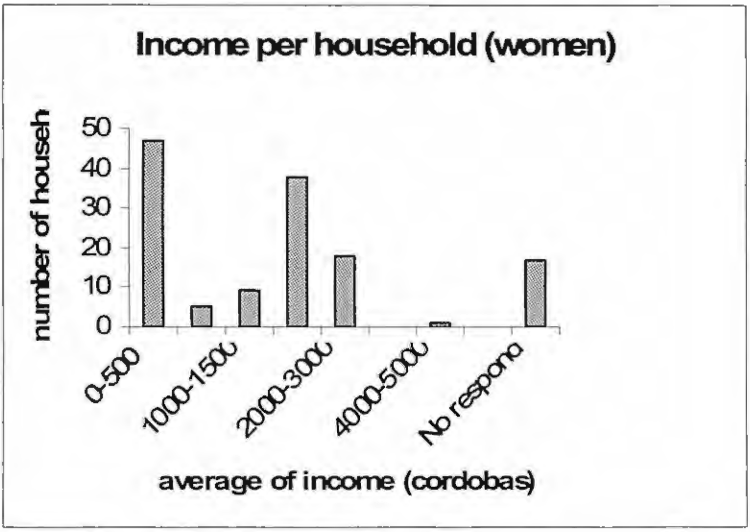


Figure 2. Average income per household on the Corn Islands RAAS—Nicaragua

The fishermen in the island making the highest annual income were the owners of boats, gears and engine, although most of them could not accurately estimate their total income.

Figure 3 represents the income per fishermen per week on the island. This graph compares how much money they was earn before and during the closed lobster season and the impact it has on their daily livelihood.

Because of the reduction of their income, the islanders have to change completely their lifestyle. There are no recreational activities; families that usually travel to Bluefield's to make shopping or to visit their family, decide to remain on the island until the closed season is over. Families whose children study off the island do not have the money to pay the fee. They buy the necessary things needed and limit themselves to other things; in place of drinking coffee with milk, they drink black coffee.

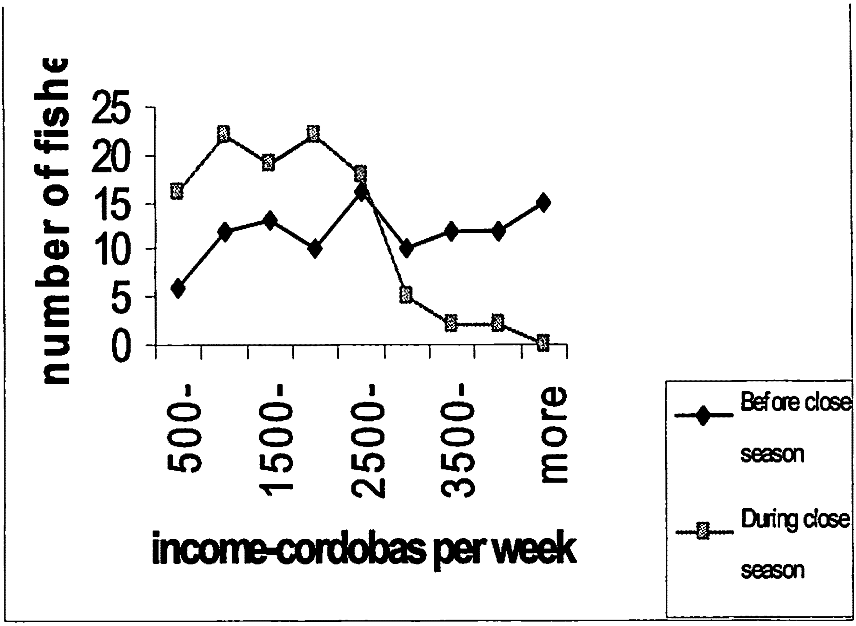


Figure 3. A comparison of fishermen income before and during the closed lobster season on Corn island

The Creoles blame the divers for ruining the lobster stock and for emptying their lobster pots at sea. While the Creole municipality would like to ban the diving industry on the island, but they are not able to prohibit diving as long as the central government still supports the diving industry..

There are two small-scale fishing organizations that they call: 1) The Fishing Union, constituted by the Black Creole trappers, and 2) the Sea Divers Cooperative, constituted by the Miskitos. These organizations are not very successful in influencing management of the fishery, however, they represent the community of Corn island.

The Miskito divers would have no alternatives to diving or money to shift to trapping since they lack the collateral to borrow money, and the Creoles would rather see them leave the Island. They do not hold enough power to demand a higher price or influence the plants' strategy. Fishers and their families do not have a history of association and institutions that work within the community. Therefore, community members have little training in collective action, representation, and reflection both within their own local community and in comparison with the larger society.

It is complex for the different fishing groups: small-scale Creole trappers; small-scale Miskito divers; industrial Miskito divers; and industrial Creole trappers, to co-ordinate their activities. The different groups do not share the same culture, language, backgrounds, or goals. The natives are worried of the situation of reduction of the fishery to their customs and as resource.

The type of problems identified during the closed lobster season is summarized in Figure 4.

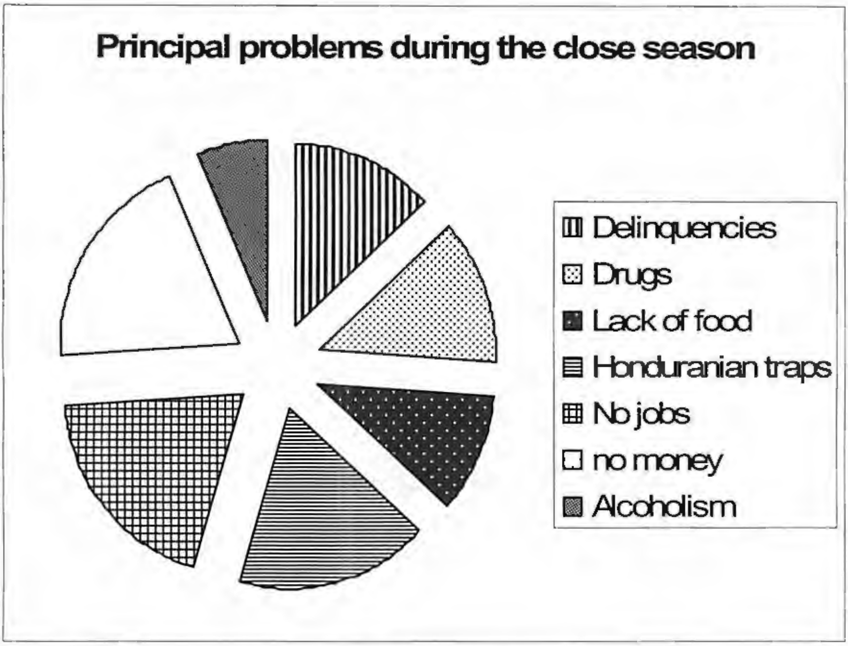


Figure 4. Principal social problems associated with the closed lobster season on the Corn Islands—RAAS, Nicaragua

Social problems include delinquencies of payments, access to money because of the absence of jobs (no other alternatives), the low value of the fish catch sales that do not cover fuel costs, and an increase in traffic and consumption of drugs and alcohol. Those who sell have money; those who do not, steal and create insecurity on the island. Taking into account all these problems, the islanders also expressed their concern with Hondurans who left their lobster traps in the water, damaging the bottom and causing ghost fishing during the closed season. To solve this specific problem, the Pacific Sea Food Company (PASENIC S.A.) pays islanders for each Honduran trap they extract from the sea and deliver to them, providing an additional source of income to the islanders.

Stealing and violent crimes are common, but the islanders express that these act are done by immigrants. They recommend that police should enforce the law. Polices are limited on the island, in the case of Little Corn Island there are no police officials; they call it the Island of No one.

The closed lobster season is composed of two different groups: those who are prepared for the closed season who are the boat owners (artisanal – Industrial), and those who are poorly prepared, who work for the owners of these boats.

The commercial sector express that they have a reduction in the demand of production, as people normally buy rice, beans, and sugar which do not cover their expenses to maintain their family, no money to purchase clothes or other things; most of them do not have money to pay their basic bills (light, telephone etc).

With regard to the two fishing industries, their activities are greatly reduced in the closed season, with a minimum number of workers processing fish, and most of the effort is dedicated to restoring, repairing, and upgrading the fishing plant in order to comply with FAO quality standards.

The islanders express that a large portion of the fishers depend on these processing plants. The lobster fishery depend on PASENIC S.A. Before and during the closed lobster season, the companies provide money or fuel and ice to the fishers. Therefore, the fishers are obligated to sell their product to the company that provides them these basic materials. The company pays the fisher the price that they establish, and the fishers have no alternative than to accept their conditions and prices in order to repay their debt. During the closed lobster season, fishing activity still takes place, primarily fishing for snappers, groupers, and kingfish, with prices oscillating between 6-9 cordobas per pound (US$0.50)

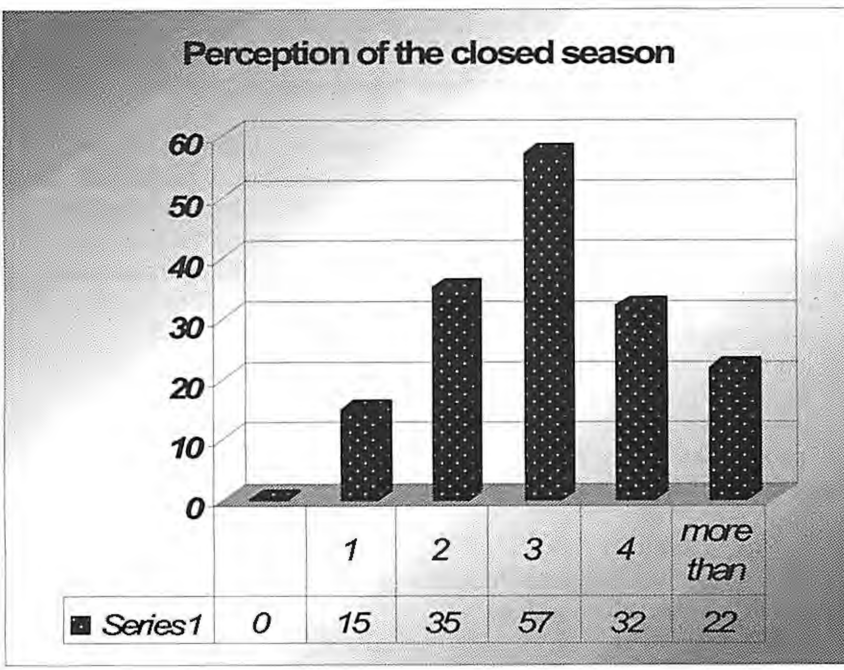


Figure 4. Fishers' perception of the appropriate length of time for a closed lobster season. Answers are presented as a percentage of those fishers interviewed (Series 1).

Most of the islanders agree with the closed lobster season; to determine the level of agreement, the following questionnaire was done. Do you agree with the closed season? How long the close season should be? Figure 4 demonstrates their level of agreement. Everyone understands the importance of the closed season, and they do recognize that it is needed. Some express their feelings around the issue and make remembrance from the pass. You can appreciate that out 159 people that this question was asked, 57 of those responded that the closed season is fine and that they can survive during this period (three months) with their savings. They express that the two first months they passed it ok, but the most difficult month was the third; but they have hopes that when the close season is over they can get back on their feet, hopeing that the catches will be higher, so they can prepare themselves for the following closed season. Thirty two of them expressed that the closed season shouldn't be just for three months, but rather it should be for more than three, some gave examples of other countries, such as Hawaii and Jamaica, where the lobster fishery collapsed and a closed season was established for years.

Reason for Decline of the Lobster Fishery

The fishery is becoming less lucrative as fishers have to go further off shore to find lobsters. Additionally, fishing effort has increased significantly as many fishers have doubled or tripled their amount of traps; an investment that has not paid off, but left many in debt.

According to the interviews the main reason for decline is thought to be over-exploitation form the national and international industrial fleets (introduction on the Hondurarian fleets and miskitos divers migrated to the island) due to a lack of enforcement of regulations limiting the fisheries. Due to lack of funding and resources, the present regulations (size-limits, protecting spawning lobster and closed seasons) have proven difficult to enforce. The current development of the fisheries has led the authorities to increase regulations.

Fishers express that the central government has been giving out fishing licenses to foreign vessels without involving the regional governmental institutions, which have requested a stop to the foreign licenses, and without taking the overexploitation into consideration.

Lobster Regulations

The Ministerio Fomento Industria y Comercio (MIFIC), have been implementing regulations such as:

i) Closed season:
   2002 01st March – 01st April.
   2003 01st March – 01st May
   2004 01st March – 29th June
   2005 01st March – 30 July

ii) Size limit: 14 inch tail or 23 inch from antenna to tail or weight of 5 ounces or greater.
iii) A lobster should have spawn even one time.
iv) Fine: Pay $ 3,800.00, confiscate the product, and cancellation of the fishing license.

PERCEPTION OF MANAGEMENT AND REGULATION

The offshore reefs, sea fan beds, and rubble-dominated shoals of the islands provide rich fishing grounds for Nicaragua's second largest export industry: the Caribbean spiny lobster fishery.

The trend towards declining fisheries output has alarmed local fisheries communities on the Corn Islands in recent years, and there has been a call for the development of management which is based on close collaboration with the fisheries community. "Closed season" has been in effect since 2000 for one month until 2002; by 2003 closed season was declared for two months; for 2004 for three months and coming closed season will be for four months. This type of management, where decision-making is shared between government and resource users, is referred as **co-management** and has increasingly gained approval as a more viable alternative to centralized management structures. By participating in the management process fishers gain a better understanding of the reasoning behind regulations, feel a common responsibility and ownership, and are more likely to comply. Co-management can also promote economic and social development within the community and reduce conflict through a process of participatory democracy.

Corn Islands, being one the centers of the artisanal lobster fisheries of the Atlantic Coast of Nicaragua, has been suggested as suitable for a pilot project for co-management. In line with this, a municipal fisheries officer has recently been appointed (beginning of 2003), and a fishery commission consisting of representatives from national and local authorities, as well as industry has been established. However, structures for fisher involvement in the management processes are still lacking.

Even though people are more prepared than other years for the closed season (2004), and expectations for an increase in lobster stock, harvest, and income for the rest of the year run high.

Fishermen are clear about the need of the close season because the lobster are limited and overexploited. Fishers realize that their income will increase if they comply with the closed season, but also they need alternative sources of income for the following season when the closed season will be increased by an additional month.

The decline in production is reflected lower income during the open season and also lower capital investment in vessels and increasing lobster trap gear costs.

Per-capita income has decreased during the last two years, particularlyl during the closed lobster season when there is no income for the majority of fishers.

One recommendation is for more investment in farming (agriculture activity), and government should emphasize and search for funds to reactivate agriculture activity to produce plantain and coconut.

The success of the lobster fishery is directly related to the economy of the island. With a decline in fishing, the population has been reduced, the number of tourists visiting the islands has declined, and drug trafficking and violent crimes have been rising, also negatively impacting tourism.

Fishers complain that official authorities and decision-makers are not really affected by the closed lobster season because they have a secure monthly salary, and do not take into account the complaints from fishers requesting alternative sources of income. Although a fishing commission was formed at the end of 2003, members of the civil society and municipal government comprised this commission without much input from the fishing community.

Most fishermen believe that the closed lobster season will make the lobster stock increase in the region, and fishers believe that they will be the primary beneficiaries of this strategy.

Finally, a majority of the respondents agree to establish the closed lobster season for the following year (four months), but government needs to provide alternative sources of income for the islanders to survive for this period. Government investment to improve tourism, construct a coconut processing plant, and incentives to develop agriculture on the islands seem to be realistic options.

The Value of Documenting Fishing Practices of Local Fishers

NORMAN J. QUINN
Discovery Bay Marine Laboratory
University of the West Indies
Discovery Bay
St. Ann, Jamaica

ABSTRACT

Much of what we know about the natural resources of developed countries can be found in libraries or on the internet. However, in lesser-developed countries, most of this knowledge exists only in the minds of experienced and skilled men and women. Together with 32 Melanesians we have assembled a 128 page illustrated book titled *Aquatic Knowledge and Fishing Practices in Melanesia*. The 30 essays recording traditional fishing customs were written by students of the Papua New Guinea (PNG) University of Technology, University of the South Pacific and the University of PNG. The essays were written after students had spoken with village elders and participated in fishing activities. Caribbean fishers also have an important body of fisheries knowledge that is largely unrecorded and under appreciated. Young, educated students in the Caribbean are among those citizens who know least about such things. Many spend their learning years away from fishing communities both physically and socially. They are seldom taught to understand and respect these knowledge systems and customs. Paradoxically, these are the citizens who will be given the duties and responsibilities to determine the future conservation and development strategies for their countries. It is unlikely that their training can be fully applied without greater fundamental knowledge of local marine resources. Many of these countries do not have the financial resources or human capacity required to conduct scientific surveys necessary to obtain information known by local fishers. I urge universities, NGOs, government agencies, and others to establish a coordinated program where young, educated Caribbean scholars work within their communities to establish partnerships with local fishing groups and document this knowledge while respecting intellectual property values.

KEY WORDS: Marine education, Caribbean, Melanesia

El Valor de Documentar las Prácticas de Pesca y el Conocimiento Acuático de los Pescadores Locales

Se dice que gran parte de lo que se conoce sobre los recursos naturales de los países desarrollados se puede encontrar en librerias o en el Internet. Sin embargo, en los países menos desarrollados, este conocimiento solo existe en la mente de los hombres y mujeres con destrezas y experiencia. Junto a 32 Melanesios, hemos ensamblado un libro ilustrado de 124 páginas titulado "*Aquatic Knowledge and Fishing Practices in Melanesia*" (Conocimiento

Acuático y Prácticas de Pesca en Melanesia). Estos 30 ensayos que recopilan costumbres tradicionales de pesca han sido escritos por estudiantes de la Universidad de Tecnología de Papua Nueva Guinea (PNG, por sus siglas en inglés), la Universidad del Pacífico Sur, y la Universidad de PNG. Los ensayos fueron escritos luego de que los estudiantes conversaran con personas de edad avanzada de la aldea y participaran en actividades de pesca. Los pescadores Caribenos poseen una importante cantidad de información acuática la cual muy pocas veces es apreciada y recopilada. Esta representa un recurso vital de información del tiempo en el que la gente aceptaba la autoridad de la naturaleza y aprendían por medio de la experimentación, sus errores, y observación. Podemos encontrar estudiantes Caribenos jóvenes con educación entre los ciudadanos que menos conocimiento tienen sobre estos asuntos. Muchos de ellos pasan sus años de estudio lejos de las comunidades pesqueras física y socialmente. Apenas se les enseña a entender y a respetar este conocimiento del sistema y las costumbres. Paradójicamente estos son los ciudadanos que tienen la misión y la responsabilidad de determinar los medios de conservación para el futuro y desarrollar estratégias para sus comunidades. Es poco probable que puedan aplicar plenamente sus conocimientos si no tienen un conocimiento fundamental de los recursos marinos locales. La mayoría de estos países no tienen los recursos financieros ni la capacidad de personal necesaria para conducir los estudios científicos necesarios para obtener la información que pueden ofrecer los pescadores locales. Yo exhorto a las universidades, a las organizaciones no gubernamentales, a las agencias de gobierno y al público en general a establecer un programa coordinado en el cual los estudiantes jóvenes del Caribe trabajen en sus comunidades para establecer una asociación con los grupos de pescadores locales para documentar esta fuente de información y conocimiento respetando sus propios valores intelectuales.

PALABRAS CLAVES: Marine education, Caribbean, Melanesia

INTRODUCTION

Much of what we know about the natural resources of developed countries can be found in libraries and accessed on the internet. However, in Melanesia and much of the Caribbean, knowledge about many fishing practices exists only in the minds of experienced and skilled fishers.

Over the ages, Melanesian societies have developed innumerable marine technologies and sciences. They have devised ways to navigate vast distances in the Pacific using their knowledge of currents and the feel of intermittent waves that bounce off distant islands, as well as acquiring an understanding of the ecology of marine resources. Much of the traditional aquatic knowledge in Melanesia is undocumented and represents each society's lifeline to a time when people accepted nature's authority and learned through trial, error and observation. Anthropologists who first explored the societies of the Pacific were more interested in kinship relations than what has sustained this coastal community for generations (Firth 1963).

Much of this knowledge is dying out or being absorbed into modern civilization. As they vanish, so does their irreplaceable knowledge. Fibreglass boats are replacing dugout canoes. With this change goes the knowledge about which are the best trees to use, when and how to cut them. The use of outboard motors is replacing the sail and with it the knowledge of the winds currents that assisted the vessels powered by natural forces.

If this knowledge had to be duplicated from scratch by scientific resources of more developed countries, it would require lots of money and take many trained scientists a long time. Much of this local expertise and Melanesian wisdom has already disappeared, and if neglected, most of the remainder could be gone within the next generation.

Together with 32 Melanesian nationals we have assembled a 128 page illustrated collection of essays titled *Aquatic Knowledge and Fishing Practices in Melanesia* (*AKFPM*). The book is based on manuscripts written by students at the Papua New Guinea (PNG) University of Technology, Lae; the University of PNG, Port Moresby; and the University of the South Pacific (USP), Fiji. The essays were written after they had spoken with village elders and in some cases participated in fishing activities. The book is an important first effort to involve indigenous citizens in the documentation and review of their culture and traditions.

DOCUMENTING MELANESIAN FISHERIES KNOWLEDGE

Young, formally educated students are among those citizens who know least about village customs and knowledge. Their learning years are spent far from their ancestral villages and they are seldom taught to understand and respect these knowledge systems and customs. Paradoxically, these are the citizens who will be given the duties and responsibilities to determine the future conservation and development strategies for their country. It is unlikely that their socio-economic and technological sophistication can be fully applied without the fundamental knowledge that their culture possesses of the surrounding natural resources.

The shorter published essays were selected from > 100 students' essays written for various courses I taught at several universities in the South Pacific between 1980 and 2000. The longer essays were specifically written by students for this project. Discussions about the value of local knowledge and resource management were conducted and students were given relevant material to read and later discuss.

The initial approach in the village was to develop a list using local names of marine organisms. Several books were used, but more frequently used was *The Fishes of New Guinea* (Munro 1967). The knowledge was not monolithic. At times when I participated I observed arguments over local names of fish species. Perhaps it was an argument over the drawing in the book and not the actual name of the fish.

The essays were edited and shortened. Changing vocabulary and shortening sentences without altering meaning is difficult. If meanings have changed it is entirely my fault. Wherever possible, the essays have been read for accuracy by other people from the area. However, the information has not been subjected to verification which is an important step in legitimizing the information and removing inconsistencies. As well, linguistic analysis would assist in determining if the local taxonomies correctly reflect scientific taxonomies (Ruddle 1994).

AKFPM has been written for two different readership groups. The first group contains short, illustrated essays, without Latin names of the biota and without citation designed to meet the needs of a secondary school system lacking local material suitably written for Melanesian youth. The second group of essays is longer with more detail and is written for a more educated readership. All of the essays offer various levels of insight into the communities and make interesting reading.

AKFPM contains not only essays about Melanesian societies who have long used the sea (Daudau and Quinn 2004), but also an essay about a Melanesian society that transitioned after World War II from upland, interior society based on tribal warfare and cannibalism to a society living on the coast, learning to utilize for the first time marine resources (Arnhambat and Quinn 2004).

Other *AKFPM* essays deal with Polynesian enclaves in Melanesia. Although Rotuma is politically part of the Republic of Fiji and 550 km from the capital Suva, it is ethnically Polynesian. Because of its remoteness and the migration of young Rotumans to find work and diversion away from Rotuma, the island's fisheries resources are free of pollution and still abundant (Fui and Naqasima-Sobey 2004).

Not all of the information deals with sustenance. The chewing of betel nut is a common social practice in regions of Melanesia where *kava* (*Piper methysticum*) is not consumed and religious practices do not presently prohibit it. Many Papua New Guineans and Solomon Islanders chew. The effect relaxes and relieves anxiety and hunger pains among other social purposes. However, in order for the effect to occur lime must be added (Mahoney et al. 1985). The source for the lime is the corals and mollusks shells of the coral reefs and coastal mangroves where it is collected, processed and sold by women (Quinn 1985).

Although the book is about local knowledge we have deliberately decided to minimize the knowledge based on spiritual belief systems or legends included in the book. Spirit (*masalai*) belief is one of the traditional concepts still commanding widespread respect, even among many educated people. *Masalai* are considered to protect resources in an environment in which humans are considered to be an intruder. The invocation of powers of a *masalai* over a resource are effective as a management tool in that the area or species is avoided for fear of sickness or death that is believed to be the result of displeasing the *masalai* (Wright 1985).

In reading the *AKFPM* essays the reader will recognize similarities among the descriptions of knowledge in the essays. The information is based on long-term, empirical, local observations that are practical and focus on valuable species. The knowledge base is also dynamic and open to accepting new technologies or concepts and is indicative of peoples who have an acute level of environment awareness.

INTELLECTUAL PROPERTY ISSUES

While the students were encouraged to document the local aquatic knowledge and were given recognition for writing up this knowledge, it is recognized that the authors are not the repository of the body of knowledge, but rather the messenger. The ownership of the knowledge belonged collectively to the people and their proprietary rights are respected.

Information deemed to have commercial implications was removed from the essays. For example, the knowledge about spawning aggregations could be used by commercial fishing operations to overexploit the resource and either harm the community's sustenance or diminish its ability to sustainably exploit the resource commercially in the future. While in the Caribbean the collection of this information from Cuban fishers is being applied in the design of marine reserve networks (Claro and Lindeman 2003), the potential for abuse in the Pacific is greater.

The preservation of these intellectual property rights (IPR) are considered to be vital to the conservation and sustainable use of biodiversity. In western society this demarcation is clearer because western IPR systems are based on private rights and only recognize collectively held knowledge if the 'community' is a company (Downes et al 1999).

THE NEED FOR LOCAL FISHING KNOWLEDGE IN THE CARIBBEAN

It is undoubtedly altruistic and naïve to think that artisanal knowledge by itself will provide a model for development of marine resources. Whatever a society's aspirations, a localized worldview and locally developed assertions about how to best manage fisheries still arise among fishing peoples at every level of technological sophistication. It is necessary to document the local knowledge to help improve the understanding of these societies if fisheries management is to be more effective in the future.

Caribbean educational institutes have a responsibility to help retain such knowledge and transmit it to future generations. However, without printed material for the teachers and students to use, it is excluded from the curricula. The exclusion amounts, unintentionally, to a tacit assertion that it is no longer worth learning. *AKFPM* is making an important contribution to fill this void in Melanesia as the book will be used by the PNG Education Department in secondary schools and in universities throughout Melanesia. But what is being done in the Caribbean?

Although there have been many publications describing the fish fauna of the region, there have been only a few efforts to document the wealth of marine knowledge and the diverse fishing practices of the Caribbean, and there is nothing written for Caribbean school children. The deeply disturbing news from the Jamaican Ministry of Education is that barely over ½ of the 10 year olds currently in school have mastered word recognition, reading, and comprehension. For teachers to motivate and stimulate students to learn to read they need good books dealing with subject matter of local interest and relevance.

The Jamaican Minister of Education said that she was going to address the problem by "putting in place in schools a new curriculum" and "new support materials" to combat the illiteracy problem. I suggest a book documenting Caribbean wide aquatic knowledge and fishing practices might help to stimulate young students to want to read and better understand the local marine world. This then might contribute to increasing the body politics' concern for implementing effective management practices and to credibly enforce them.

I urge universities, NGOs, government agencies, and others to establish a coordinated program where young, educated Caribbean scholars work within their communities to establish partnerships with local fishing groups and document local aquatic knowledge while respecting intellectual property values. The essays could be written by tertiary level students throughout the Caribbean either as part of a course or as paid summer employment. Having tertiary level students seek the knowledge of local fishers is a dramatic change from the current approach which dismisses local fishing knowledge. It is important to recognize that communities be participants in the management process. With a respect built upon an understanding of artisanal fisheries managers would be in a better position to make management decisions in a partnership with fishers.

ACKNOWLEDGEMENTS

I am deeply grateful to all fishers throughout Melanesia who willing shared their knowledge, wisdom, time, hospitality and sense of humor. Their patience and cooperation helped me develop many ideas that guided this project. Professors L. Hill and P. Newell are thanked for their support and encouragement. Financial support for the travel expenses was provided by the Papua New Guinea University of Technology, the University of Papua New Guinea, the University of the South Pacific, University of the West Indies and the Tropical Discoveries Fund. The final editing and layout was completed while I was on study leave from the University of the West Indies. This is DBML publication #699. B.L. Kojis is gratefully acknowledged for reviewing this manuscript.

LITERATURE CITED

Arnhambat, J. and N.J. Quinn. 2004. Recent acquisition of marine knowledge and fishing techniques of Nuos villagers on Malekula Island, Vanuatu. Pages 116-120 in: N.J. Quinn (ed.). *Aquatic Knowledge and Fishing Practices in Melanesia*. CBS Publishing, New Delhi, India. 128 pp.

Claro, R. and K.C. Lindeman. 2003. Spawning aggregation sites of snapper and grouper species (Lutjanidae and Serranidae) on the Insular shelf of Cuba. *Gulf and Caribbean Research* 14(2):91-106.

Daudau, P. and N.J. Quinn. 2004. Subsistence fishing practices and local knowledge at Ferafalu Village, Maana'oba Island, Malaita Province, Solomon Islands. Pages 100-113 in: N.J. Quinn (ed.). *Aquatic Knowledge and Fishing Practices in Melanesia*. CBS Publishing, New Delhi, India. 128 pp.

Downes, D., G. Dutfield, M. Halle, C. Takase and T. Winqvist. 1999. Intellectual Property Rights: A Battleground for Trade and Biodiversity. IUCN, Gland 16 pp.

Firth, R. 1963. *We, the Tikopians*. Beacon Press, Boston, Massachusetts USA. 488 pp.

Fui, M. and M. Naqasima-Sobey. 2004. Fishing practices and related customs of Rotuma, Fiji. Pages. 81-85. in: N.J. Quinn (ed.). *Aquatic Knowledge and Fishing Practices in Melanesia*. CBS Publishing, New Delhi, India. 128 pp.

Mahoney, D., N.J. Quinn, P. Afenya, and S. Hugman. 1985. The technology and economics of *kambung* (CaO) production for *buai* mastication in Papua New Guinea. Pages 65-70 in: Proceedings of the 2nd PNG Chemistry Society Congress. Lae, Papua New Guinea.

Munro, I.S.R. 1967. *The Fishes of New Guinea*. Department of Agriculture, Stock and Fisheries. Port Moresby, New Guinea. 650 pp.

Quinn, N.J. 1985. Labu Butu's lime factory. *Yumi Kirapim* **28**:10-11.

Quinn, N.J. (ed.) 2004. *Aquatic Knowledge and Fishing Practices in Melanesia*. CBS Publishing, New Delhi. 128 pp.

Quinn, N.J., B.L. Kojis, B. Anguru, C. Chee, O. Keon, and P. Muller. 1985. The status and conservation of a newly "discovered" Leatherback turtle (*Dermochelys coriacea* L., 1766) chelonery at Maus Buang, Papua New Guinea. *Proceedings of the 3rd South Pacific National Parks and Reserves Conference*. **2**:90-99.

Ruddle, K. 1994. Local knowledge in the folk management of fisheries and coastal marine environments. Pages 161-206 in: C.L. Dyer, and J.R. McGoodwin (eds.). *Folk Management in the World's Fisheries*. University Press of Colorado, Boulder, Colorado USA. 347 pp.

Wright, A. 1985. Marine resource use in Papua New Guinea: Can traditional concepts and contemporary development be integrated? Pages 79-99 in: K. Ruddle and R.E. Johannes (eds.). *The Traditional Knowledge and Management of the Coastal Systems in Asia and the Pacific*. UNESCO Jakarta, Indonesia. 313 pp.

BLANK PAGE

Negotiating Difference: Stakeholder Challenges in MPA Co-Management

TARA C. GOETZE
McMaster University
46 Mary Street
Georgetown, Ontario, Canada L7G 4V3

ABSTRACT

This paper considers the complexities involved in the co-management of marine protected areas involving local NGOs. Based on field research in Belize, it examines the interactions between local NGOs involved in the MPA co-management process with state agencies, and local users, focusing on fishers and tour guides. These interactions highlight the fact that the interests of local NGOs and the resource users they represent are not always convergent. Yet the challenges of negotiating the shifting and, at times, divergent interests are ones for which NGOs are often not prepared to meet. This paper argues that, in tandem with training in strategic planning and proposal writing, negotiation and conflict mediation skills are crucial to the success of building positive relations between local NGOs and community stakeholders and, in turn, to fostering long-term success in the co-management process.

KEY WORDS: Belize, Co-management, Marine Protected Areas

Negociando Diferencias: Retos en el Co-manejo de Áreas Protegidas Marinas

Este documento considera a las complejidades involucradas en el co-manejo de áreas protejas marinas involucrando a ONG's locales. Basado en investigaciones de campo realizadas en Belice, este estudio examina las interacciones entre ONG's locales involucradas con agencias estatales y usuarios locales en el proceso de co-manejo de Áreas Protegidas Marinas, con un enfoque en pescadores y guías turísticas. Estas interacciones demuestra que las intereses de las ONG's locales y los usuarios de los recursos no siempre son convergentes. Sin embargo, los retos de negociar intereses inconstantes y a veces divergentes son tal que los ONG's no están preparados de cumplir. Este documento argumenta que capacitación en planificación estratégico y escribiendo propuestas en conjunto con capacidades en negociación y mediación de conflictos son cruciales para la formación de relaciones positivas entre ONG's locales y usuarios de los recursos de las comunidades y a la vez, para cultivar los éxitos a largo plazo del proceso de co-manejo.

PALABRAS CLAVES: Belice, áreas protejas marinas, co-manejo

INTRODUCTION

It is widely agreed that co-management is as much, if not more, about managing the relationships between stakeholders as it is about managing the resources themselves (Pinkerton 1989, Berkes et. al. 1991, Buckles and Rusnak 1999, Berkes et. al. 2001). In this paper, I examine one dimension of the complex process of managing stakeholder relations in the co-management of MPAs.

Co-management of MPAs involves multiple stakeholders in the implementation of various conservation strategies as the means to the protection of particular marine species or ecosystems. There are typically three key stakeholders: local users, state agencies, and transnational conservation NGOs (CNGOs). While all three share the desire to protect marine resources, it is not unusual for them to have divergent ideas about how this is best achieved. This can, and often does, lead to conflict between stakeholders, a situation that compromises the cooperative effort and, in turn, the effective management of the resource(s) (Goetze 1998, Buckles and Rusnak 1999). The conflict in most cases, is between local users; for example between fishermen and tour guides.

The co-management of Gladden Spit Marine Reserve (GSMR) in southern Belize exemplifies such a scenario of stakeholder conflict, but at a different level. While there are many intriguing dimensions to stakeholder relations in this case, one of the most challenging stakeholder relationships to manage is that between donors and local users. Here I focus specifically on conflicting understandings between local fishers and researchers working for CNGOs concerning 'the problem' of overfishing of spawning aggregations (SPAGs) in GSMR . This conflict underscores the fact that (1) conflicts can take place at levels that transcend local issues, and (2) that negotiating such differences in local and global level stakeholders' perspectives concerning the cause of 'resource problems' and the attendant solution represents a key challenge in the successful co-management of MPAs.

The Co-Management of Gladden Spit Marine Reserve

GSMR was declared an MPA in 2000, based largely on CNGOs' concerns over the threats to grouper and snapper SPAGs in the area, which are noted as being among the healthiest in the Caribbean region. Historically, local fishers have harvested the SPAGs as a means to surviving economically during the months in which Belize's lobster season is closed (February to June). The most popular SPAG to fish features snapper, which spawn during the full moons from April to June. While fishers have also harvested grouper SPAGs (November to January), it is viewed as a less commercially viable species. Moreover, one can still fish for lobster during those months, a far more lucrative activity: during the 2000 - 2001 season, lobster fetched $15.00/lb at the local Co-operative, while scale fish garnered a mere $2.50/lb (Placencia Fishermen's Co-operative 2001:5). As a result of this and an increase in local tourism from November to April, area SPAGs have received increasingly less attention from local fishermen over the past decade. Indeed, production numbers from the local Co-op show a steady decline in scale fish production since the mid-nineties (Palacio 2001:30). More recently, Gladden's SPAGs, which predictably attract whale sharks, have become a popular tourist attraction. Locally-based and foreign tour operators offer trips to snorkel and dive among the whale sharks during the spawning season.

Similar to the co-management of MPAs elsewhere, the stakeholders involved in the co-management of GSMR include local users (fishermen and tour guides), state agencies (Department of Fisheries) and CNGOs (World Wildlife Fund, The Nature Conservancy, etc). Legally, the co-management partners for GSMR are Friends of Nature (FON), a community-based NGO which represents local users (largely fishermen and tour guides) in five area villages, and the Fisheries Department. As stipulated in the co-management agreement, FON has legal responsibility for developing a management plan for GSMR and implementing the daily management activities contained therein. Co-management of GSMR would not be realized, however, without the funding from CNGO donors such as the Oak Foundation, Conservation International, the Global Environment Facility and, more recently, The Nature Conservancy.

Overfishing? Conflicting Local-Global Perspectives

During thirteen months of fieldwork in Placencia Village, where FON is based, I conducted over fifty semi-structured recorded interviews and dozens of informal interviews with local, national and international stakeholders. Interview questions focused on stakeholders' understandings of MPAs, co-management and what the key resource management and/or conservation issues were in the MPAs that FON co-manages. During both the formal and informal interviews the issue of overfishing of the SPAGs was raised as a key problem in GSMR, and a concern for local fishermen and CNGOs alike. That being said, each group holds divergent views of the cause of the problem of overfishing in the area. CNGO representatives focused heavily on the use of the SPAGs by local fishermen, and consistently pointed to the need to promote alternative livelihoods for fishers to reduce the stress to the resource caused by their seasonal harvest. The implication suggested that the solution to the problem of overfishing was for local fishermen were to shift their efforts to non-extractive tour guiding activities.

Fishermen, on the other hand, were aware of these claims, and were at a loss to see how their fishing with a two-hook handline system could alone significantly affect the SPAGs. Rather, they argued, it was fishers from other areas of Belize, together with those from Guatemala and Honduras (who did not have licenses), who were causing the depletion of fish from the SPAGs. Indeed, they had observed the used of illegal gear such as nets, and suggested that foreign fishers used technology such as fish attracting devices and GPS that, together with fishing at night, amounted to their 'stealing' far more fish than local fishers could ever harvest themselves. Since foreign fishers take their catch out of the country, they said, there is no way to know just how much is being 'lost' to their harvest of the SPAGs. The solution as they see it, it to increase patrols of the GSMR area during the spawning season, and to both increase the punishment for poaching and implement it when transgressors are caught, something they complain is not happening at the present time.

Co-Management Challenges

The point of exposing the divergent views on the problem of overfishing in GSMR's SPAGs here is not to evaluate which actor's claim or knowledge is more accurate, and therefore 'more legitimate'. This paper does not seek to establish who is 'right' concerning the issue, but to highlight how such differences relate to the process of successfully co-managing MPAs.

The first point, then is that stakeholders' understandings of the problem of overfishing relates to their *interests* concerning the resources of GSMR and how they value the SPAGs. CNGOs wish to protect the SPAGs as a critically important biological phenomenon that relates to the survival of the species by restricting fishing of these key breeding grounds. Though not to the exclusion of local livelihoods, the focus is on biodiversity as key to the survival of the planet. Hence the promotion of alternative livelihood training for local fishermen harvesting the SPAGs in GSMR. Fishermen wish to protect the SPAGs by eliminating foreign fishers as their value of the resource relates to their means of livelihood; their ultimate concern is for the protection of the SPAGs as a resource that facilitates the survival of their families. As a result, they emphasize the need to increase enforcement of existing management regulations. Thus, there is an intersection of global and local interests regarding the use and management of SPAGs in GSMR.

Second, the differences in understanding between fishers and donor researchers reflect a fracture between local and global perceptions of a key management issue. This is a serious challenge to the successful co-management of GSMR. Stakeholders who view the problem differently will also differ in what they think the most appropriate solution(s) would be. Tension, and often conflict, emerges as a result. In this case, fishermen suspect that CNGOs simply want to 'get them out of the way' and are threatening their survival. Such a lack of trust impedes the cooperative spirit that allows for the negotiation of differences required for co-management to succeed (Pinkerton 1989, Goetze 1998). Ultimately, this tension in the relationship between the local fishers that use the resources of GSMR and CNGOs that fund the co-management of the MPA, affects not only the level of cooperation between stakeholders but also the ability of FON to implement management strategies with which local users will willingly comply.

It was during the process of community consultation regarding the draft management plan for GSMR that FON faced the challenge of negotiating the differences between donor and fishers' perceptions concerning the means to protecting the resources of GSMR. As the organization charged with developing and implementing GSMR management activities, FON has become caught between meeting the demands of its CNGO donors to promote alternative livelihoods for local fishers and, at the same time, representing the interests of those fishers who cry foul over being, as they see it, unfairly targeted as the cause of overfishing. This is a difficult scenario for FON to negotiate as an organization that grew out of community concern for the protection of local marine resources, yet also was greatly assisted in its development by CNGO staff and project funding. Moreover, it has caused delays in finalizing the management plan and implementing measures for the protection of SPAGs in

GSMR. While it has had success in managing conflict between local stakeholders, negotiating differences in local-global perceptions of resource issues in GSMR is a role for which FON was not prepared. It is a unique challenge, and mechanisms for addressing such a scenario, while not the scope of this paper, would usefully addressed in future research.

CONCLUSION

Using the issue of overfishing of GSMR's spawning aggregation, this paper showed the ways in which local and global claims to marine resource management come into conflict over how the problem of overfishing is constructed and, in turn, what the solution to the problem is imagined to be. This highlights the fact that one of the key challenges to achieving successful MPA co-management is the negotiation of the differences between local and global perspectives regarding the means to effectively achieving the conservation of marine resources.

LITERATURE CITED

Berkes, F., P. George, and R.J. Preston. 1991. Co-Management: The Evolution in Theory and Practice of the Joint Administration of Living Resources. *Alternatives* 18(2):12-18.

Berkes, F., R. Mahon, P. McConney, R. Pollnac, and R. Pomeroy. 2001. *Managing Small-Scale Fisheries: Alternative Directions and Methods.* International Development Research Centre, Canada. 320pp

Buckles, D. and G. Rusnak. 1999. Conflict and Collaboration in Natural Resource Management. Pages 1-12 in: D. Buckles (ed.). *Cultivating Peace: Conflict and Collaboration in Natural Resource Management.* International Development Research Centre, Ottawa, Canada.

Goetze, T. 1998. Reaching for New Perspectives on Co-Management with First Nations: Exploring the Possibilities for Conflict Management, Indigenous Rights, and Systemic Change Under the Interim Measures Agreement in Clayoquot Sound, BC. MA Thesis, Department of Anthropology, McMaster University, Ontario, Canada.

Palacio, J. 2001. *Past and Present Uses of Coastal Resources in Southern Belize.* International Development Research Centre, Ottawa, Canada.

Pinkerton, E. 1989. Introduction: Attaining Better Fisheries Management through Co-Management - Prospects, Problems, and Propositions. Pages 3-33 in: E. Pinkerton (ed.). *Co-operative Management of Local Fisheries.* UBC Press, Vancouver, Canada.

Placencia Fishermen's Cooperative. 2001. *Annual Report.* Placencia, Belize.

BLANK PAGE

Possible Paths to Co-managing the Sea Egg Fishery of Barbados

CHRISTOPHER PARKER[1] and MARIA PENA[2]
[1]*Fisheries Division, Ministry of Agriculture and Rural Development,*
Princess Alice Highway
Bridgetown, Barbados
[2]*Centre for Resources Management and Environmental Studies*
University of the West Indies,
Cave Hill, St. Michael, Barbados

ABSTRACT

From the latter half of the 1980s and throughout the 1990s, consistently low stock sizes had effectively collapsed the fishery for the white sea urchin *Tripneustes ventricosus* (locally known as the sea egg) in Barbados. In 2001, the sea egg stock recovered to a level that had not been observed during the preceding two decades. Government authorities and scientists all agree that sustainability of the fishery can only be achieved through co-management arrangements that include fishers. The resource's wide distribution around the island and ease of accessibility negates the possibility of adopting the small-scale community management model that has proved successful in the St. Lucia sea egg fishery. From the latter half of the 1990s, a number of governmental and non-governmental agencies have investigated the potential and means to co-manage this fishery. The outputs of projects, conducted during the last five years, which facilitated fisher participation in resource assessment and analysis and examined ways of establishing formal co-management arrangements for the Barbados sea egg fishery, are examined in this paper. The multi-phase Coastal Co-management Project (CORECOMP) commenced in 2001, implemented first by the Caribbean Conservation Association (CCA) and then the Centre for Resources Management and Environmental Studies (CERMES) of the University of the West Indies (UWI). As a result of these and other efforts, fisher participation in monitoring the status of the resource and in influencing management decisions to some degree has increased over the last five years. However, a formal co-management arrangement for this fishery remains elusive for reasons that are biophysical, socio-economic and institutional.

KEY WORDS: Sea egg fishery, CORECOMP, co-management

Posibles vias para el Co-manejo de la Pesca de Erizo de Mar en Barbados

A partir de finales de los años 1980s y a lo largo de los 1990s la consistente baja en tamaños, ha logrado colapsar de manera efectiva la pesca de erizo de mar blanco *Tripneustes ventricosus* (conocidos localmente como huevos marinos) en Barbados. En el 2001 la reserva de erizo de mar logró recuperarse a un nivel que no se había observado durante las dos decadas pasadas. Las autoridades de gobierno y los científicos coincidieron que la sostenibilidad de la pesca solo puede lograrse a través de acuerdos para el co-manejo que incluya a los pescadores. La amplia distribución del recurso alrededor de la isla y su facil acceso niegan la posibilidad de adoptar un modelo de manejo comunitarioa pequeña escala que ha probado ser exitoso en la pesca de huevos marinos en Sta. Lucía. A partir de finales de los años 1990s un sinnúmero de agencias gubernamentales y no gubernamentales han investigado el potencial y los medios para el co-manejo de esta pesquería. Los resultados de proyectos, conducidos durante los pasados cinco años, que facilitaron la participación de pescadores en evaluación y análisis del recurso y examinado las formas para establecer arreglos para un co-manejo formal para a pesca de huevos marinos en Babados, son examinados en esta ponencia. El multifase proyecto de Co-manejo Costero (CORECOMP) inició en el año 2001, implementado inicialmente por la Asociación para la Conservación de Carribe (CCA) y posteriormente por el Centro de Manejo de Recursos y Estudios Ambientales (CERMES) de la Universidad de West Indies (UWI)). Como resultado de estos y otros esfuerzos, la participación de pescadores en el monitoreo del estatus del recurso y en influenciar decisiones para el manejo, hasta cierto grado, ha aumentado a lo largo de estos cinco años. Sin embargo, un arrreglo formal de co-manejo para esta pesca aún no se consolida por razones bio-físicos, soco-económco e nstitucional.

PALABRAS CLAVES: Pesca de erizo de mar, CORECOMP, co-manejo

INTRODUCTION

The Barbados sea egg (*Tripnuestes ventricosus*) fishery has been under legislative control since 1879. Closed seasons, coinciding with the presumed peak reproductive period of the animals, have hitherto been the main regulatory mechanism employed for managing this fishery. Historical records indicate that during this long period of management, the sea egg fishery has declined sufficiently on a number of occasions to become of concern for management authorities. However, it was not until the mid-1980s that it was deemed that the local stock had collapsed. Apart from a few years during which some moderate increases in stock sizes were noted, the stock remained in a depleted state for most years between the mid-1980s and throughout the 1990s (Parker 2002, Mahon et al. 2003, McConney et al. 2003, Parker In prep).

The collapse of the stock triggered a flurry of interest in the sea egg fishery from government, scientists, the general public, and of course, the fishers and called for investigations aimed at identifying the causes of the collapse and ways to rehabilitate the stock and subsequently manage the sea egg fishery in a sustainable manner. From the early 1990s the consensus of researchers and management authorities was that management regulations requiring government enforcement would be unsuccessful. Co-management arrangements involving fishers and government were recommended. The Fisheries Division advocated co-management of the sea egg fishery in its first Fisheries Management Plan (FMP) for the period 1997 - 2000 (Fisheries

Division 1997). All three subsequent FMPs have continued to promote co-management of the fishery.

The 1997 - 2000 FMP promoted fisher participation in the management of local fisheries in general not just for the sea egg fishery. Indeed the FMP itself had been developed through a process that involved the participation of fishing industry stakeholders. The organisation of fisherfolk into coherent bodies that could provide a collective representative voice for the fishing community was the first step in developing co-management. However, up to the late 1990s, Barbadian fisherfolk organisations had deservedly earned the reputation of being ephemeral as they were usually only formed and active during times of perceived crises or as a means to lobby government to redress situations specific to their members. The few longer-lasting organisations eventually came to rely heavily on government assistance to maintain them. With this history, it was clear that efforts on the part of government and other relevant non-governmental agencies were needed to forge viable and sustainable fisherfolk organisations (McConney et al. 1998).

While a formal co-management arrangement is not yet in effect for the Barbados sea egg fishery, several strides have been made in facilitating the participation of fishers in the decision-making process. A number of agencies, both governmental and non-governmental have been integral in the fostering of co-management of the fishery through specific projects. Detailed reports of these projects have been produced with some remaining in the domain of "grey literature" and others published in mainstream journals. However, it is important that these projects not to be viewed as isolated but rather as stepping-stones defining a path to the final goal of co-management. To this end an overview of the significant outcomes, both successes and failures, of these projects in addition to other relevant issues such as the ecology of the resource and the framework of fisheries legislation, is needed to guide policy-makers and stakeholders. The main objective of this paper is to provide such a guiding overview.

LEGISLATIVE FRAMEWORK

The first laws governing the sea egg fishery were embodied in the Sea Egg Preservation Act of 1879. The main regulatory mechanism in the Sea Egg Preservation Act was the establishment of an annual fishing closed season presumably planned to encompass the animals' peak spawning season. Although the period between 1st April and 31st August, inclusive, was stipulated as the closed fishing season in the Act, a clause was also included giving the authorities the legal right to change the harvest period via an announcement in the Official Gazette. Fines, terms of imprisonment and confiscation of fishing gear and boats were the punitive measures recommended for breaking the laws embodied in the Act. In 1904 the articles of the Sea Egg Preservation Act were retained in the Fisheries Regulation Act, which consolidated a number of pieces of fisheries legislation in existence at the time. Apart from occasional periodic increases in fines, it was the ending dates of the annual closed season and thus the start of the fishing season that was most often altered during the life of the Act. Adjustments to the dates of the closed season notably only took place during the first half of the century until 1987 when the closed season was extended to two-years to facilitate a harvest moratorium (Parker 2002, Parker In prep).

The Fisheries Regulation Act was finally repealed and replaced with the Fisheries Act of 1993. The new Act mandated the appointment of a Chief Fisheries Officer (CFO) and charged him with the responsibility of managing and developing local fisheries. In 1997 the first Fisheries Management Plan was produced in accordance with this edict. The plan espoused co-management of the sea egg fishery.

In the Fisheries Act, stakeholder input into management decisions is facilitated through the appointment of a Fisheries Advisory Committee composed of representatives of government agencies and representatives of key sectors of the fishing industry. The CFO is also given the option of consulting with stakeholders when preparing or reviewing a management scheme. However a very important facet of the Fisheries Act is that the Minister responsible for fisheries ultimately must make all management regulations.

The Fisheries Act does, in itself, not include any management regulations for the sea egg fishery but mandates the Minister to dictate appropriate regulations for the fishery. It also provides the Minister with a range of management tools other than only closed seasons. It was not until five years later, in 1998, that the first suite of fisheries regulations was enacted. For sea eggs the tried and tested imposition of an annual closed season was retained, however fixed dates were not included up front, thus permitting dates to be set on an annual basis. The option for restrictions on the use of fishing gear was exercised by banning the use of SCUBA for fishing sea eggs. This also effectively set a depth range restriction aimed at protecting those sea eggs living at depths beyond the reach of free divers.

Co-management encompasses several possible arrangements that are often depicted as a scale constructed from the relative sharing of responsibility and authority between government and stakeholders (Pomeroy and Berkes 1997, Berkes et al. 2001). McConney et al. (2003) suggest the following labels for three different degrees of co-management:

i) *Consultative co-management* — Government interacts often but makes all the decisions
ii) *Collaborative co-management* — Government and the stakeholders work closely and share decisions
iii) *Delegated co-management* — Government lets formally organised users/stakeholders make decisions

In its present form, the Fisheries Act does not allow for the divestment of the governance of any fishery to user groups. It *de facto* restricts power sharing through co-management to the level of collaborative co-management as defined above. The potential exists for government both at the level of the CFO and the Minister to derail any management decisions or policies derived by any stakeholder group. From a pragmatic perspective, verification that policy recommendations have originated from consultation with as many stakeholders as possible will be the best defence against possible top-down governmental interventions. A recognised representative stakeholder group with which government can interact is needed.

THE STEPPING STONES TO CO-MANAGEMENT

Although, since 1879, management of the sea egg fishery was through state legislation, and thus "top-down" in nature; it appears that fishers were at least occasionally consulted in governance decisions for the fishery. For example, no record has been found to suggest that any scientific study was used to fix the period for the fishing closed season first prescribed in 1879. It can only be assumed that local knowledge, presumably mainly from fishers, was used to determine the timing of the animals' peak reproductive season and thus the period for the closed season. It was not until 1958 that a comprehensive scientific study of the animals' biology was published (Lewis 1958). The study confirmed that the animals' peak spawning period fell within the range of the closed season as had been prescribed by law since 1879.

In 1899, fears of an imminent collapse of the sea egg fishery prompted the tabling of a bill in parliament calling for the imposition of a two-year harvesting ban to protect the stocks. A parliamentary committee mandated to investigate the issue consulted fishers before suggesting changes in the legislation that were duly enacted. Correspondence between the Director of Agriculture and the Fisheries Officer in charge of the Fisheries Division suggest that in 1946 the Director wanted to open the fishery before the customary 1st September opening date. While the Fisheries Officer conducted the logical science-based step of testing the readiness of the roe, he also obviously consulted fishers as he duly reported the divergent views of fishers from different communities on allowing an early start to the season. No records of government-fisher consultations have been found for the next forty years and since the periods of the fishing season were not altered until 1987, it would appear that if there were any such consultations during that period, they did not result in altering the legislated *status quo*.

In 1994, Vermeer et al (In press), conducted a questionnaire-based survey of 35 fishers on the potential for co-management of sea eggs in Barbados. About half of the fishers interviewed reportedly thought that community-based management groups could be formed or that community action could result in greater cooperation of fishers with management efforts. The wide distribution of sea egg fishers around the island, and the fact that fishers traditionally freely operated from any site, indicated that the small community-based structure that was in place in St. Lucia to manage its sea egg fishery was not suitable for Barbados. Instead, it was suggested that a flexible closed season be introduced and that fishers should be encouraged to conduct annual assessments of the stock and the timing and duration of fishing seasons, should be based on the results of these surveys following consultation with the Fisheries Division. Given the inherent unpredictability of the stock this was a very astute recommendation. Vermeer et al. also felt that fishers would be more likely to respect regulations that they had participated in developing. While this approach would include volunteer fishers in the decision making process, it did not suggest a mechanism to organise the fishers into a formal group that could be recognised as a representative decision making entity.

In 1998 an ambitious project of the Coastal Zone Management Unit (CZMU) attempted to foster co-management of the fishery as was being advocated in the 1997-2000 FMP. The goal of the project was to establish a co-management mechanism operated by the fishers themselves with technical and advisory support from the Fisheries Division (Mahon et al. 2003). The first phase of the project involved identifying groups of fishers and contact persons in recognised fishing communities. Dialogue with individuals and small groups was initiated and attempts were made to draw these persons into successively larger group meetings organised by key persons in the communities to reach consensus on management approaches. The Technology of Participation (ToP) was used to develop a shared vision for the fishery and to develop a strategic plan for achieving the vision.

One of the strategic directions identified at the end of the process was cooperating for the betterment of the industry. In response to this call, attempts were made to establish a fisherfolk organisation. The decision was made that the organisation should not be restricted to sea egg fishers but to all persons involved in dive fishing. Fortuitously, the project was underway when Dr. Anton Atapattu, a Fisherfolk Organisation Development Adviser (FODA) was on assignment in Barbados with the express mandate to develop fisherfolk organisations. The first meeting of the Barbados Fisherfolk Divers Association (BFDA) was held at the Fisheries Division in February 1999. A constitution based along the same lines as for the other fisherfolk organisations and developed by the FODA was agreed to and the fishers present elected the seven-member executive (Mahon et al. 2003).

However, attendance at the meeting was very poor. This was attributed to the meeting coinciding with the peak of the pelagic fishing season when many fishers would be at sea. It was decided that an interim executive committee could still be formed by those present and another general meeting be called when the pelagic fishing season was over. The next meeting was held in August 1999 but turnout was even poorer and a meaningful electoral process could not go forward. No further meetings were called, and attempts to form the fisherfolk organisation had failed.

As Mahon et al. (2003), pointed out, the BFDA was unique to Barbados in that it focused on resource management rather than development and improvement of conditions for fishers. As a result great efforts on the part of government would be needed to maintain its structure, especially when addressing contentious issues. A more immediate problem was that its members were widely dispersed throughout the island. As a result, members from different communities did not know each other well enough for the electoral process to be meaningful. Due to a lack of human resources at the Fisheries Division, a familiarisation process could not be undertaken and was probably a major cause of the collapse of the organisation. Despite the failure of the BFDA, the project demonstrated a willingness of fishers to participate in-group processes aimed at managing the fishery (McConney et al. 2003).

In 2001, the Coastal Resources Co-management Project (CORECOMP), a 3-year project of the Caribbean Conservation Association commenced.

CORECOMP offered assistance to the Fisheries Division and the Barbados Union of Fisherfolk Organisations (the umbrella organisation for local fisherfolk organisations) as the co-management partners to establish a pilot project on co-management of the sea egg fishery. The project was especially timely and welcomed, since in 2001 the Barbados sea egg stock underwent what can only be deemed a dramatic recovery reaching abundances that had not been observed for over thirty years. The stock recovery coincided with the expiration of a three-year harvest moratorium that was due to be lifted at the end of July. With the lifting of the ban, the fishery would be opened with no co-management in place. It was even more important that the stock be protected from another collapse due to over-harvesting.

The first order of business was to assess the true status of the stock to advise the best policy to allow a sustainable harvest. A proper scientific stock survey was therefore needed to determine appropriate start times for the harvest and duration of the fishing season to prevent over-fishing. The time had come to establish the flexible harvest seasons and draw the fishers themselves into the scientific aspect of fisheries management and thus make them real participants in the management process, as was suggested by Vermeer et al. in 1994.

The survey programme was designed by the Fisheries Division's fisheries biologist and involved organising 16 volunteer fishers into four groups. Twenty-six index sites located around the island were chosen and the survey teams were assigned to survey a number of the sites with which they were most familiar. A simple quadrat method was used to estimate population densities and the diameters of samples of the animals at each site were measured and recorded. The sampling protocol and the rationales for collecting the information were explained to fishers in both a classroom and field sessions by the biologist and an assistant. The field surveys were conducted in July and August. The results of the surveys were collated and analysed by the biologist, and the results explained to the fishers. The fishers were also invited to actually input and manipulate the data themselves to further familiarise them with the scientific process of resource assessment. The information generated by this collaborative research was used to prepare a policy paper to government advocating a two-month fishing season starting from1st October. Despite the delay in the start and the substantially reduced duration of the season, government accepted the recommendations and passed them into law. Long-standing traditions for managing the fishery had been altered through a collaborative effort of the Fisheries Division and fishers in a scientifically sound assessment.

Similar surveys have been conducted in each successive year and the results used to determine the duration and timing of the annual seasons. However, funding of the successive surveys have been undertaken out of the Fisheries Division's budget and have been constrained to fewer index sites. In 2002 and 2003 fisher involvement after submitting the survey data was much reduced and the final management decisions were largely made through consultations between BARNUFO and the Fisheries Division based on the survey results. Due to a perceived reduction in the standing stock at several sites in 2002 compared with 2001, a one-month harvest season was recomwhich was made somewhat shorter by days of inclement weather, proved very unpopular with a number of fishers who, with the assistance of some of their parliamentary representatives, successfully lobbied government to extend the season by one month against the public outcry of the president of BARNUFO. This event provided an example of how co-management decisions can be overturned under the present governance structure if not firmly supported by a large and representative body of stakeholders.

In August 2004, the Fisheries Division held a meeting with the fishers involved in the stock surveys along with a number of other sea egg fishers and representatives of BARNUFO to facilitate consensus on the timing and duration of the upcoming fishing season. Even one self-confessed sea egg poacher was deliberately invited to the meeting to benefit from his perspective. The results of the survey were discussed along with anecdotal information offered by the fishers present who were not involved in the survey. The outcome of the meeting was truly that of compromise. For example the durations of the seasons proposed by the fishers ranged from none at all to one month, the final recommendation being two weeks and the proposed start dates ranged from 1st September to 1st October, with 15th September being finally decided upon. The outcome of this meeting clearly demonstrated that, for the sake of conserving the stock, well-informed fishers were quite willing to take tough stances that would be unpopular with many of their peers. Such fishers had the makings of true managers. It is noteworthy that, in spite of protests from some fishers, this extremely short fishing season, which was also much affected by inclement weather, was not extended.

In 2002, the Caribbean Conservation Association (CCA), in association with the Marine Resources Assessment Group Ltd. (MRAG) and Natural Resources Management Program of the University of the West Indies (NRM-UWI), implemented the Caribbean Coastal Co-management Guidelines Project. The objective of the project was "to ensure that integrated coastal management in the Caribbean is done in a way that involves and benefits those who depend on the resources of coastal areas, especially where there is poverty" (McConney et al. 2003). The Barbados sea egg fishery was chosen as a case study under this project. The project comprehensively reviewed issues related to developing co-management of the Barbados sea egg fishery through use of document analysis, key informants, semi-structured interviews, questionnaire surveys, and workshops with all stakeholders.

In May 2002, a multi-stakeholder project inception workshop was held involving persons involved in the sea egg fishery, fisheries authority, researchers, enforcement agencies, environmental NGOs and others to decide what the project should address. The responses from the group included issues that had been cited on numerous previous occasions such as improved enforcement of the regulations including prosecutorial success, improved public education, and the formation of local area management to improve compliance. During the fishing season, a questionnaire-based survey was conducted amongst sea egg fishers at three major harvesting sites to obtain their views on what was needed for the fishery. Again, much of the same sentiments expressed by stakeholders reported in previous reports were reiterated. However, of particular interest was that the majority of persons interviewed (60%) suggested that government mended and subsequently passed into law. However, the shortened season, and fishers should equally share control of the fishery, and 70% also thought that fisherfolk organisations could help in management, although 75% of the respondents were not members of fisherfolk organisations. One interpretation of these results is that many fishers want to have a say in management but don't want to participate in the processes involved, such as becoming members of organisations themselves. This suggests that they are more willing to have their opinions voiced through an emissary.

THE STUMBLING BLOCKS

Historical records clearly indicate that out of season poaching has been a feature of the sea egg fishery since the concept of a closed season was introduced. There are numerous negative impacts of poaching on the management of the fishery. The activity directly undermines the benefits of the closed season (i.e. removal of the animals before they have spawned) and the need to take more animals during the spawning season to satisfy catch demands since the roe is not in a fit state for harvest (e.g. runny when spawning and very small after spawning). As the level of poaching is unknown then accurate assessments of fishing effort cannot be made to advise management measures that involve controlling fishing effort.

Effective ongoing monitoring supported by active enforcement along with punishments that adequately deter poaching are essential for converting legislation into real control. Earlier works have already discussed in detail the possible contribution of fines that are small when compared with the potential financial gains from poaching sea eggs to the collapse of the stock during the 1970s and 1980s (Parker 2002, Parker In prep.). This weakness in the legislation was removed by the 1998 fisheries regulations that set maximum fines of $50,000 and/or two years imprisonment as punishment for sea egg poaching. Despite these sterner potential penalties, anecdotal information tends to indicate that the incidence of sea egg poaching may actually have increased following the recovery of the sea egg stocks observed from 2001.

A number of important contributing factors for this apparent increase in poaching incidents may be identified. The first is that the overall increased number of sea eggs can support increased fishing effort whether legal or illegal. The bitter irony here is that the animals left on the grounds by fishers who only harvested the animals within the substantially shortened fishing season then become the prey of the poachers. The positive impacts made by the sacrifices of these many law-abiding fishers for the conservation and even increase of the stock in the first place thus increases the profitability of poaching. This cannot engender cooperation in management.

The second contributing factor is the existence of a lucrative black-market for the poached sea eggs reportedly largely fuelled by some of the wealthier and powerful residents of the island. Fishers must surely view this situation as one of laws being only applicable to the poor.

The third contributing factor to poaching is that although the courts have started imposing stiffer penalties for sea egg poaching, (maximum recorded was Bds. $2,500 in 2003), the fines still fall well below the maximum allowable under law and are still effectively below the level at which the fisher would perceive that the cost of his capture exceeds the potential financial gains from poaching.

Authorities have found the capture and subsequent conviction of sea egg poachers to be challenging exercises. The rugged terrain of the coastline which fronts much of the more productive sea egg grounds in the north and southeast of the island is replete with small bays and beaches that are difficult or impossible to access by vehicles on land or by boats at sea. These secluded areas are havens for poachers who use them as a landing site for their catches and if challenged by authorities can use the poor accessibility features to make good their escape when necessary. In addition poachers often use lookouts to warn of the approach of enforcement officers and have developed clever strategies to quickly dump their catches and thus the evidence of their crime. The high incidence of successful poaching due to failures in enforcement has a snowballing effect, as more fishers perceive that the risk of punishment is low and capitalize on this weakness, while law-abiding fishers poach when they become anxious that few sea eggs will be left for them during the legal fishing season.

An important aspect of successful management of the sea egg fishery is sensitisation of the general public to the rationales behind management measures. The general public must be made aware of their role as stakeholders in the fishery. Historically, sea egg poaching has been viewed as a very trivial offence, but as pointed out by McConney et al. (2003), this perception must be changed to one of outrage if management is to be successful. Each of the major projects outlined in the previous sections have recognised this need for public education. In response, an informational booklet on the sea egg fishery was produced out of the 1998 CZMU project (Mahon and Parker 1999) and an informational brochure was produced by the Fisheries Division in collaboration with BARNUFO with funds supplied out of the CORECOMP project and the Oak Foundation. In 2004 the Barbados Government Information Service produced a short (30 second) programme featuring the Fisheries Division's Fisheries Biologist advising the general public against poaching sea eggs or purchasing poached sea eggs. The clip was screened on numerous occasions prior to the opening of the season. Indications are that the clip was very successful at getting the simple message across to a very wide audience and this seems to be a useful format for public education.

THE FINAL STEPS

In November 2003, the Fisheries Division hosted a Sea Egg Fishery Management Small Group Meeting at the Fisheries Division as part of the post evaluation of the 2003 sea egg fishing season (McConney and Pena 2004). Participants included fishers that had participated in sea egg stock assessment surveys and other fishers who were known to be interested in participating in management. The meeting also served as a forum to generate recommendations for inclusion in the Fisheries Management Plan for 2004 - 2006. The fisheries biologist delivered a Powerpoint presentation outlining his recommendations for managing the fishery and the rationales for them. From the beginning of the meeting the fishers were advised that they were free to interject at any time to ask questions or offer comments (positive or negative) or offer suggestions. Consensus agreement was sought on all relevant issues. Following discussions, the participants agreed among other things that:

i) Closed seasons were the most appropriate management tool for the fishery.
ii) The timing and duration of fishing seasons should be agreed on an annual basis following stock surveys, and the length of the season should be used as the means of controlling allowable catches.
iii) Allowable catches should ensure that a reserve adult stock be retained at the end of each season.
iv) More index sites should be surveyed necessitating the inclusion of more fishers in the programme.
v) Licensing should not be introduced as a means of limiting the numbers of fishers involved; however, all fishers should be registered so that fishing effort can be determined.
vi) The issue of the ban on the use of SCUBA gear in the fishery should be reviewed.
vii) Poaching must be eliminated.
viii) Public education on proper traditional harvesting techniques, such as testing roe quality before picking and leaving unripe animals, should be undertaken.

An important aspect of the meeting was the introduction of a proposal for establishing a Sea egg Management Council (SMC) as a means of facilitating co-management. The proposed council would comprise representatives of relevant government agencies including enforcement agencies, BARNUFO, an independent fisheries biologist and representatives of major sea egg fishing communities. More than half the council's membership would be fishers. Community representatives would be responsible for advising members of their communities on relevant issues and reporting the concerns and opinions of whom they represent to the council meetings. The council would coordinate stock assessments, formulate management policies, and develop ways of enforcing any management regulations. The fishers accepted the proposal in principle, and as a result, the recommendation was included in the 2004 - 2006 FMP.

A number of hurdles must necessarily be first overcome in developing the council. For example, mechanisms will have to be put in place to allow communities to elect their representatives. However, given the need to kick-start the formation of the council, it is proposed that the representatives be appointed initially. Financing of the council will also become an issue, as it is unlikely that participants will be willing to devote their time and effort to make the council work in the longer term for free. While donor agencies and government would be willing to finance the initial set up stages, the council will have to eventually find ways to at least partially finance its work.

DISCUSSION

Several features of the sea egg fishery, including the very nature of the animal and its market worth, make the resource vulnerable to overexploitation which can lead to fishery collapse. For example, the animals are broadcast spawners, which makes spawning success highly dependent on the numbers of spawning animals and their proximity to each other. The several factors that impact on the survival and transport of the animals through the long planktonic phase of their life cycle through settlement to the benthos, all make recruitment success highly unpredictable. The animals live in shallow-water and are sedentary, making them easy to collect with minimal capital investment. Finally, there remains a ready local market, both legal and illegal, for this high-priced commodity. Based on these features alone, no management measures are likely to succeed without the cooperation of harvesters and the buying public. To facilitate this, there is little doubt that the sea egg fishery would be best managed through a co-management arrangement.

However, developing co-management of this fishery has proven to be a daunting task. McConney et al. (2003) aptly describes co-management of the Barbados sea egg fishery as being only in the pre-implementation stage. While industry representatives and enforcement agencies continue to demonstrate interest in co-management, patience may be wearing thin as the same issues are discussed at successive meetings without any apparent resolution (McConney and Pena, 2004). Tangible successes are needed urgently.

At some level there have been notable improvements in the level of fisher participation in governance. So far, the only sustained fisher-government collaborative success has been in the annual resource assessments. This has led to the now generally accepted norms of shorter fishing seasons with the possibility of variation from the traditional start date of 1st September. It is now also accepted in principle by most involved in the fishery that the state of the stock should dictate the length and timing of the fishing season. The level of impact that these changes on how the stock is exploited have had on its sustainability cannot be accurately measured. However, certainly the fact that annual harvests following the 2001 stock recovery have been either fair or good must send the message to the public that the fishery is being managed with some success.

However, many fishers not involved in the stock surveys customarily cast suspicion on the validity of the assessments and consider that longer fishing seasons would not endanger the stock. It is understandable that there would be fears of coercion on the part of government when the same small group of fishers are repeatedly used to conduct the stock surveys on which the information that advises this principal management measure. To avoid this misperception the assessments should be expanded to include more index sites on a regular basis. This would not only improve the soundness of the survey programme from a scientific perspective, but also will draw new fishers into the programme. In addition, anecdotal information on stock status and other relevant information should be systematically collected from a wider group of fishers for the same reasons. The policy of inclusion in the area of information gathering must be improved.

Finally, formal fisher participation in the decision making process must be extended beyond the information gathering stage. Again, at this level a mechanism must be put in place to draw the opinions of all stakeholders together. Stakeholders in this context include government agencies as well as fishers. This is the only way that critical management measures can be dealt with in a frank, transparent manner. The proposed Sea Egg Management Council will be one such mechanism.

It is however, unlikely that sea egg fishers on their own have the will or capacity to organise themselves to facilitate self-representation. To this end the Fisheries Division must take the lead in nurturing this process. Limitations on human resources at the Division are unlikely to change in the near future. However, one hitherto unmentioned intangible benefit of the long years of this co-management process is the creation of a number of personal alliances between Fisheries Division staff, BARNUFO and the sea egg fishing community. A number of people who would make meaningful contributions to the development and success of the council are thus known to the Fisheries Division. These persons should be brought together in an effort to kick-start the development of the council. However processes whereby fishers can select their own representatives should be developed as soon as possible.

It seems unlikely that Government will be inclined in the near future to release its primary control on managing this fishery, which is of such economic, social and cultural importance to the island. However it is more probable that the recommendations of the council would be sufficiently weighty to effectively advise government policy once it demonstrates that it truly represents the majority of stakeholders.

ACKNOWLEDGEMENTS

Assistance was received from the UWI Coastal Management Research Network (COMARE Net), a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID, UWI or the Barbados Fisheries Division.

LITERATURE CITED

Barbados Fisheries Division. 1997. Barbados fisheries management plan 1997-2000. Ministry of Agriculture and Rural Development. 69 pp.

Berkes, F., R. Mahon, P. McConney, R. Pollnac, and R. Pomeroy. 2001. *Managing Small-scale Fisheries: Alternative Directions and Methods.* International Development Research Centre, Canada. 320 pp.

Mahon, R. and C. Parker. 1999. Barbados sea eggs, past, present and future. Fisheries Division. Ministry of Agriculture and Rural Development, Barbados Fisheries Management Plan, Public Information Document No. 1. 16 pp.

Mahon, R., S. Almerigi, P. McConney, C. Parker, and L. Brewster. 2003. Participatory methodology used for sea urchin co-management in Barbados. *Ocean and Coastal Management* 46:1-25.

McConney, P.A., A. Atapattu, and D. Leslie. 1998. Organizing fisherfolk in Barbados. *Proceedings of the Gulf and Caribbean Fisheries Institute* 51:299-308.

McConney, P., R. Mahon, and C. Parker. 2003. Barbados case study: the sea egg fishery. Caribbean Coastal Co-management Guidelines Project. Caribbean Conservation Association, Barbados. 74 pp.

McConney, P. and M. Pena. 2004. Events and institutional arrangements in the management of the 2003 Barbados sea egg fishing season (15 September – 15 October). Coastal Resources Co-management Project (CORECOMP). Centre for Resource Management and Environmental Studies, University of the West Indies, Cave Hill Campus, Barbados. 38 pp.

Parker, C. 2002. The contribution of inadequate fines to the collapse of the sea egg fishery of Barbados. *Proceedings of the Gulf and Caribbean Fisheries Institute* 53:203-217.

Parker, C. [In prep.]. UWI doctoral dissertation on the sea urchin fishery. Department of Biology. Faculty of Pure and Applied Sciences. Cave Hill, Barbados.

Pomeroy, R. and F. Berkes. 1997. Two to tango: the role of government in fisheries co-management. *Marine Policy* 21:465-480.

Vermeer, L.A., W. Hunte, and H.A. Oxenford. 2005. An assessment of the potential for community level management of the sea urchin fishery in Barbados. *Proceedings of the Gulf and Caribbean Fisheries Institute* 47:70-103.

U.S. Caribbean Fish Trap Fishery Costs and Earnings Study

JUAN AGAR[1,6], M. SHIVLANI[2], J. WATERS[3], M., VALDÉS PIZZINI[4], T. MURRAY[5], J. KIRKLEY[5], and D. SUMAN[6]
[1]*Southeast Fisheries Science Center, NOAA Fisheries*
75 Virginia Beach Drive
Miami, Florida 33149 USA
[2]*Division of Marine Biology and Fisheries, University of Miami*
4600 Rickenbacker Causeway
Miami, Florida 33149 USA
[3]*Southeast Fisheries Science Center, NOAA Fisheries*
101 Pivers Island Road
Beaufort, North Carolina 28516 USA
[4]*Faculty of Arts and Sciences, University of Puerto Rico*
Mayagüez, Puerto Rico 00681-9011
[5]*Department of Coastal and Ocean Policy, College of William and Mary*
Rt. 1208, Greate Road
Gloucester Point, Virginia 23062-1346 USA
[6]*Division of Marine Affairs and Policy, University of Miami*
4600 Rickenbacker Causeway
Miami, Florida 33149 USA

ABSTRACT

This article summarizes the main findings of the US Caribbean fish trap fishery costs and earnings study. The study collected economic and demographic data about fish trap fishermen in Puerto Rico and in the US Virgin Islands. In-person surveys were administered to one hundred randomly selected trap fishermen. The survey elicited information on household characteristics, annual catch and revenue, trap usage, capital investment on vessels and equipment, fixed and variable costs and on the spatial distribution of traps. In addition, fishermen were asked how they would respond to a trap reduction program. Comparisons across islands showed a high degree of heterogeneity among fishery participants. This article also details how this information will be used to develop economic models to evaluate management proposals.

KEY WORDS: Fish trap, socio-economics, U.S. Caribbean.

Estudio sobre Costes e Ingresos de la Pesquería de Nasas en el Caribe Americano

Este artículo resume los principales resultados de un estudio de costes e ingresos de la pesquería de nasas en el Caribe Americano. El estudio recolecto información económica y demográfica sobre pescadores que utilizan nasas en Puerto Rico e Islas Vírgenes Americanas. Cien encuestas se administraron a pescadores de nasas seleccionados al azar. La encuesta solicitó información sobre las características del hogar, ingresos y capturas anuales, uso de nasas, inversión de capital en embarcaciones y equipo, costos fijos y variables y distribución espacial de las nasas. También se indago como los pescadores se comportarían frente a un programa de reducción de nasas. Comparaciones entre islas muestra un alto grado de heteroneidad entre los participantes de esta pesquería. Este artículo también señala como se utilizará esta infamación para desarrollar modelos económicos que evalúan propuestas de gestión.

PALABRAS CLAVES: Nasas, socio-economía, Caribe Americano

INTRODUCTION

The fish trap fishery is one of the most valuable fisheries in the U.S. Caribbean. In Puerto Rico, this fishery accounts for 22 percent of the landings and 24 percent of the revenue. Spiny lobster and snappers account for over 60 percent of the revenue. In the U.S. Virgin Islands, fish traps are responsible for 37 percent of the landings and revenue. Spiny lobster and triggerfish alone account for 48 percent of the revenues.

Fish traps are commonly used in coral reef and related habitats, where they target a variety of species including spiny lobsters, deep-water snappers, shallow-water snappers, grunts, and groupers. During the last decade, the impact of traps on coral reefs has been the focus of considerable debate. A number of organizations, including environmental groups, have expressed concern over the physical damage caused by the setting and hauling of traps (Sheridan et al. 2003). Early research indicated that 40% of the traps off St. Thomas were placed over hard corals, resulting in an estimated annual loss of 100 m^2 of hard coral (Quandt 1999). Healthy reefs can yield up to 35 metric tons of fish per square kilometer annually (Russ 1991). However, on-going research suggests that about 20% of the traps are on hard coral in the U.S. Virgin Islands (Sheridan et al. 2003). More recently, Garrison et al. (2004) found that in St. John, fishermen preferentially set traps in algal plains.

In addition to potential habitat damage, the non-selective nature of fish traps is another source of concern. Fish traps catch a variety of overexploited reef fish species. Reef-fish species, particularly groupers, are vulnerable to harvesting because of their life history characteristics, which include slow growth, delayed reproduction, and sedentary behavior. For example, Nassau and Goliath groupers remain overexploited, despite commercial harvest bans since the early 1990s. Because of the widespread use of traps by small-scale fishermen, addressing the anthropogenic impacts of habitat-gear interactions not only requires biological assessments but also socioeconomic assessments.

In anticipation of the need to evaluate the effects of proposed trap regulations on fishermen and their communities, we conducted a costs and earnings study. The primary objective of the study was to collect socio-economic information on the U.S. Caribbean fish trap fishery to support the management and conservation efforts of the Caribbean Fishery Management Council (CMFC). The draft Amendment to the Fishery Management Plans (FMPs) of the U.S. Caribbean to Address Required Provisions of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) is considering among other alternatives, either reducing the number of existing fish traps and/or phasing out their use over a five to ten year horizon. Socio-economic assessments are vital to evaluate the potential impacts of trap regulations on fishermen and fishing communities.

This study describes the salient socio-economic characteristics of the U.S. Caribbean fish trap fishery. The questionnaire elicited information on household demographics, annual catch and revenue, fishing practices, capital investment on vessels and equipment, fixed and variable costs, behavioral response to a hypothetical trap reduction program, and the spatial distribution of traps. However, for space sake, we only present information on demographics, capital investment on vessel and equipment, and revenue and cost structure of the fleet.

In addition to providing summary statistics, we discuss how this data can be used to develop models that evaluate the economic performance of various regulatory proposals such as a trap reduction program. The study encompasses the Commonwealth of Puerto Rico and Territory of the U.S. Virgin Islands (i.e., St. Thomas, St. John, and St. Croix).

METHODS

The sampling designed called for a voluntary, in-person interview of 60 fishermen in Puerto Rico, 20 fishermen in St. Thomas and St. John, and 20 fishermen in St. Croix. For each geographic area, the sampling plan divided fishermen into two or three strata (or tiers) to reflect the scale of operation, defined by the number of traps owned, from which a simple random sample was drawn.

The number of traps owned to qualify for a given tier varied by island. In Puerto Rico, tier I consisted of fishermen who owned between 1 - 40 fish traps, tier II was made up of fishermen who possessed between 41 and 100 fish traps, and tier III consisted on fishermen who held in excess of 100 fish traps. In St. Thomas and St. John, tier I was composed of fishermen who held between 1 and 50 fish traps, tier II consisted of fishermen who had between 51-150 fish traps and tier III was made up of fishermen who had in excess of 150 fish traps. Lastly, in St. Croix, tier I was made up of fishermen who had less than 19 fish traps and tier II consisted of fishermen who had in excess of 20 fish traps (Table 1).

The rationale for the stratification was to capture the fleet's heterogeneity (i.e., small, medium, and large-scale operators) and to minimize the possibility of inadvertently marginalizing or excluding components of the fleet. Thus, the stratification disproportionately sampled large-scale operators while broadly mirroring the universe of the trap fishermen. In addition, the stratification made the survey more cost effective and convenient to administer. Scale of operation tiers were determined in consultation with local fisheries experts.

Table 1: Survey universe, sample size, and number of responses by tier

Area	Tier (number of fish traps)	Population (number of fishermen)	Target number of interviews	Number of completed interviews	Number of contacts
	1-40	258	30	30	57
Puerto Rico	41-100	53	20	22	31
	^{3}101	13	10	8	13
Puerto Rico Total		324	60	60	101
	1-50	19	8	5	19
St. Thomas and St. John	51-150	20	7	10	17
	^{3}151	13	5	5	9
	1-19	31	13	13	30
St. Croix					
	^{3}20	14	7	7	12
USVI Total		97	40	40	88
Grand Total		421	100	100	188

To meet the requirements of the sampling protocol, interviewers contacted selected fishermen from a randomized list that recorded fisherman's name, address, and phone number. Surveyors were also instructed to select a replacement if fishermen:

i) Refused to participate,
ii) Were not available due to illness, death, or travel, and
iii) Could not be contacted after eight, separate attempts.

When the number of willing participants prevented the contractors from meeting the stratum goal, interviewers completed additional interviews in other strata. This allowed the contractors to reach the one hundred interviews required under the contract. This situation occurred twice, as surveyors conducted two additional interviews in the second tier stratum for Puerto Rico and three extra interviews in the second tier stratum for St. Thomas and St.

John (Table 1).

Notwithstanding considerable effort and resources devoted to this endeavor, the actual response rate was 53.2%. We calculated the response rate by dividing the total number of completed interviews over the total number of people contacted (Table 1). A close examination at the non-response reasons showed that 52 fishermen were unreachable and 18 fishermen refused to participate. This accounted for 59.1% and 20.5% of the non-response rate, respectively. If we ignore those fishermen who were unreachable, and those who no longer fished with traps (i.e., no longer qualified); then, the effective response rate increased to 80.6%.

RESULTS

Demographic Profile

The age of the sampled population ranged from 23 to 84 years. On average, Crucian fishermen were older than Puerto Rican, St. Thomian, and St. Johnian fishermen. St. Croix fishermen's average age was 57 years whereas Puerto Rican fishermen's average age was 51 years, and St. Thomian and St. Johnian fishermen's average age was 48 years (Table 2). With the exception of St. Thomas and St. John fishermen, the greater the number of traps owned, the older the fisher. Frequency analysis showed that there were 4 respondents in the 20 to 29 age group, 17 respondents in the 30 to 39 age group, 20 respondents in the 40 to 49 age group, and 27 respondents in the 50 to 59 age group. Twenty respondents were in the 60 to 69 age group, 9 respondents in the 70 to 79 age group, and 3 respondents in the 80 to 89 age group.

The survey showed that the respondents were seasoned commercial fishermen. As a group, Puerto Rican and Crucian fishermen had 30, and 29 years of fishing experience, respectively; whereas St. Thomian and St. Johnian fishermen had 25 years of fishing experience (Table 2). As a group, St. Thomian and St. Johnian, Puerto Rican, and Crucian fishermen had 10, 10, and 9 years of formal education, respectively (Table 2). Commercial fishing experience varied considerably across tiers, with the exception of Puerto Rico stratum. In St. Croix, participation in the fishing industry ranged from 25 years in the lower trap tier to 38 years in the higher trap tier. Notwithstanding, the prevalence of fish traps in the Caribbean, most respondents did not operate fish traps for their entire commercial fishing history. Fishermen from Puerto Rico, St. Croix, and St. Thomas and St. John had been fishing with fish traps for 23, 23, and 21 years, respectively.

Trap fishermen's formal education ranged between 1 to 16 years. About 53 percent of the respondents had not completed high school. The majority of the respondents were highly dependent on commercial fishing for their household income. In St. Croix, commercial fishing made up 83% of the fishermen's household income, whereas in St. Thomas and St. John and Puerto Rico, commercial fishing contributed 74% and 68% of the household income, respectively (Table 3).

Table 2: Demographic characteristics

Variable	Region	Tier I	N	Tier II	N	Tier III	N	All	N
Age of fish trap fisherman (years)	Puerto Rico	50.33 (2.84)	30	52.14 (2.33)	22	54.87 (1.63)	8	50.81 (2.3)	60
	St. Thomas & St. John	50.40 (4.94)	5	49.20 (1.91)	10	43.20 (3.42)	5	48.14 (2.13)	20
	St. Croix	55.07 (3.45)	13	62.57 (2.51)	7			57.41 (2.50)	20
Commercial fishing experience (years)	Puerto Rico	29.80 (2.79)	30	31.18 (2.35)	22	31.25 (2.48)	8	30.08 (2.26)	60
	St. Thomas & St. John	20.0 (4.11)	5	29.0 (2.03)	10	25.8 (4.01)	5	24.91 (1.96)	20
	St. Croix	24.61 (3.68)	13	38.29 (1.50)	7			28.87 (2.51)	20
Commercial fishing experience with fish traps (years)	Puerto Rico	22.33 (2.57)	30	28.09 (2.52)	22	27.12 (2.99)	8	23.47 (2.09)	60
	St. Thomas & St. John	20.0 (4.11)	5	26.3 (2.67)	10	23.6 (3.26)	5	23.32 (1.99)	20
	St. Croix	18.08 (3.41)	13	28.71 (4.03)	7			21.39 (2.67)	20
Formal education (years)	Puerto Rico	9.68 (0.656)	28	9.73 (0.56)	22	8.75 (0.97)	8	9.65 (0.52)	58
	St. Thomas & St. John	9.25 (1.37)	4	10.55 (0.54)	9	10.80 (0.94)	5	10.19 (0.56)	18
	St. Croix	8.08 (0.69)	12	10.66 (1.06)	6			8.85 (0.58)	18

Table 3: Indexes of fishing dependence

Variable	Region	Tier I	N	Tier II	N	Tier III	N	All	N
Percentage income derived from commercial fishing	Puerto Rico	64.0 (5.72)	28	88.81 (3.361)	21	78.12 (5.49)	8	68.73 (4.57)	57
	St. Thomas & St. John	49.0 (18.03)	5	85.5 (4.73)	10	93.0 (4.57)	5	74.04 (6.93)	20
	St. Croix	84.23 (5.55)	13	81.43 (7.78)	7			83.36 (4.53)	20
Percentage of commercial fishing income derived from fish trap fishing	Puerto Rico	56.14 (5.55)	28	68.75 (4.45)	20	84.37 (5.54)	8	59.37 (4.49)	56
	St. Thomas & St. John	50.75 (16.6)	4	61.0 (6.95)	10	73.0 (9.89)	5	61.00 (6.54)	19
	St. Croix	61.82 (8.84)	11	99.29 (0.51)	7			74.86 (5.77)	18
Number of dependents (including self)	Puerto Rico	3.27 (2.51)	30	3.36 (0.30)	22	2.87 (0.36)	8	3.27 (0.21)	60
	St. Thomas & St. John	2.80 (0.63)	5	2.6 (0.34)	10	3.2 (0.46)	5	2.82 (0.29)	20
	St. Croix	3.46 (0.32)	13	3.14 (0.62)	7			3.36 (0.29)	20
Percentage of catch retained for personal or family use (%)	Puerto Rico	2.76 (0.77)	23	2.93 (0.55)	21	4.73 (1.65)	7	2.88 (0.60)	51
	St. Thomas & St. John	7.6 (2.98)	5	1.6 (0.41)	10	1.0 (0.32)	4	3.78 (1.16)	19
	St. Croix	2.17 (0.51)	12	3.14 (0.62)	7			2.49 (0.4)	19

The contribution of fish traps to commercial fishing income ranged from 51% in the lowest St. Thomas and St. John trap tier to 99% in the highest St. Croix trap tier. On an island basis, fish traps' contribution to fishing income was 75 % in St. Croix, 61% in St. Thomas and St. John, and 59% in Puerto Rico. In contrast, lobster traps' contribution to fishing income ranged from 0% in St. Croix to 14% in St. Thomas. In Puerto Rico, lobster traps' contribution to fishing income was 11% (Table 3).

The number of dependent household members ranged from 1 to 8, including the respondent. Overall, 90% of the households had at least one dependent. The average number of dependents across islands was constant, ranging between 2.8 in St. Thomas and St. John and 3.4 in St. Croix (Table 3).

Percentage utilization of catch for personal or family use was relatively low. Regionally, the percentage of personal or family catch use ranged from 2.5% in St. Croix to 3.8% in the St. Thomas and St. John. Notwithstanding these results, the lowest trap tier in St. Thomas and St. John exhibited a relatively high percentage for personal or family consumption of catch (7.6%). US Virgin Islands Territorial regulations require individuals who use pots and traps for personal consumption to obtain a commercial fishing permit (Table 3).

Vessel and Equipment Characteristics

The value of fully rigged vessels ranged from $400 to $250,000. Fifty-one percent of the fleet was worth $10,000 or less. The St. Thomas and St. John fleet had the highest mean value, averaging $58,518. The Crucian and Puerto Rican fleets were of considerably less valuable averaging $19,831 and $8,652, respectively. Capital investment value increased with trap usage (Table 4).

The length of the vessels ranged from 14 to 40 feet. Fifty-nine percent of the vessels were at least 23 feet in length. As a group, the fleet based in St. Thomas and St. John had larger vessels averaging 28 feet (Table 4). The fleets based in St. Croix and Puerto Rico had an average length of 21 feet. While mean vessel size increased with the number of the traps owned, there was very little variation across tiers (i.e., less than five feet in difference).

The age of the fleet varied between 2 and 60 years. About 50 percent of the sampled fleet was at least 14 years old. Fishermen from St. Thomas and St. John had the relatively older vessels relative to their counterparts. The fleet's mean age was 18 years in St. Thomas and St. John, and 16 years in St. Croix and Puerto Rico (Table 4). With the exception of the Puerto Rico's trap tier II, vessel age increased with the number of traps owned. The fleet's engine propulsion ranged from 8 to 400 horsepower (hp). The mean engine power was 208 hp in St. Thomas St. John, 108 hp in St. Croix, and 77 hp in Puerto Rico (Table 4).

Fiberglass hulled vessels were prevalent across the islands (Table 5). All of the vessels sampled in St. Thomas and St. John had fiberglass hulls compared to 95% of the vessels in St. Croix and 87% of the vessels in Puerto Rico. The few wooden hulled vessels corresponded to the lower trap tiers of Puerto Rico and St. Croix (Table 5).

Table 4: Vessel characteristics

Variable	Region	Tier I	N	Tier II	N	Tier III	N	All	N
Fully rigged vessel value ($)	Puerto Rico	5,431.03 (1,053.08)	29	18,598 (2,516.72)	21	31,750 (10,752)	8	8,652.393 (1,033.95)	58
	St. Thomas & St. John	33,100 (3,550.68)	5	56,111 (7,456.77)	9	99,000 (31,657)	5	58,518 (8761.98)	19
	St. Croix	18,346 (4,276.15)	13	23,667 (10,908)	6			19,831 (4332.42)	19
Vessel length (ft)	Puerto Rico	19.8 (0.62)	30	24.5 (0.77)	22	24.75 (1.19)	8	20.77 (0.51)	60
	St. Thomas & St. John	26.0 (2.57)	5	27.7 (1.38)	10	31.0 (2.15)	5	27.90 (1.21)	20
	St. Croix	20.23 (0.87)	13	23.29 (2.07)	7			21.18 (0.88)	20
Vessel age (years)	Puerto Rico	15.97 (1.76)	30	18.54 (2.19)	22	15.25 (1.64)	8	16.36 (1.361)	60
	St. Thomas & St. John	16.4 (2.96)	5	17.7 (2.14)	10	21.2 (3.564)	5	18.1 (1.62)	20
	St. Croix	15.46 (2.05)	13	16.0 (3.52)	7			15.63 (1.787)	20
Engine power (hp)	Puerto Rico	65.04 (12.12)	27	131.73 (14.87)	22	61.12 (125)	8	76.72 (9.80)	57
	St. Thomas & St. John	187.0 (33.95)	5	228.0 (12.04)	10	210.0 (5.55)	4	208.44 (13.99)	19
	St. Croix	98.69 (23.10)	13	129.29 (27.66)	7			108.21 (18.09)	20

Table 5: Number and percent of hull construction and engine types

Variable	Region		Tier I	%	Tier II	%	Tier III	%	Tier %
Hull construction	Puerto Rico	Fiberglass	23	76.67	21	95.45	8	100	86.67
		Wood	6	20	1	4.55	0	0	11.67
		Non- response	1	3.33	0	0	0	0	1.67
	St. Thomas and St. John	Fiberglass	5	100	10	100	5	100	100
		Wood	0	0	0	0	0	0	0
		Non-response	0	0	0	0	0	0	0
	St. Croix	Fiberglass	12	92.31	7	100			95
		Wood	1	7.69	0	0			5
		No response	0	0	0	0			0
Engine type	Puerto Rico	Inboard	0	0	7	31.82	1	12.5	13.3
		Outboard	27	90	15	68.18	2	75	80.0
		Other	3	10	0	0	1	0	0
		Non-response					1	12.5	6.67
	St. Thomas and St. John	Inboard	3	60	8	80	4	80	75
		Outboard	2	40	2	20	1	20	25
		Other	0	0	0	0			0
		Non-response	0	0	0	0			0
	St. Croix	Inboard	0	0	1	14.3			5
		Outboard	13	100	4	57.14			85
		Other	0	0	1	14.3			5
		Non-response	0	0	1	14.3			5

Engine types varied across the islands. Outboard engines were more common in Puerto Rico and St. Croix whereas inboard engines were prevalent in St. Thomas and John. In St. Croix and Puerto Rico, outboard engines accounted for 85% and 80% of engines types used, respectively. Only 25% of the engines in St. Thomas and St. John were of the outboard type (Table 5).

Mechanical trap haulers and depth recorders were the most common onboard equipment used (Table 6). About 55% of the sampled population had mechanical trap haulers. In St. Thomas and St. John, all of the respondents reported owning haulers compared to 51.7% in Puerto Rico and 20% in St. Croix. Mechanical trap haulers were more prevalent in the higher trap tiers. Forty-seven percent of the fishermen surveyed stated having depth recorders. Depth recorders were more common in the St. Thomas and St. John fleet (80%) and least common in the Puerto Rican fleet (37%).

Thirty-seven percent of the sampled population had global positioning systems (GPS). Sixty-five percent of the vessels in St. Thomas and St. John were equipped with GPS compared with 31.7% in Puerto Rico. About 25% of the Crucian fleet had GPS (Table 6).

The limited presence of emergency position indication radio beacons (EPIRBS) and radar was common among the fish trap fleet. Only eight percent of all respondents had EPIRBS and only one percent had radar. Thirty-five percent of the St. Thomas and St. John fleet had an EPIRB whereas five percent of the St. Croix fleet had an EPIRB. These results are consistent with Kojis (2004), who found that 9% of the US Virgin Islands fleet had EPIRBs, and that the St. Thomian and St. Johnian fleet carried almost twice as many EPIRBs as the Crucian fleet. None of the Puerto Rican vessels sampled had an EPIRB. Only one fisherman in St. Croix had radar. None of the St. Thomian and St. Johnian and Puerto Rican vessels sampled had radar (Table 6). Kojis (2004) found that about 1.6 % of the U.S. Virgin Islands fleet had radars.

Trap Characterization

Respondents fished between 1 and 350 fish traps. On average, Puerto Rican respondents fished 39 fish traps whereas St. Thomian and St. Johnian and Crucian respondents fished 94 and 27 fish traps, respectively (Table 7). The number of fish traps built or bought ranged between 0 and 175 (Table 7). Fifty-two percent of the sampled population built or purchased 25 fish traps or less. The survey showed that Puerto Rican fishermen built or bought 30 fish traps, St. Thomian and St. Johnian fishermen built or bought 30 fish traps, and Crucian fishermen built or bought 25 fish traps.

Table 6: Number and percent of various fishing equipment

Region	Equipment usage	Tier I	Percentage	Tier II	Percentage	Tier III	Percentage	Tier Percentages
Puerto Rico	Mechanical trap hauler	6	20	18	81.82	7	87.5	51.67
	Depth recorder	10	33.33	10	45.45	2	25	36.67
	GPS	8	26.67	8	36.36	3	37.5	31.67
	Radar	0	0	0	0	0	0	0
	EPIRB	0	0	0	0	0	0	0
	Other	2	6.67	0	0	0	0	3.33
St. Thomas and St. John	Mechanical trap hauler	5	100	10	100	5	100	100
	Depth recorder	3	60	9	90	4	80	80
	GPS	2	40	8	80	3	60	65
	Radar	0	0	0	0	0	0	0
	EPIRB	0	0	3	30	4	80	35
	Other	0	0	2	20	0	0	10
St. Croix	Mechanical trap hauler	1	7.69	3	42.86			20
	Depth recorder	5	38.46	4	57.14			45
	GPS	2	15.38	3	42.86			25
	Radar	0	0	1	14.29			5
	EPIRB	0	0	1	14.29			5
	Other	1	7.69	0	0			5

Table 7: Trap usage characteristics

Variable	Region	Tier I	N	Tier II	N	Tier III	N	All	N
Number of fish traps fished last season	Puerto Rico	24.7 (2.41)	30	63.77 (5.35)	22	212.25 (21.66)	8	38.62 (2.28)	60
	St. Thomas & St. John	33 (6.31)	5	107.3 (8.15)	10	161 (5.02)	5	93.58 (4.09)	20
	St. Croix	20.23 (3.57)	13	42.14 (8.18)	7			27.05 (3.54)	20
Number of fish traps fished built or bought last season	Puerto Rico	24.43 (3.34)	30	45.73 (6.59)	22	71.25 (9.77)	8	29.79 (2.9)	60
	St. Thomas & St. John	12.2 (2.98)	5	31.1 (3.65)	10	53.2 (13.21)	5	29.72 (3.75)	20
	St. Croix	18.31 (3.83)	13	40.71 (9.143)	7			25.28 (3.88)	20
Average life of fish traps	Puerto Rico	1.35 (0.15)	29	1.58 (0.19)	22	3.37 (0.61)	8	1.47 (0.12)	59
	St. Thomas & St. John	5.17 (1.27)	3	4.85 (0.51)	10	4.8 (0.72)	5	4.92 (0.45)	18
	St. Croix	1.25 (0.27)	13	1.5 (0.20)	7			1.33 (0.19)	20
Cost of arrowhead traps ($/unit)	Puerto Rico	88.75 (13.78)	16	112.22 (9.67)	9	133.33 (14.82)	6	94.33 (11.32)	31
	St. Thomas & St. John	260 (34.34)	2	243.76 (23.25)	4	250 (22.64)	3	251.11 (15.64)	9
	St. Croix	123.57 (19.93)	7	108.75 (10.84)	4			118.77 (13.92)	11

The most common trap design was chevron or arrowhead style. Antillean Z (or S) traps, rectangular and star traps are also used. Although Z-traps are considered the most productive trap design, fishermen prefer the smaller-sized arrowhead and square traps because they are easier and less expensive to build and larger number of them can be safely deployed. The cost of a fish trap complete with rope and buoys varied significantly. On average, arrowhead traps commanded $94 in Puerto Rico, $251 in St. Thomas and St. John, and $119 in St. Croix (Table 7). The high variability in trap longevity and cost is due to the size and construction materials employed. Traps usually have a supporting frame and a mesh. Reinforced steel, wood, plastic, or some combination of these materials, make up the trap frame, whereas galvanized wire or plastic coated wire make up the trap mesh (Schärer et al. 2002, Kojis 2004). Galvanized wire lasts about a year whereas plastic coated wire lasts about two years (Schärer et al. 2002). In addition, many fishermen do not use buoys (i.e., set traps blindly) to protect themselves from theft and poaching and to minimize trap loss due to entanglement (Schärer et al. 2002, Kojis 2004).

Fishing Practices

The number of trips per week ranged between 1 and 6. Fishermen from St. Thomas and St. John took fewer but longer trips than their Puerto Rican and Crucian counterparts. As a group, St. Thomian and St. Johnian fishermen took 1.4 trips per week while Puerto Rican fishermen took 2.1 trips per week, and Crucian fishermen took 2.5 trips per week (Table 8). Seventy two percent of the respondents mentioned that they took a maximum of two trips per week. Most fishing trips start at dawn and finished early in the afternoon. Over eighty-two percent of the trips lasted eight hours or less.

Fishermen from St. Thomas and St. John fished on average of nine hours per trip whereas fishermen from Puerto Rico and St. Croix fished for six hours (Table 8). The number of traps hauled also varied. Table 8 shows that St. Thomian and St. Johnian fishermen hauled 68 fish traps per trip, while Puerto Rican and Crucian fishermen hauled 27 and 26 fish traps per trip, respectively.

St. Thomian and St. Johnian fishermen soaked their fish traps for seven days while Puerto Rican and Crucian fishermen soaked their fish traps for six and four days, respectively (Table 8). These results are consistent with earlier findings by Schärer et al. (2002) who report that 53% of the Puerto Rican fishermen use single trap layouts. The same study notes that the mean soak time for Puerto Rican fish traps was five days.

The number of traps per string varied considerably across islands. On average, St. Thomian and St. Johnian fishermen had 8.7 traps per line while Puerto Rican and Crucian fishermen 2.2 and 1.6 traps per line, respectively (Table 8). In St. Croix, 84 percent of the respondents had a single trap per line. In St. Thomas and St. John, only 10 percent of the respondents had a single trap per line. About fifty-five percent of the St. Thomian and St. Johnian fish trap fleet had at least 10 traps per string. Over forty-three percent of the Puerto Rican respondents used one traps per string.

Table 8: Fishing trip characteristics

Variable	Region	Tier I	N	Tier II	N	Tier III	N	All	N
Number of weekly trips	Puerto Rico	2.07 (0.18)	25	2.46 (0.21)	14	2.28 (0.11)	7	2.13 (0.15)	46
	St. Thomas & St. John	1.0 (0)	5	1.3 (0.15)	10	2.2 (0.16)	5	1.41 (0.07)	20
	St. Croix	2.46 (0.31)	12	2.71 (0.33)	7			2.54 (0.23)	19
Trip duration (hours)	Puerto Rico	5.36 (0.31)	25	6.78 (0.42)	14	7.14 (0.51)	7	5.62 (0.26)	46
	St. Thomas & St. John	6.5 (1.30)	5	11.6 (1.47)	10	9.1 (0.95)	5	9.11 (0.78)	20
	St. Croix	4.96 (0.4)	12	6.78 (1.16)	7			5.55 (0.47)	
Number of traps hauled per trip	Puerto Rico	23.08 (2.44)	25	38.71 (3.51)	14	69.43 (4.19)	7	27.13 (2.08)	46
	St. Thomas & St. John	33.0 (6.31)	5	87.4 (8.3)	10	89.6 (9.61)	5	68.07 (4.61)	20
	St. Croix	21.92 (3.62)	12	33.43 (6.46)	7			25.7 (3.23)	19
Soak time (days)	Puerto Rico	4.68 (0.59)	25	4.32 (0.43)	14	6.71 (0.92)	7	5.73 (0.92)	47
	St. Thomas & St. John	7.0 (0)	5	6.9 (0.32)	10	6.6 (0.31)	5	6.86 (0.15)	20
	St. Croix	3.5 (0.48)	12	3.71 (0.71)	7			3.57 (0.40)	19
Number of traps per line	Puerto Rico	2.0 (0.31)	25	2.96 (0.55)	14	3.0 (0.83)	7	2.171 (0.27)	46
	St. Thomas & St. John	3.6 (1.45)	5	11.9 (1.13)	10	11.2 (1.3)	5	8.7 (0.76)	20
	St. Croix	1.83 (0.57)	12	1.28 (0.20)	7			1.65 (0.39)	19

Revenue and Costs

The average St. Thomian and St. Johnian and Crucian fisherman annual gross revenue was $39,018 and $33,317, respectively (Table 9). The average Puerto Rican fisherman annual gross revenue was $15,306. Annual gross revenues generally doubled with increasing tier size. For instance, the lowest St. Thomas and St. John tier reported gross revenues of $17,600, the middle tier reported gross revenues of $34,092, and the highest tier report gross revenues of $77,900 (Table 9).

Economists recognize two types of cost: variable and fixed. Variable costs are those expenses incurred during the operation of the vessel. These vary with the level of harvesting activity. Variable costs can be further categorized into running expenses, which include fuel, lubricants, bait, ice, food, and supplies, and into crew labor expenses. Typically, crew wages are paid as a share of the trip's revenue after deducting operating expenses. Crew compensation excludes returns to owner-operator labor.

The survey showed that the annual average running costs for the St. Thomas and St. John fleet were $ 7,426 and the annual average running costs for the St. Croix fleet were $5,653. The Puerto Rican fleet annual average running costs were $3,550. Fuel expenses accounted for 54.8% of the running costs in St. Thomas and St. John, 48.3% in Puerto Rico and 45.6% in St. Croix. Bait expenses were responsible for 22.6% of the running costs in St. Thomas and St. John, 22.5% in St. Croix and 14.2% in Puerto Rico. Grocery costs varied between 10.8% and 20% of the running costs. Table 9 shows crew compensation by the various trap tiers.

Fixed costs are those expenses incurred regardless of whether the vessel operates or stays idle. They are independent of the level of fishing activity. Fixed costs include mooring fees, hull, engine, and fishing gear maintenance and repair expenses, fishing permit and vessel registration fees, vessel and gear mortgage payments, and insurance payments. Annual average fixed costs were $9,813, $4,202, and $2,348 for the St. Thomas and St. John, St. Croix, and Puerto Rico fleets, respectively (Table 9). Maintenance expenses account for the largest share of the fixed costs. Over fifty percent of the total fixed costs in St. Thomas and St. John, and St. Croix were due to vessel and gear maintenance (other than fish traps) whereas in Puerto Rico they accounted for 35.2% of such costs. Fish trap maintenance costs were the highest in Puerto Rico where they accounted for 52.2% of the fixed costs. Fish trap maintenance was responsible for 28.3% of the fixed costs in St. Croix, and for 15.3% of the fixed costs in St. Thomas and St. John.

Table 9: Revenue and costs

Variable	Region	Tier I	N	Tier II	N	Tier III	N	All	N
Annual gross revenue ($)	Puerto Rico	11,198 (1929.74)	29	27,837 (3,271.4)	19	54,940 (6,810.32)	7	15,306 (1,663.53)	55
	St. Thomas & St. John	17,600 (4,637.24)	5	34,092 (6469.31)	10	77,900 (10,645)	5	39,018 (4,017.98)	20
	St. Croix	24,340 (6,130.38)	11	50,136 (12,466)	7			33,317 (5,898.84)	18
Annual running costs ($)	Puerto Rico	3,173.88 (704.11)	25	5,696.79 (1,049.57)	14	4,282.57 (1,051.98)	7	3,549.51 (599.48)	46
	St. Thomas & St. John	3,952 (361.53)	5	6,520.8 (610.67)	10	13,894 (2,164.61)	5	7,425.6 (604.53)	20
	St. Croix	4,888.32 (787.51)	12	7,216.86 (938.33)	7			5,653.29 (612.09)	19
Annual crew payments ($)	Puerto Rico	2,607.88 (619.06)	24	6,326.07 (1,108.44)	12	9,641.74 (2,216.13)	6	3,326.36 (544.73)	42
	St. Thomas & St. John	3,959.47 (1,710.15)	5	11,413 (2,298.34)	10	41,427 (12,226)	5	16,193 (3,242.53)	20
	St. Croix	10,127 (4,409.26)	11	24,017 (11,441)	7			14,961 (4,910.84)	18
Annual fixed costs ($)	Puerto Rico	1,775.83 (654.95)	30	3,985.45 (437.85)	22	7,015.25 (1,150.07)	8	2,347.51 (528.45)	60
	St. Thomas & St. John	9,252 (3,868.49)	5	7,690 (1,166.06)	10	13,900 (2,250.05)	5	9,813.23 (1,586.03)	20
	St. Croix	4,653.85 (1,081.14)	13	3,201.43 (1,067.47)	7			4,201.98 (815.48)	20

DISCUSSION AND CONCLUSION

Resource and habitat degradation, and poverty imperil the survival of small-scale fishing communities. Confronting these challenges demands policies that ensure that the harvesting potential is commensurate with the productivity of the resource and habitat. The present study contributes to management by describing the socio-economic condition of the U.S. Caribbean fish trap fleet. The study highlights the presence of a diverse fleet. The study found that an important segment of the small scale sector was highly dependent on this fishery. In some instances, trap fishing accounted for 50 - 80% of their household income. The study also highlighted differences in the harvesting technologies, scale of operation and practices employed. For instance, St. Thomas and St. John fishermen had considerable more capital invested in the fishery (vessel, fishing equipment, etc) than their St. Croix and Puerto Rico counterparts. The study also showed appreciable difference in harvesting practices. For example, St. Croix and Puerto Rican fishermen, on average, tended to set one or two traps per line, whereas, St. Thomas and St. John fishermen tended to set nine traps per line.

While costs and earnings studies provide helpful information for describing the socio-economic conditions of the fishery, their value lies in the provision of accurate economic data that can be used to develop economic models to evaluate management proposals. For example, if managers were interested in examining the socio-economic impacts of a trap reduction plan, several relationships, such as value marginal product (VMP) and marginal cost (MC), could be estimated. Figure 1 presents the schematics of a stylized economic model that examines rationalizing the number of traps. The VMP is the gross revenue that is generated by adding one more trap into the fishery. As more traps are added into the fishery, the productivity per trap decreases. The MC is the expense of tending one more trap. The area underneath the VMP curve captures the total gross revenue and the area underneath the MC curve captures the total cost. The difference between these areas is the economic profit. If we assume that the fishery is operating under open access conditions, then the fleet would continue to set traps until the VMP is equal to the MC of tending then. If the Council decides to limit the number of traps from $E_{with\ traps}$ to $E_{w.o.traps}$, then the forgone benefits would be given by the area ABC. The forgoing analysis assumes that the stock remains constant.

The development of bioeconomic models could further contribute to realize the full economic potential of the fishery. Bioeconomic models could assist not only in identifying socio-economic benchmarks, such as maximum economic yield and optimal yield, but also could help estimate harvesting paths that maximize social welfare. This study can also yield valuable information to investigate the socio-economic effects of other regulatory proposals such as gear and vessel buybacks, harvest quotas, and access limitations.

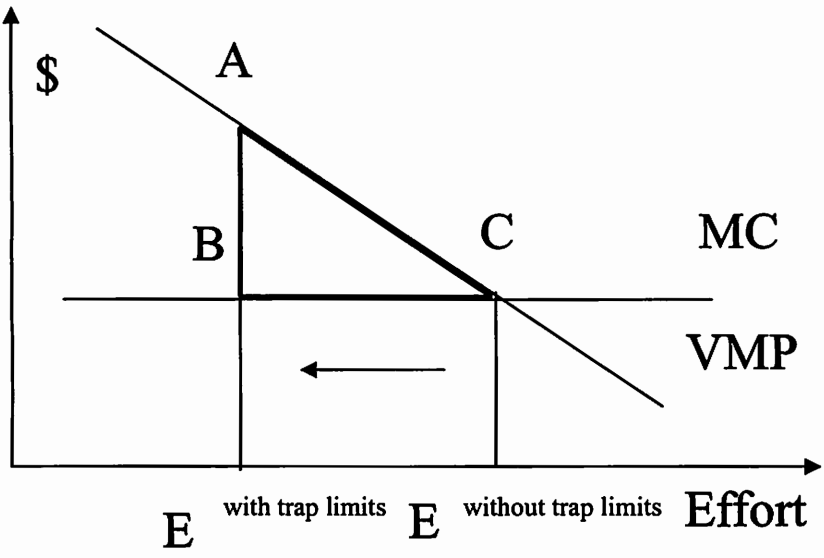


Figure 1: Economic impact of trap reduction proposal

LITERATURE CITED

CMFC. 2001. Draft Option Paper for Amendment No. 4 to the FMP for the Reef Fish Fishery of Puerto Rico and U.S. Virgin Islands, including a Regulatory Impact Review and Initial Regulatory Review. Caribbean Fishery Management Councils, San Juan, Puerto Rico. October 31, 2001.

Garrison, V. H., C. S. Rogers, J. Beets, and A. M. Friedlander. 2004. The habitats exploited and the species trapped in a Caribbean island trap fishery. *Environmental Biology of Fishes* **71**:247-260.

Kojis, B. 2004. Census of the Marine Commercial Fishers of the U.S. Virgin Islands. Department of Planning and Natural Resources. USVI Division of Fish and Wildlife, St. Thomas, USVI.

Quandt, A. 1999. An assessment of fish trap damage on coral reefs around St. Thomas, USVI. University of the Virgin Islands, St. Thomas, USVI. 14 pp.

Russ, G.R. 1991. Coral reef fisheries: effects and yields. Pages 601-637 in: P.F. Sale (ed.). *The Ecology of Fishes on Coral Reefs*. Academic Press, London, United Kingdom.

Schärer, M.T., M.C. Prada, R.S. Appeldorn, R. Hill, P. Sherida, and M. Valdés Pizzini, 2002. The use of fish traps in Puerto Rico: current practice, long-term changes, and fishers' perceptions. *Proceedings of the Gulf Caribbean Fisheries Institute* 55:744-756.

Sheridan, P., R. Hill, G. Matthews, and R. Appeldoorn, 2003. The effects of trap fishing in coralline habitats: What do we know? How do we learn more? *Proceedings of the Gulf Caribbean Fisheries Institute* **54**:1-12

BLANK PAGE

Workshops to Assess Fishers' Attitudes Toward Potential Capacity and Effort Reduction Programs in the US Caribbean

ROBERT J. TRUMBLE[1], JUAN J. AGAR[2], and [3]WALTER KEITHLY, JR.

[1]*MRAG Americas, Inc.*
110 S. Hoover Blvd, Suite 212
Tampa, Florida USA
[2]*NOAA Fisheries*
75 Virginia Beach Drive
Miami, Florida 33149 USA
[3]*Louisiana State University*
Baton Rouge, Louisiana 70803 USA

ABSTRACT

The Caribbean Fishery Management Council has determined that several species in the US Caribbean EEZ require harvest reduction. MRAG Americas and NOAA Fisheries jointly conducted two series of workshops at several locations with commercial fishers of Puerto Rico and the US Virgin Islands to determine their attitudes toward capacity and effort reduction ("limited entry") programs, as a potential part of the management scenario in the US Caribbean. Fishers generally preferred a system that limited entry to "genuine" fishers, those who derived substantial income from fishing. A preference for license limitation, used in this sense, was virtually universal. However, Puerto Rico fishers did not want to limit the total number of genuine fishers, while USVI fishers supported a limit on numbers. Different regions of the USVI had different views on appropriate limited entry. Any efforts to establish a limited entry program in Puerto Rico will require extensive consultation and education of fishers, and a common Federal/State program seems unlikely in the near future.

Most fishers felt that other limited entry/capacity reduction methods would overly restrict flexibility of fishers. Fishers commonly stated that small boats used in the US Caribbean do not have enough fishing power to cause a resource problem. Fishers face many socio-economic obstacles, have few economic opportunities other than fishing, and felt that management restrictions directly reduced their standard of living. Fishers in the USVI recommended financial and technical assistance for local efforts to develop a license limitation plans. Fishers, especially in Puerto Rico, stated a desire to have greater input into management decisions, and recommended future activities to enhance consultation and cooperation between government agencies and fishers.

KEY WORDS: Limited entry; US Caribbean; Fishery management

Actitudes de Pescadores hacia Programas de Reducción de Capacidad y Esfuerzo en el Caribe Americano

El Consejo de Administración Pesquera del Caribe (CFMC, por sus siglas en inglés) ha determinado que se debe reducir las capturas de varias especies en el Caribe Americano. MRAG Americas y el Servicio Nacional de Pesquerías Marinas (NOAA Fisheries, por sus siglas en inglés) llevaron a cabo conjuntamente una serie de talleres en Puerto Rico y en las Islas Vírgenes Americanas con el fin de determinar actitudes de los pescadores comerciales respecto a un posible programa que limita la capacidad y el esfuerzo pesquero ("acceso limitado"). En general, los pescadores señalaron que preferían un sistema de acceso limitado que favorezca a pescadores genuinos, es decir aquellos pescadores que obtienen gran parte de sus ingresos de la pesca. Concebido de esta manera, el sistema de acceso limitado tuvo una aceptación casi universal. Sin embargo, los pescadores de Puerto Rico no apoyaban una limitación en el número de pescadores genuinos, mientras que los pescadores de las Islas Vírgenes Americanas si apoyaban una limitación en el número de pescadores genuinos. Diferentes regiones de las Islas Vírgenes Americanas tenían perspectivas distintas sobre el sistema de acceso limitado más adecuado. Futuros esfuerzos para establecer un programa de acceso limitado en Puerto Rico necesitará de un amplio programa de consultas y educación. Un programa conjunto entre agencias federales y estatales parece poco probable en un futuro próximo.

La mayoría de los pescadores sostuvo que los otros métodos de acceso limitado, restringirían la flexibilidad de pescadores de manera excesiva. Pescadores frecuentemente señalaron que sus pequeñas embarcaciones carecían de suficiente poder pesquero para causar daño al recurso. Los pescadores también mencionaron que enfrentan varios obstáculos socio-económicos, incluyendo pocas oportunidades económicas fuera de la pesca y que regulaciones restrictivas directamente reducen su nivel de vida. Los pescadores de las Islas Vírgenes Americanas recomendaron dar asistencia financiera y técnica a sus esfuerzos para desarrollar un programa de limitación de licencias. Pescadores, especialmente en Puerto Rico, señalaron su deseo de tener una mayor participación en la toma de decisiones, y recomendaron actividades para realzar el nivel de consultas y cooperación entre agencias gubernamentales y pescadores.

PALABRAS CLAVES: Acceso limitado, Caribe Americano, Ordenación pesquera.

INTRODUCTION

The Caribbean Fishery Management Council (Council) is examining the potential use of fishing capacity and effort reduction mechanisms to rebuild over-exploited resources. Capacity reduction refers to reducing the absolute amount of fishing capability (e.g., vessel and license buybacks), while effort reduction refers to limiting the amount of fishing without eliminating it (e.g., reductions in days at sea).

The US Virgin Islands Department of Planning and Natural Resources (DPNR) implemented a moratorium on new entrants to the fisheries, but has not developed a permanent limited entry program or other regulatory revisions due to limited resources for consultation with the fishing industry. Puerto Rico currently has no limited entry program in place. The government of Puerto Rico has recently approved new fishery regulations to implement a 1998 fishery law, and intends to fully enact the regulations before undertaking efforts to develop limited entry programs.

To assist the Council, MRAG Americas, Inc. (MRAG) and NOAA Fisheries Southeast Fisheries Science Center (SEFSC) teamed with US Caribbean fishermen, to conduct a series of workshops in Puerto Rico (PR) and the US Virgin Islands (USVI). The objectives of these workshops were to explore limited entry concepts with commercial fishers and to assess the opinions of fishers on effort and capacity reduction programs (subsequently referred to as "limited entry").

Two rounds of workshops were held in Cabo Rojo, Ponce, and Fajardo in PR, and St. Croix and St. Thomas in USVI. During the first round, we presented background on the need to reduce catches, and the role and experience with limited entry programs. During the second round, we focused on issues specific to license limitation, the limited entry method most favored by fishers in attendance at Round 1. This paper details the main findings from these series of workshops.

PREPARATION FOR WORKSHOPS

The team prepared two bilingual announcements for distribution to fishers, agencies, and the media, that emphasized that the Council had scheduled management action for late 2004 to protect several fish stocks at risk from overfishing. The announcements offered limited entry and capacity reduction as management options for consideration by fishers.

During Round 1, summarized the characteristics and pros and cons of six limited entry and/or capacity reduction methods:

i) License limitation
ii) Co-management
iii) Vessel/license/gear buy back
iv) Limited days at sea
v) Gear limits (trap certificates)
vi) Quotas (fleet-wide, individual)

For Round 2, the team reviewed the opinions expressed during Round 1 and presented a list of issues with discussion points for which decisions are necessary for defining the license limitation program, and initiated a discussion with fishers about the next steps for developing a limited entry regime.

The workshop format was designed to be simple. The fisher partner introduced the team and indicated the purpose of the workshop. A team member then made a short presentation to introduce limited entry and how it might fit within a management program. Following the presentation, the team turned the floor over to fishers for questions and comments. The team responded as appropriate, trying to provide information without implying a preferred approach. In all cases, the team emphasized that it was trying only to obtain fisher opinions on management issues, and not advocating a particular management method.

ROUND 1 WORKSHOP RESULTS

The workshops were relatively well attended. In PR, approximately 200 fishers attended the workshops. The 2002 PR Fishers' Census reports that there are approximately 1,200 active commercial fishers in the island. In USVI, about 50 fishers attended the workshops. USVI has about 400 licensed commercial fishers. An attendance breakdown by location is offered in Table 1.

Table 1. Location, dates, and attendance at workshops

Location	Round 1		Round 2	
	Date	Attendance	Date	Attendance
Cabo Rojo	April 19	50	June 8	1
Ponce	April 20	50	June 9	20
Fajardo	April 21	100	June 10	28
St. Croix	April 22	40	June 6	4
St. Thomas	April 23	9	June 7	25

The number of participants offered an opportunity for a wide diversity of opinions. In PR, the implementation of the new fisheries regulations dominated the discussion. Several fishers did not know the real intent of the workshops, and came primarily to express displeasure with the law and regulations. Fishers expressed suspicions of our motives, suspecting that we were trying to generate support the new fishery regulations. Much of the discussion was directed against the new regulations. Fishers stated that too many restrictions currently existed, that they do not want restrictions imposed on them without an opportunity to participate. They also noted that DNER did not show them studies that demonstrated the need for the regulations nor the benefits that would accrue.

Fishers from all islands generally favored a license limitation that privileged "full time" fishers as the best of the possible limited entry methods (Table 2). Most favored a single license for Federal and State waters. PR fishers selected license limitation in part because of competition from fishers not considered as genuine and in part to help rebuild the resource (see footnote 1). PR fishers generally recognized that the fishery resource is in poor condition, although some from Fajardo and most from St. Croix and St. Thomas considered the resource in satisfactory condition but under stress from too many fishers. Most fishers did not perceive advantages to the other methods, and felt that the other methods would overly restrict their fishing operations. Fishers frequently stated that small boats used in the US Caribbean do not have enough fishing power to cause a resource problem. A number of fishers favored registration and limitation of traps/pots or SCUBA tanks, but most did not support this. Support for trap limits was greatest in the St. Thomas meetings, which had low attendance. Others recommended additional seasonal or permanent time area closures, but this did not elicit much support. Several brought up a perceived need for artificial reefs, fish attracting devices (FAD) and/or aquaculture.

Fishers face many socio-economic obstacles, and wanted maximum flexibility in fishing operations to deal with them. Fishers have few economic opportunities other than fishing, and felt that management restrictions directly reduced their standard of living. Fishers consistently brought up the idea of compensation by the government for present and especially future fishery restrictions: "The government pays farmers not to farm." In addition, fishers suggested that pollution and coastal development (e.g., new marinas, clearing of mangroves) had a greater adverse impact on habitat than fishing.

Fishers from PR and the USVI generally agreed that fisheries currently have too many regulations or restrictions, and that the existing regulations are adequate or excessive. Fishers supported revisions in fishery regulations, but the fishers from the two areas had vastly different views of the management process. USVI fishers meet with the support of DPNR to update old regulations. USVI fishers supported using the FAC to develop and incorporate fisher positions into Territorial regulations but lack of funding reduces effectiveness of the process. They strongly opposed the imposition of large closed areas in USVI waters. PR fishers strongly opposed the new regulations that implement the current fishing law, not only because they consider them excessive but also because they were developed in a non-consultative manner. PR fishers want to change the regulations adopted only a month before by what they see as an unresponsive government. In contrast to the USVI, PR fishers have no consultative mechanism comparable to the FAC process with which to develop fisher positions for license limitation or other management measures.

Fishers supported stronger coordination among the State and Federal management agencies. Fishers stated that lack of enforcement is a serious problem. St. Thomas fishers, especially, felt that lack of enforcement jeopardized current and future management effectiveness, and that only limited benefits would accrue from a limited entry program or other management changes. Fishers want to know how current restrictions will improve the resource, and timing or projected rebuilding, and most want more information on studies that conclude declining abundance and at-risk stocks and on studies that evaluate socio-economic impacts of proposed (or past) restrictions.

Table 2. Ranking of limited entry methods by fishers, by location

Issue	Location				
	Cabo Rojo	Ponce	Fajardo	St. Croix	St. Thomas
License limitation	Recommended	Preferred – Limit to genuine fishers	Preferred – Limit to genuine fishers Concern that retiring and death will reduce number of fishers too low	Preferred – Limit to genuine fishers	Preferred Opposed Uncertain
Co-management	No discussion	No discussion	Opposed – too political Should be highest priority – increase consultation	No discussion	Need more information
Vessel/ license/gear buy back	No discussion	No discussion	Opposed – "not feasible"	Opposed Supported if sufficient payment	Opposed – fishers would just share the same boat Supported as part of comprehensive plan
Limited days at sea	No discussion	Opposed – Weather already limits days at sea	Opposed – Weather already limits days at sea	No discussion	No discussion
Gear limits (trap certificates)	No discussion	No discussion	Opposed – Fishers need to determine how much to fish, small vessels have only small amounts of gear Supported – trap registration to prevent trap robbing	No discussion	Would work only for traps and SCUBA tanks Would trade gear limits for more open areas Lack of enforcement reduces effectiveness
Quotas (fleet, individual)	No discussion	Opposed	No discussion	No discussion	Opposed – too easy to cheat, would reduce catches too low

ROUND 2 PLANS

Of the issues discussed by fishers, the license limitation program was the only one with sufficient agreement to offer a good short-term opportunity for solutions. Based on discussions with fishers, the team concluded that fishers in all areas generally supported a permanent license limitation program, but did not all agree on the details of a program.

For the Round 2 workshops, the team developed a series of discussion points (Table 3) for further consideration of license limitation programs for PR and the USVI. The discussion points had both general issues common to both jurisdictions, and jurisdiction-specific issues. Table 3 was not intended as a decision-making document, but as a mechanism to indicate the complexity of the issues and stimulate discussion.

The desire by fishers to have a consistent venue for discussing management options with management agencies suggests that some form of consultative or cooperative management may be appropriate. However, the most reasonable form of cooperative management cannot be determined without further consultation with agencies and fishers to determine the interest and ability in participating in various forms of cooperative management. The plan for Round 2 workshops called for the project team to explore with fishers, especially in PR where no fisher-agency forum exists, possible steps for further consideration of cooperative management.

ROUND 2 WORKSHOP RESULTS

Fishermen participation in the second round of workshops declined somewhat. In PR fisher participation dropped from 200 to 50 and in USVI fisher participation declined from 50 to 30 (Table 1). As in the first round, fishers took very different positions on various issues.

Licence and Capacity Limitation Issues

Fishers generally preferred a system that limited entry to "full time" or genuine fishers (Table 2). PR fishers did not want to limit the total number of genuine fishers, while USVI fishers supported a limit on numbers. During the Round 1workshops, the project team explained the term *license limitation* to mean limitations on the *number* of licenses, and based discussions on this concept. However, at the second round workshops in Ponce and Fajardo, we discovered that fishers there interpreted license limitation to mean limitations on the individuals who could receive licenses. The preference of PR fishers in attendance could be considered a "regulated open access." Fishers face many socio-economic obstacles, have few economic opportunities other than fishing, and felt that management restrictions directly reduced their standard of living.

Table 3. Key issues for the design of a license limitation program

Issue	Discussion Points
Goal	Do you want your fishery to have fewer entry restrictions (more fishers) but be less profitable? or Do you want your fishery to have more entry restrictions (fewer fishers) but be more profitable?
License types	Should fishing license be generic or gear-specific license? Should licenses be multi-species with no endorsements, multi-species with species endorsement, or single (or group) species? Should there be full-time, part-time, and/or subsistence categories?
Eligibility	How would you define a full-time, part-time commercial fishers and/or subsistence fisher? Income using tax returns, or landings reports Number of days at sea, poundage thresholds based on landing reports Other criteria
Limitations restrictions	Attach license to the vessel and/or individual? Should part-time and/or subsistence fishers be confined to a specific gear (e.g., hook and line, spears) and gear amount (e.g., 20 traps)? Should the license only apply to Commonwealth/Territorial waters or jointly to Commonwealth/Territorial and Federal waters?
Duration	Should the license be granted for a specific amount of time (e.g., 5, 10, 15 years), until the fisher dies or retires, or in perpetuity?
Transferability	Should the transfer of licenses be allowed? Who should be able to receive a "transferred" license (e.g., family, friends, helper, etc)? Should license holders be able to sell and/or lease their license? Who should be able to buy and/lease the license (part-time fishers, helpers, etc)?
New entrants to the fishery	Should there be no new entrants for a set period of time (e.g., moratoria)? Should there be helper license as prerequisite for entry for full-time fishers? Should fishes be required to acquire to 1, 2, or more licenses to enter the fishery?
Representation	Should representation be by Association heads, Federation of associations, Fishery Advisory Committee (FAC), or direct election by fishers?

PR and USVI fishers shared a common view on the need for license limitation but often did not agree on the details of the concepts. In general, fishers wanted to limit commercial fishing licenses to genuine fishers – those who made a substantial part of their income from fishing. A preference for license limitation, used in this sense, was virtually universal. However, PR and USVI fishers had opposite opinions on whether to limit the number of licenses. While PR fishers at the workshops did not want a limit on the number of fishers, USVI fishers wanted to make the current moratorium permanent. In most cases, fishers in both areas preferred a tiered license system that designated full-time fishers and other categories, although some did not want any separation among fishers. Those who wanted a tiered system had various ideas for the details. Virgin Island fishers were more receptive to licenses or endorsements for species or gear, while PR fishers opposed this idea (the new PR regulation calls for endorsements by species). Fishers in both areas preferred a management system that reduces the administrative difficulties in dealing with government, including a single license for State and Federal waters, at least several years duration for licenses, and a single location for renewing licenses. Fishers in both areas felt that enforcement was inadequate to prevent illegal fishing. USVI fishers further felt that lack of enforcement could jeopardize future management actions including license limitation, but recommended moving forward with developing a program was worthwhile in part to raise the profile of the enforcement inadequacies. Manipulation of landings records and tax forms were identified as issues needing resolution in PR.

General Concerns — Puerto Rico

Fishers in PR expressed suspicion of and/or unhappiness with government agencies. Fishers typically blamed DNER for a lack of responsiveness to fisher input and for imposing restrictions unilaterally. Fishers commented on a need for coordination among management agencies (DNER, Puerto Rico's Department of Agriculture (PRDA), NOAA Fisheries, and the Caribbean Council). Fishers continuously commented on the non-responsiveness of DNER and PRDA. The concern with and opposition to the new fishery regulations arose as a consistent theme. A central reason for PR fishers' apprehension to the new regulations, specifically the mandatory reporting of fish landings, is the potential loss of welfare benefits. Key informants have suggested that about 80% of the Puerto Rican fishers receive some form of government assistance.

Puerto Rico's Department of Agriculture provides a number of social assistance programs. In addition, PRDA allows commercial fishers to qualify as bona fide farmers. A bona fide farmer: 1) has in effect a certification issued by the Secretary of Agriculture with the advice of the Secretary of the Treasury, stating that during such year the person was engaged in an agricultural business, and 2) derived 50% or more of gross income from an agricultural business, as an operator, owner or lessee, as shown on his income tax return. The bona fide designation provides commercial fishers with 90% tax exemption on income derived from agricultural businesses.

Commercial fishers fear that by having to report their landings, government benefits maybe jeopardized. Depending on the fisher's income, there may be an incentive to either under-report or over-report. If a fisher has no (or modest) reported (non-fishing) income, he/she may have an incentive to under-report catches to minimize the Commonwealth tax burden, and to qualify for PRDA programs such as food stamps. Depending on the particular situation, the fisher may also qualify as a bona fide farmer. Conversely, if a fisher has a reported (non-fishing) income (e.g., military pension), then depending on its magnitude, the fisher may have an incentive to over-report landings to ensure he/she qualifies as a bona fide farmer (i.e., 51% of the fisher's income comes from fishing) to reduce the tax burden. The DNER is aware of the welfare and income tax implications on catch reporting, and has taken some steps to address them. PR fishers expressed a desire for more direct input into management decisions.

General Concerns — US Virgin Islands

USVI fishers expressed suspicion of and or unhappiness with government agencies. Fishers felt overwhelmed by the myriad of territorial and federal agencies with some control over fishing activities. Many expressed reluctance to cooperate with the agencies because of a perceived ineffectiveness of cooperation or dishonesty on the part of the agencies, giving examples as imposition of parks and monuments in the US Caribbean. USVI fishers have a FAC with which to develop and transmit ideas to management. However, it has not been entirely successful, due in part to lack of funding and expertise in support of the FAC and in part to lack of participation by fishers. Fishers commented that members who participate in unpopular decisions may be the target of retaliation in the form of gear destruction. St. Croix fishers desire a fishery liaison position with local government to assist fishers in dealing with the government.

RECOMMENDATIONS

During the second round of workshops, the team asked participants 1) if they supported a recommendation to seek funds to help fishers develop a license limitation program, and 2) if they supported a recommendation to evaluate mechanisms for enhancing management cooperation among fishers and agencies. USVI fishers supported both ideas. PR fishers opposed limiting the number of fishers, but supported a process for enhanced cooperation. During the course of these workshops, the team became aware of the incentives for misreporting catch and income. Misreporting has serious implications for many management programs. Some better means of confirming catch seems imperative.

The project team used a consensus of opinions expressed during the workshops to develop the following recommendations to build on the results of the workshops:

i) Do not attempt at this time to develop a license limitation that sets a maximum number of fishers for PR without extensive outreach and education. PR fishers are adamantly opposed to this concept. Fishers believe that limiting licenses to genuine fishers will reduce the total number of licenses and will concomitantly reduce the catching capacity to levels commensurate with the resource productivity. PR fishers seemed to have misconceptions of the various methods of limited entry and the implications of the methods. Extensive education and discussion with the fishers and their leaders will be required to explore limited entry.

ii) Fund technical support for FACs to develop new regulations for license limitation in the USVI. Fishers, DFW, and the Council support establishing a process to develop a permanent license limitation program for the USVI. The Commissioner of DPNR has charged the USVI FACs with updating and rewriting fishery regulations, including regulations for a limited entry program. The FACs have met several times to discuss limited entry, but have not successfully completed this project. Additional funds to support the FAC process and to provide outside expertise will help the FAC reach a consensus.

iii) Address the desire for increased fisher participation by exploring mechanisms that both fishers and government can support. Increasing cooperation is not a trivial process, as both fishers and agencies have issues they prefer to include or exclude from the process. Fishers objected the lack of studies that justified management actions. We recommend preparation of a proposal to obtain funds to survey agencies (State and Federal) and fishers to determine appropriate organizational structures, and to help fishers and agencies implement the organization.

iv) Develop a system to verify reported landings. The quality of landings reports depends on the willingness of fishers to report correctly. Quality of record-keeping by fishers, fisher interest in the data, and incentives have a major influence on data quality. Especially in PR, welfare and tax benefits can provide incentives to under report or over report (DNER is working to address these issues). As a result of these incentives, catch statistics may not accurately track even trends. PR fishers stressed the need to certify landings. Such mechanisms could range from certification of landings by the head of a fisher's association head (recommended by PR fishers, but not available in USVI) to a requirement to sell to licensed and bonded processors. We recommend evaluation of alternative mechanisms consistent with the culture to increase reliability of the catch data.

BLANK PAGE

Establishing a Socio-economic Monitoring Program for Glover's Reef Atoll, Belize

JANET GIBSON,[1] DOMINIQUE LIZAMA[2], and ROBERT POMEROY[3]
[1] *Wildlife Conservation Society*
P.O. Box 2038
Belize City, Belize
[2] *48 Gabourel Lane*
Belize City, Belize.
[3] *University of Connecticut*
380 Marine Science Bldg., 1080 Shennecossett Road
Groton, Connecticut 06340-6048 USA

ABSTRACT

In an effort to strengthen the management of the Glover's Reef Marine Reserve in Belize, a socioeconomic monitoring program is being developed. Although the Marine Reserve was declared in 1993, comprehensive socioeconomic data have not been systematically collected for the site. The SocMon protocol for the Caribbean was applied and the results provide a baseline of the status of the Atoll against which future surveys can be compared. Results presented for the survey of fishermen from Sarteneja, Dangriga and Hopkins include summaries on demographics, marine activities, attitudes and perceptions, perceived threats, and material style of life. By continuing this program, information will be generated which should ensure adaptive management occurs, introducing measures that are acceptable and effective.

KEY WORDS: Fishing, marine reserve, socioeconomics

Estableciendo un Programa de Manitoreo Socioeconomico en Glover's Reef Atoll, Belize

Con el esfuerzo de resforzar el manejo de la la Selva Marina de Glover's Reef en Belize, se esta desarrollando un programa de monitoreo. Informacion socioeconomica debera de ser incorporada en la planificacion de gerencia para asegurarse que las medidas implementadas responden a las prioridades y nececidades comunitarias y mas. Implementando este tipo de medidas entonces motivara a la comunicadad a apoyar la conservacion. Aun cuando la Reserva Marina de Glover Reef fue declarada en 1993, informacion comprensible no ha sido colectada en una manera sistemamatica, con la exepcion de algunas encuestas que se han llevado acabo en las comunidades del area de pesca. La pesca es la actividad mas importante de Atoll, una area tradicionalmente especializada en la crianza de langosta, caracol y pescado finfish. El turismo es la segunda fuerza social y economica, el cual se esta desarrollando rapidamente con actividades como buseo, buseo en las profundidades, kayakin, y la pesca deportiva. En este estudio se desarrollaron unas encuestas durante un taller de entrenamineto y consideraban a los pescadores, guias turisticos y las familias. Las encuestas se llevaron acabo en mayo, junio y julio del 2004 en las tres comunidades mas importantes de pescadores, guias turisticos los cuales estan activos en Glover's Reef, especificamente en Sartaneja, Dangriga y Hopkins. El Protocolo de SocMon desarrollado en el Caribe se aplico y los resultados indicaron asi una base de la situacion socioeconomica de Atoll con los cuales se podran comparar futuras encuestas. La informacion incluye sintesis de actividades marinas y demograficas, actitudes y perceptciones, amenazas y problemas percividos y material sobre el estilo de vida. Con la continuidad de este programa se generara informacion la cual puede asegurar que se lleve acabo un manejo adaptable, introduciendo medidas de manejo que son aceptables y efectivas.

PALABRAS CLAVES: Programa de monitoreo, Reserva Marina de Glover Reef, Belize

INTRODUCTION

Located 30 miles off the coast of Belize, Glover's Reef Atoll supports extraordinarily high biological diversity and possesses the greatest range of reef types in the Caribbean Sea (Dahl et al. 1974). This elongate atoll, measuring 32 km long and 12 km wide, has also been identified as a global and regional priority for conservation attention (Kramer and Kramer 2002).

Fishing is the most important economic activity on the Atoll. The Nassau grouper spawning bank on the northeastern point has been traditionally exploited by fishermen from the village of Hopkins. The number of fishermen on the bank has been decreasing with the dramatic decline in numbers of spawning groupers over the last 25 years (Sala et al. 2001), and the bank was closed to fishing in 2002. Fishermen from Dangriga and Sarteneja also fish the Atoll, diving for lobster and conch, and catching finfish using a variety of methods.

Tourism is a second major social and economic force at Glover's Reef. Six tourism facilities are based on the Atoll; boats from other resorts and private yachts also visit the area. The main activities include snorkeling and scuba diving; kayaking has recently developed, and some sport fly-fishing occurs (Gibson 2003).

These reefs also have cultural and archeological significance. Glover's Reef lies on the pre-Columbian trade route between Honduras and Yucatan. Pottery shards are evidence of pre-Classic Maya (500-900 A.D.) settlements on some of the islands of the Atoll. Since then the Atoll has been inhabited by shipwrecked Spanish and British sailors.

The Atoll was declared the Glover's Reef Marine Reserve in 1993, and a World Heritage Site in 1996. Encompassing 35,076 hectares, the reserve has been zoned into four management areas, including a Conservation Zone that covers about one-fifth of the area, the largest 'no take' zone of the reserves in Belize.

Despite its protected status, Glover's Reef is threatened by various factors, including a lack of support for the reserve, primarily from the fishing community. Socioeconomic data have not been systematically collected for the site, apart from a couple of surveys in two of the communities that fish the area. Establishing a socioeconomic monitoring program is one step in addressing this weakness, by providing a mechanism for community input to the management process, and by also generating information that will improve the development of measures that are responsive to community priorities, needs and mores. A second objective is to ensure that the potential benefits and costs of management of the reserve to stakeholders are fully documented and accounted for.

Glover's Reef fishermen come mainly from three coastal communities: Sarteneja, Dangriga and Hopkins (Figure 1).

Figure 1: Map showing the location of Sarteneja, Dangriga, Hopkins and Glover's Reef

Sarteneja

Sarteneja village, with a population of approximately 1,591 (CSO 2003), is located on Corozal Bay in northern Belize. The community was established in 1854 by the Mexican and Mayan peoples fleeing persecution by the Spaniards in Mexico, and the primary language remains Spanish. Today, fishing is the major economic activity, and the village has one-third of the total population of commercial fishermen in Belize (Programme for Belize 2003). Sarteneja fishers travel long distances to their fishing grounds, which include areas along the entire coast of Belize. Garaway and Esteban (2002) indicated that Glovers Reef was the major fishing area for Sarteneja fishermen.

The heavy dependence of villagers on fishing is due to several environmental and socioeconomic constraints such as geographic remoteness, few choices for employment, limited education, lack of access to financial capital and land, and language (Pantin et al. 2004). The tourism industry is very underdeveloped with few tourist facilities located in the village. Due to this dependence and lack of alternatives, Sarteneja villagers are most at risk of losing their fishing livelihood (Palacio 2002).

A recent boat census (Grant 2004) noted that eight sail boats from Sarteneja fish at Glover's Reef, ranging in size from 21 to 38 ft, and carrying 7 to 14 dories each. The fishermen free dive using hook sticks for catching lobster, Hawaiian slings and spear guns to spear fish, and collecting conch by hand.

Dangriga

Dangriga is the largest town in the Stann Creek District and is located in the centre of the mainland coast, at the mouth of the North Stann Creek River. The town has a population of 8,814 (CSO 2003), and has experienced a faster rate of population growth since 1990 than Sarteneja, possibly due to the greater growth of tourism in the area (Palacio 2002).

The main economic activities include agriculture, particularly the citrus and banana industries, aquaculture, fishing, tourism and commerce, including activities related to the port at Commerce Bight located just south of the town (Dangriga Town Council 2004). The main ethnic groups are the Garifuna and Creole.

Glover's Reef is the third most important area for Dangriga fishers (Garaway and Esteban 2002). According to Grant (2004), only two boats from Dangriga are currently active at Glover's Reef. These are skiffs of 23 ft, with two and three crew members each. The Dangriga fishers use mainly hand lines (drop and set lines) and hook sticks, for catching finfish and lobster, respectively.

Hopkins

Hopkins is a village of 994 persons (CSO 2003), located a few miles south of Dangriga on one of the few mainland beaches in Belize. It is a Garifuna community, and fishing is part of the subsistence tradition of the people (Perez 2003, Pantin 2004). Other economic activities include working in agricultural plantations, subsistence farming, and government employment (Garaway and Esteban 2002). Tourism is also now well established and growing.

Glover's Reef is the third most important fishing area for fishers from Hopkins, who have traditionally fished the Nassau grouper aggregation site on the atoll during the spawning season (Garaway and Esteban 2002). Twelve skiffs, powered by outboard engines and ranging in size from 20 to 26 ft, fish at Glover's Reef (Grant 2004). Several of the skiffs also carry one or two dories, and have two to four crew members. The Hopkins fishers use a range of gear: hand line, spear gun, hook stick, and rod and reel.

METHODS

The methods used in the study generally followed the protocol described in the manual *Socioeconomic Monitoring Guidelines for Coastal Managers in the Caribbean: SOCMON Caribbean* (Bunce and Pomeroy 2003) and the *GCRMN Socioecomomic Manual for Coral Reef Management* (Bunce et al. 2000). These included carrying out document analysis, holding discussions with key persons in each community, and conducting surveys of fishermen, tour guides and households.

As a practical exercise during a two-day training workshop on the SocMon guidelines, participants developed a draft questionnaire targeting Glover's Reef fishermen. The survey team refined the draft to apply to fishermen in

Sarteneja, Dangriga and Hopkins and also used it as the basis for developing the questionnaires for tour guides and households.

The interviews were conducted during May, June and July 2004. An effort was made to interview at least 10% of fishermen who fish at Glover's Reef. Twenty fishermen in Sarteneja, eight in Dangriga, and 15 in Hopkins were interviewed, including both captains and crew. The questions in the questionnaires were coded and the data entered in Excel spreadsheets. The data were then analyzed and the results of the fishermen interviews are presented below.

Documents providing secondary data were also collected and reviewed. Many of these provided background information on the three coastal communities, and included papers on population statistics, previous surveys conducted and community assessments.

RESULTS

Demographics

All those interviewed were males. In Dangriga, the average age of respondents was 40, with half of the eight respondents having a primary education and half a secondary education. The average household size was five people. Half of the respondents reported that fishing was their primary occupation. Five of the eight respondents reported that other family members were involved in income-generating activities.

In Hopkins, the average age was 28, with 11 of the 15 respondents having primary, three having secondary, and one having tertiary level education. The average household size was six people. Fourteen of the 15 respondents reported that fishing was their primary occupation. Five respondents reported that other family members were involved in income-generating activities.

In Sarteneja, the average age was 34, with 19 of the 20 respondents having primary level education and one having secondary level education. The average household size was five people. All respondents reported that fishing was their primary occupation. Eight fishermen reported that other family members were involved in income-generating activities.

Coastal and Marine Activities

The majority of Dangriga respondents had fished at Glover's Reef for more than eight years and received more that 50% of their annual catch from the area. The fishermen used primarily fishing lines and fishing rods to target finfish including snappers, kingfish, barracudas, marlin, tuna and wahoo. Boats had an average of three crew members. Only one respondent sold 100% of his catch to a cooperative, while two sold 100% to hotels, three sold their fish primarily in local markets, and two kept 100% for their own use.

The respondents in Dangriga felt that the condition of fisheries resources at Glover's Reef had worsened in the last five years. This was reportedly due to overfishing, more fishermen in the area, the marine reserve being established, and hurricanes. The majority (75%) felt that fishermen could work together to solve a problem in the fishery, and all felt that there should be co-management with the government. The majority of respondents (75%) would support Glover's Reef being managed by a partnership between government and another group, such as an NGO or fishing cooperative.

The majority of Hopkins respondents had fished at Glover's Reef for more than ten years and received an average of 50% of their annual catch from the area. The fishermen primarily dived using hook sticks and spear guns to target lobster, conch and reef fish. Several fishermen also used fishing lines and rods to target a more varied number of fish species including snappers, kingfish, and barracuda. Boats had an average of three crew members. The majority of respondents sold their catch primarily to a fishing cooperative. Two sold their catch primarily to hotels, three to local markets, and two kept their catch for their own use.

The Hopkins respondents felt the condition of fisheries resources at Glover's Reef had got worse in the last five years due to climate change, the marine reserve, and research being conducted. The majority (93%) felt that fishermen could work together to solve a problem in the fishery. Most fishermen felt there should be co-management with government. The majority of respondents (54%) would support Glover's Reef being managed by a partnership between government and another group.

The majority of Sarteneja respondents had also fished at Glover's Reef for more than ten years and 85% of them received 76 to 100% of their annual catch from the area. The fishermen dived, using spear guns and hook sticks to primarily target lobster and conch, and secondarily finfish such as hogfish, grouper, snapper and rockfish. Boats had an average of nine crew members. All respondents sold their catch primarily to a fishing cooperative, although two sold part of their catch to local markets.

The respondents in Sarteneja felt that the condition of fisheries resources at Glover's Reef had declined in the last five years. This was overwhelmingly reportedly due to the marine reserve, although other causes included hurricanes, more fishermen in the area and illegal fishing. All respondents felt that they could work together to solve a problem in the fishery and almost all felt that there should be co-management with government. The majority (60%) would not support Glover's Reef being managed in partnership between government and another group; only five of the 20 respondents would support such a partnership.

Attitudes and Perceptions

All respondents in Dangriga were aware that Glover's Reef is a marine reserve and seven of the eight respondents were familiar with the management zones. All respondents in Hopkins were aware that Glover's Reef is a marine reserve and 14 of the 15 respondents that there are management zones. All respondents in Sarteneja were also aware of the marine reserve and its management zones. Table 1 shows the fishermen's familiarity with the various other rules and regulations of Glover's Reef.

Table 1. Familiarity with rules and regulations at Glover's Reef (percent familiar)

	Dangriga	Hopkins	Sarteneja
Commercial fishing	100	93	95
Sport fishing	75	67	60
Mangrove use	88	60	65
Resort development	75	60	25
Tourism snorkeling/diving	88	53	45

Three of the respondents in Dangriga and seven in Hopkins belonged to Northern fishing cooperative. In Sarteneja, 17 respondents belonged to a fishing cooperative; eight were members of National fishing cooperative and nine of Northern fishing cooperative.

In Dangriga, of three respondents to the question, only one felt that the fishing cooperative represented them well on the Glover's Reef Advisory Committee. In Hopkins, of seven respondents to the question, one reported being well represented and four poorly represented on the Committee. In Sarteneja, of 18 respondents to the question, seven reported being very well or well represented, while seven reported being poorly represented by their cooperative on the Committee.

Half of the respondents in Dangriga stated that they were willing to change to another occupation if it provided equal or more income than fishing. One preferred to be a tour guide, and three others preferred an unspecified occupation. Five of the respondents in Dangriga stated that they would choose an occupation for their children. Two preferred education for their children, two preferred cooperative jobs, and one preferred tourism.

Eighty percent (12) of the respondents in Hopkins stated that they were willing to change to another occupation if it provided equal or more income than fishing. Six preferred to be a tour guide, one a sport fishing guide, one in aquaculture, and two respondents preferred an unspecified occupation. Four of the respondents in Hopkins stated that they would choose an occupation for their children. One respondent each chose education for their children, doctor, trade school, and tourism.

Sixty percent (12) of the respondents in Sarteneja stated that they were willing to change to another occupation if it provided equal or more income than the fishing occupation. Five preferred to be a tour guide and seven other respondents preferred an unspecified occupation. Eighteen of the respondents in Sarteneja stated that they would choose an occupation for their children. Fourteen preferred education for their children, four preferred tourism, and one preferred cooperative job.

The respondents were asked to indicate their degree of agreement with a series of statements concerning the marine resources, marine resource management and tourism:

i) The marine reserve is important for protecting the atoll's coral reef system,
ii) The conservation zone is helping to sustain fisheries,
iii) More area should be opened to fishing in the marine reserve,
iv) Penalties for illegal fishing should be increased,
v) Mangroves should be protected at Glover's Reef,
vi) Enforcement of the reserve regulations is adequate,
vii) Participation in management decisions about Glover's Reef marine reserve is important to you,
viii) The closure of the NE point spawning aggregation site is a good management measure, and
ix) Most fishermen respect the marine reserve regulations.

Respondents from Dangriga agreed with the statements on the marine reserve, conservation zones, increasing penalties, protecting mangroves, and participation in management. In Hopkins they agreed with the statements on the marine reserve, conservation zones, opening more area of the marine reserve for fishing, increasing penalties, protecting mangroves, participation in management, and respect for regulations. In Sarteneja there was agreement for the marine reserve, opening more area of the marine reserve for fishing, protecting mangroves, and participation in management, but weaker agreement for the conservation zones.

Threats and Problems

Respondents were asked to state the three major threats to the marine resources at Glover's Reef. The primary problems reported by respondents in Dangriga were illegal fishing, over fishing, and area too large to patrol. The main problems reported by those in Hopkins were illegal fishing, area too large to patrol, oil well, and human resources. The primary problems reported by Sarteneja respondents were caye owners fish in reserve, fisheries staff is biased, over fishing, illegal fishing, and area too large to patrol.

The respondents were asked to state the possible solutions to these problems. In Dangriga, the solutions included enforce laws, more patrols, and more rangers. Solutions proposed by Hopkins respondents included increasing fishing area, more patrols, new marker buoys, and enforce laws. In Sarteneja, the solutions included increasing fishing areas, enforce laws, no special licenses, more patrols, more rangers needed, and change rangers.

Material Style of Life

As a proxy of the measure of wealth, respondents were also asked questions concerning their household assets and construction materials of their house. The results indicated that more respondents in Hopkins own their house (87%) and lot (93%) than those in Dangriga and Sarteneja. Respondents in Dangriga own more household assets, such as stereos, telephones, and refrigerators, than respondents in Hopkins and Sarteneja. The quality of housing of Sarteneja respondents was slightly higher than those in Dangriga and Hopkins, with more respondents having concrete walls and floors. Poorer quality houses of palmetto with thatch roofs, however, were recorded only in Sarteneja.

DISCUSSION

Of the three communities, Dangriga appeared to be the least dependent on fishing at Glover's Reef. Apart from having the smallest number of fishers using the Atoll, 50% of the respondents had activities other than fishing as their primary occupation. In contrast, all respondents in Sarteneja, and almost all in Hopkins, indicated that fishing was their primary occupation.

Dangriga and Hopkins respondents obtained about 50% of their catch from the Atoll. Sarteneja fishers, however, obtained 76% to 100%, demonstrating their greater dependence on the resources of the Atoll.

Marketing and use of the catch also differed amongst the communities. Fishers in Dangriga sold their catch mainly in local markets and hotels, with a significant portion kept for subsistence use. Fishers in Hopkins sold their catch mainly to the cooperative, some was sold in local markets and to hotels, and some was also kept for subsistence use. In Sarteneja, however, virtually all the catch was sold to the co-operatives, with just a small amount sold locally. The portion of catch used by fishers and their families in Dangriga and Hopkins probably represents an important source of their protein consumption.

Fishers from the communities differed in the type of gear used and the species targeted. Fishers from Dangriga used mainly fishing lines and rods, targeting benthic and pelagic finfish. Fishers from Hopkins used a mixture of gear, with most fishers being divers using hook sticks and spear guns to catch lobster, conch, and reef fish. In addition, several fishers used fishing lines and rods capturing a variety of pelagic species. On the other hand, fishers from Sarteneja were all divers using hook sticks and spear guns, taking conch, lobster, and reef fish.

Respondents from all communities agreed that the fishing resources are in worse condition compared to five years ago. All communities indicated that one reason was the establishment of the marine reserve in 1993. This was ranked as the most important reason by the respondents from Sarteneja.

Respondents from all communities had a high awareness of the reserve and its management zones. All fishers were familiar with the commercial fishing regulations, but were less so with those regarding mangrove use, tourism, and resort development. Dangriga fishers appeared to be the most familiar with the various rules and regulations, whereas those from Sarteneja were the least familiar. This could possibly be a reflection of Sarteneja fishers being only concerned with fishing, while the Dangriga fishers have more varied activities related to the reef, such as tourism.

Significantly, the majority of respondents in Dangriga and Hopkins, and 50% from Sarteneja, felt they were poorly represented by their respective co-operatives on the Glover's Reef Advisory Committee.

Fifty percent of respondents from Dangriga and 60% from Sarteneja were willing to change to another occupation. Willingness to change was particularly high amongst the respondents from Hopkins (80%), possibly a factor of the younger average age of the fishers in this village. In Hopkins the fishers were mainly interested in becoming involved in tourism. Although many respondents from Sarteneja were also interested in tourism, the overwhelming majority in this village were interested in further education for their children. Sarteneja offers fewer livelihood options than Hopkins and Dangriga as, for example, there are fewer tourism opportunities.

Despite concerns about the negative impacts of the reserve, the majority of fishers from all communities agreed with the importance of the reserve in protecting the Atoll's resources and the Conservation Zone's role in helping to sustain fisheries. The degree of agreement was weakest in Sarteneja, however, where fishers are more dependent on the reserve for fishing and have fewer alternatives. Nevertheless, the majority in all communities, particularly Sarteneja, felt more of the reserve area should be opened to fishing.

Respondents from Hopkins felt that most fishermen respected the reserve rules; in contrast, the majority from Sarteneja did not agree. On the other hand, Sarteneja respondents felt strongly (70%) that enforcement was not adequate, while most from Dangriga and Hopkins did not have a strong opinion.

Finally, contrary to the common belief that fishermen are not prospering economically, the results indicated that the majority of respondents in all communities own their house lot and home, and also their boat and engine (or dory in the case of Sarteneja). The majority also own a wide variety of household assets and appliances such as washers, VCRs, telephones, televisions, stereos, stoves, and refrigerators. This economic progress, however, may have been realized at the expense of the marine resources, which the majority of respondents agreed have declined over the past few years.

RECOMMENDATIONS FOR PRIORITY ACTIONS

Based on the results of the survey, we recommend several priority actions related to education, alternative livelihoods, legal issues, reserve management and improved participation.

Education and Awareness

Gaps in the fishermen's knowledge of the regulations of the reserve management zones, particularly amongst Hopkins fishers, need to be urgently addressed by the reserve staff. Although good support for the reserve was evident, respondents generally felt that fishers do not respect the reserve regulations. The benefits of the reserve need to be clearly demonstrated to fishers, especially to those in Sarteneja who were the least supportive.

Fishers also need to be educated in the regulations governing mangrove use, tourism, and coastal development. An awareness campaign on marine-related environmental laws should be conducted to provide a comprehensive legal knowledge base for fishers. Although education efforts can be channeled through the fishing co-operatives, programs also need to be developed that will reach the independent fishermen. The primary level of education of most fishers must be considered, and material should be translated into Spanish for those from Sarteneja.

Alternative Livelihoods

Sarteneja fishers are almost totally dependent on fishing. If fishing effort is to be reduced in order to achieve sustainable fishing levels, alternatives for these fishermen need to be provided. Fishermen were mainly interested in becoming involved in the tourism industry; however, tourism in Sarteneja cannot be considered an immediate alternative unless fishers enter the industry at other sites, such as becoming guides for the cruise tourism trade. Although efforts should continue in tourism training and marketing, these are longer term aims and short-term alternatives need to be identified, such as training in computer skills, small business development, handicrafts, and aquaculture.

Hopkins fishers also rely very heavily on fishing as their source of income. Options for tourism alternatives, however, are more well developed in this village. As the fishers' willingness to change to tourism-related activities was also very high, projects that facilitate their move to this industry are recommended, as they should have a very good chance of success.

Legal Concerns

Many respondents emphasized the need to adequately charge those who fish illegally. As penalties are charged at the discretion of the magistrates, they may need to be better informed of the importance of the industry and the harmful effect illegal fishing is having on the resources. Penalties may need to be increased or new measures introduced, such as cancellation of fishing licenses.

The reserve regulation allowing subsistence fishing by caye owners within the Conservation Zone should be repealed. This law has caused resentment amongst fishermen who consider it unfair, as the Zone is closed to commercial fishing. The Conservation Zone should be designated a fully protected area, with no exceptions allowed.

As many respondents felt strongly that the use of the Atoll by too many fishermen is causing a decline in the resources, we recommend that special fishing licenses be issued only to traditional fishers. This is provided for in the reserve regulations but has not yet been implemented. Traditional fishers feel that, as they have forfeited some of their fishing area by respecting the Conservation Zone on the Atoll, they should be the beneficiaries of the enhanced catches that may result from the protected area.

Reserve Management

Strong concerns were expressed regarding the need to strengthen patrols and improve the caliber of rangers. Although patrols have improved recently, recommendations on ways to further improve surveillance on the Atoll could be made by the Glover's Reef Advisory Committee. Records of warnings, arrests, and convictions should continue to be reported to the Committee through the reserve's quarterly reporting system, thus aiding in the formulation of recommendations for patrols to be more strategic and effective.

In an effort to hire the most suitable rangers, it may be beneficial to involve the Committee in the review of applications. Additional training could also be provided for rangers to help enhance the use of education as a tool fostering compliance, strengthen the process of collecting evidence and making arrests, emphasize the importance of record-keeping, and ensure safety when on patrol.

Representation and Participation

Many fishermen felt that they were not well informed by their representatives on the Glover's Reef Advisory Committee. As the Committee provides the main mechanism for their participation in the management of the reserve, this is a matter of critical importance. Their representation could be enhanced by the reporting of Committee proceedings at monthly and annual general meetings of the two fishing co-operatives. Communications between Committee representatives and their membership could also be improved by the preparation and distribution of bulletins that update the membership on issues under discussion by the Committee. Training of Committee members in their responsibilities should also continue to help strengthen their ability to fulfill their role.

The majority of respondents identified illegal fishing and inadequate patrols as a major problem on the Atoll. Most respondents also felt problems should be addressed jointly by fishermen and government, and were interested in increasing their participation in reserve management. This provides the perfect opportunity to seek their involvement in assisting the Fisheries Department and reserve personnel in surveillance of the Atoll, thus improving patrols and reducing illegal fishing.

In conclusion, the study provided useful baseline data against which future surveys can be compared to detect socioeconomic trends. Applying the recommendations can also help management be more responsive to the concerns expressed by one of the reserve's major stakeholder groups, the fishermen.

ACKNOWLEDGEMENTS

We are very grateful to the key informants and fishermen who were interviewed. We also thank those who helped with the organizing the surveys, namely Sergio Hoare, Danny Wesby, Normando Mora, Brian Castillo and Jamal Martinez. We are grateful to NOAA for funding the study. Assistance was also received from the UWI Coastal Management Research Network (COMSARE Net), a project funded by the UK Department of International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID or UWI.

LITERATURE CITED

Bunce, L. and R. Pomeroy. 2003. *Socioeconomic monitoring guidelines for coastal managers in the Caribbean: SocMon Caribbean.* WCPA, NOAA, Cermes, and GCRMN. 88 pp.

Bunce, L., P. Townsley, R. Pomeroy, and R. Pollnac. 2000. *Socioeconomic manual for coral reef management.* GCRMN, IUCN, Australian Institute of Marine Science, NOAA. 251 pp.

Central Statistical Office (CSO). 2003 *Abstract of Statistics 2003.*

Dahl, A.L., I.G. Macintyre, and A. Antonius. 1974. A comparative study of coral reef research sites. *Atoll Research Bulletin* **172**:37-120.

Dangriga Town Council. 2004. Profile of Dangriga. 20 pp.

Garaway, C. and N. Esteban. 2002. The impact of marine protected areas on poorer communities living in and around them: institutional opportunities and constraints: Appendix 4 – case study of Glover's Reef Marine Reserve, Belize. December 2002.

Gibson, J. 2003. Glover's Reef Marine Reserve & World Heritage Site Management Plan. Wildlife Conservation Society, March 2003. 106 pp.

Grant, S. 2004. Glover's Reef Marine Reserve Fisheries Boat Census 2004. Wildlife Conservation Society and Caribbean Regional Fisheries Mechanism Secretariat, Belize. 38 pp.

Kramer, P.A. and P.R. Kramer (ed. M. McField). 2002. *Ecoregional conservation planning for the Mesoamerican Caribbean Reef.* World Wildlife Fund Washington D.C. USA. 140 pp.

Palacio, J.O. [2003]. Community Management of Protected Areas Conservation Project (COMPACT). Community Assessment Final Draft Report. 47 pp. Unpubl. MS.

Pantin, D., D. Brown, M. Mycoo, C. Toppin-Allahar, J. Gobin , W. Rennie, and J. Hancock. 2004. *Feasibility of Alternative Sustainable Coastal Resource-based Enhanced Livelihood Strategies.* Sustainable Economic Development Unit, University of the West Indies, Trinidad & Tobago. 90 pp.

Programme for Belize. [2003]. Strategic Planning Workshop for the Sarteneja New Vision Association for Development (Sarnvad). Sarteneja, June 2003. 10 p. Unpubl. MS.

Perez, A. 2003. Assessment of socioeconomic conditions of Placencia, Hopkins and Monkey River in Belize, Central America. M.S. Thesis. University of the West Indies, Trinidad & Tobago. 42 pp.

Sala, E. E. Ballesteros, and R.M. Starr. 2001. Rapid decline of Nassau grouper spawning aggregations in Belize: fishery management and conservation needs. *Fisheries* **26**(10):23-30.

BLANK PAGE

Trap Fishing in the U. S. Virgin Islands: How and Where Effort is Exerted

PETER SHERIDAN [1], RONALD HILL [2], and BARBARA KOJIS [3]
[1] *NOAA Fisheries, Southeast Fisheries Science Center,*
anama City Laboratory]
3500 Delwood Beach Road
Panama City, Florida 32408 USA
[2] *NOAA Fisheries, Southeast Fisheries Science Center*
Galveston Laboratory
4700 Avenue U
Galveston, Texas 77551-5997 USA
[3] *Virgin Islands Department of Planning and Natural Resources*
Division of Fish and Wildlife
6291 Estate Nazareth 101
St. Thomas Virgin Islands 00802-1104 USA

ABSTRACT

Trap fishing for fishes and lobsters is common in waters of the U. S. Virgin Islands and may affect coral ecosystem structure and function. We examined data on overall fishing patterns from trip reports by 103 fishermen during July 2000 - June 2001. Trip reports indicated fishermen preferred southwestern and northeastern St. Croix and southwestern and northwestern St. Thomas. Fishermen landed over 34,900 kg of spiny lobster and 193,000 kg of fish (primarily parrotfishes and triggerfishes) during the 12 month period. We subsequently interviewed 30 fishermen during November - December 2001 to obtain more detail on fishing gear, methods, and habitat types fished. Ten trap fishermen from St. Croix and 20 from St. Thomas (who also fished St. John) were surveyed. These fishermen operated 5,172 (60.8%) of the estimated 8,500 traps fished in the USVI. St. Croix fishermen concentrated off the south coast in relatively shallow waters (mean 17.7 m, maximum 30.5 m), while St. Thomas / St. John fishermen concentrated effort off southern St. Thomas in moderate to deep waters (mean 47.5 m, maximum 183 m). Fishermen moved traps regularly and seasonally, but unfortunately, our survey did not capture the magnitude of distances moved. Trap construction was uniform in St. Thomas / St. John, whereas traps varied in size and were somewhat smaller in St. Croix. Individually buoyed traps were used off St. Croix, whereas trap lines (mean 13 traps per line, range 4-25 traps per line) were used off St. Thomas / St. John. Trap lines used buoyant rope that enabled off-bottom grappling. Fishing times were shorter off St. Croix than off St. Thomas / St. John (means 3.2 days vs. 7.2 days, respectively). Traps were most often deployed in vegetation (seagrass or algae), sand, or rubble habitats, but six fishermen targeted corals. These data are important for assessment of potential for trap damage to coral reef habitats.

KEY WORDS: Coral reef ecosystem, gear impacts, traps Pesca con Trampas en Las Islas Virgenes de los E.E.U.U.

Pesca con Trampas en Las Islas Virgenes de los E.E.U.U.: Cómo y Donde Esfuerzo se Ejerce

La pesca de peces y langostas con trampas es práctica habitual en aguas de las Islas Vírgenes de los EE.UU. y puede afectar la estructura y funcionamiento de los arrecifes coralinos. Examinamos datos sobre patrones de pesca provenientes de informes de viaje de 103 pescadores durante el período julio 2000-junio 2001. Los informes de viaje indicaron que los pescadores prefieren el suroeste y noreste de St. Croix y el suroeste y noroeste de St. Thomas. Los pescadores desembarcaron más de 34,900 kg de langosta y 193,000 kg de pescado (principalmente peces loro y peces cochino) durante este período de 12 meses. Posteriormente entrevistamos a 30 pescadores durante los meses de noviembre a diciembre del 2001 para obtener más detalles sobre las artes de pesca, métodos y tipos de hábitat pescado. La muestra incluyó a 10 pescadores de trampas de St. Croix y 20 de St. Thomas (que también pescaban en St. John). Dichos pescadores operaron 5,172 (60.8%) de las 8,500 trampas que se estima son utilizadas para la pesca en las USVI. Los pescadores de St. Croix se concentraron en la costa sur en aguas relativamente someras (media 17.7 m, máximo 30.5 m) mientras que los pescadores de St. Thomas / St. John concentraron el esfuerzo en el sur de St. Thomas en aguas de profundidad mediana a alta (media 47.5 m, máximo 183 m). Los pescadores desplazaron las trampas regular y estacionalmente pero desafortunadamente nuestra prospección no capturó la magnitud de las distancias de dichos desplazamientos. La estructura de las trampas era uniforme en St. Thomas / St. John mientras que en St. Croix el tamaño de las trampas era variable y algo menor. En St. Croix se utilizaron trampas dotadas de boyas individuales mientras que en St. Thomas / St. John se utilizaron líneas con varias trampas (media de 13 trampas por línea, rango de 4-25 trampas por línea). Las líneas con trampas utilizan cuerda boyante que permite que las trampas no toquen el fondo. Los tiempos de pesca fueron menores en St. Croix que en St. Thomas / St. John (medias de 3,2 y 7,2 dias, respectivamente). Las trampas se colocaron más frecuentemente en hábitats con vegetación (plantas marinas o algas), arena o fragmentos de coral muerto, pero seis pescadores las desplegaron específicamente sobre corales. Estos datos son importantes para la evaluación de daños potenciales a hábitats de arrecifes coralinos debido al uso de trampas.

PALABRAS CLAVES: Ecosistema de arrecife coralino, impactos de artes de pesca, trampas.

INTRODUCTION

Trap fishing occurs in coral ecosystems in both territorial waters (within 5.6 km or 3 nml) and Federal waters (5.6 - 370 km or 3 - 200 nml) of the coastline of the U. S. Virgin Islands (USVI). There are directed fisheries for both spiny lobster *Panulirus argus* and various reef fishes (Garrison et al. 1998), as opposed to many other areas of the Caribbean where spiny lobster is an incidental catch for trap fishermen (Holthuis 1991). There is concern that traps may have direct and indirect effects on coral ecosystem habitats and on structure and function of benthic communities (Jennings and Kaiser 1998, Sheridan et al. 2005); however, actual damage to corals is thought to be minimal (Caribbean Fisheries Management Council 1998).

The Virgin Islands Department of Planning and Natural Resources (VIDPNR) employs a monthly logbook system wherein licensed fishermen record a variety of data for each day during the year that catches are landed. These data are supplied to the national landings monitoring system of the U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries). Such data might be useful in judging the potential for fishing gear impacts. However, the logbook data are limited to basic information, such as area fished, numbers of traps fished, and landings. We felt that we needed to ask active fishermen specific questions on how and where they fished so that we could better understand fishing patterns and the potential for gear impacts to coral ecosystem habitats (Sheridan et al. 2003, 2005). Our objective was to define more accurately fishing gear and methods as well as fishing pressure by area and habitat type.

METHODS

VIDPNR and NOAA Fisheries catch statistics are made available for 12-month periods known as "fishing years" or "biological years". When we initiated our study, the most recently completed data set for USVI was the period July 2000 - June 2001. We examined:

i) Number of uniquely identified fishermen (by code or vessel number),
ii) Dates each fisherman filed a trip report,
iii) Hours per trip spent working traps,
iv) Traps fished per trip,
v) Areas fished (Figure 1), and
vi) Landings per trip. Landings are recorded by common names such as parrotfishes or grunts.

Following this assessment, we developed a series of questions that we thought would better represent how and where fishermen operated (Table 1). We wanted to know depths fished, trap dimensions, single traps versus trap lines, use of buoys, and gear used to set and haul traps or to locate lost traps.

Interviews were conducted during November-December 2001 with 10 fishermen from St. Croix and 20 fishermen from St. Thomas (few fishermen are based in St. John). VIDPNR visited landing sites and interviewed commercial fishermen who were most likely to respond. VIDPNR estimated that there were 30 - 40 full time trap fishermen each in St. Thomas / St. John and St. Croix. In St. Thomas, 20 of 22 fishermen who were asked to participate subsequently agreed to answer the questionnaire. In St. Croix, all 10 fishermen who were asked answered the questionnaire. With 30 interviews, we thus estimated 37.5 - 50% coverage of all commercial fishermen.

If a fisherman operated in more than one area, then the total number of traps fished was split equally among all areas fished. Answers supplied as ranges (e.g., depth range fished, traps per line, length of line between traps, or soak time) were converted to midpoints. Island-related differences in fishing characteristics were assessed with a t-test using STATISTICA (StatSoft, Inc., Tulsa, OK).

Table 1. U. S. Virgin Islands trap fishing survey, November-December 2001. Phrases in parentheses were used by interviewers to elicit specific responses.

1. Location (St. Thomas / St. John, or St. Croix), Survey Number, and Date
2. What are the target species? (Lobster, fishes in general, or name specific fishes)
3. Where are traps set? (Indicate VIDPNR area codes, e.g. TNW or C-5; refer to logbook map)
4. What depths are traps fished? (Indicate depth or depth range and units, e.g. ft, m, or fm)
5. Are there differences in location by season? (Yes / no) Why? (Weather, fish movement, etc.)
6. How many traps do you own? How many traps are fished? (in the water at one time)
7. Has the number of traps changed over time? If Yes, is the number increasing or decreasing?
8. How are traps constructed? (Material, mesh size, length x width x height in in or cm)
9. Are traps fished as single traps? (Yes / no) If single, do all traps have buoys? (Yes / no)
10. Are traps fished as trap lines? (Yes / no) If lines, do you buoy both ends, one end, or neither?
11. If lines, how many traps per line? If lines, how long is the line between traps? (Ft or m)
12. If lines, is a floating line used between traps? (Yes / no)
13. Can you tell what type of habitat you are setting your traps in? (Yes / no)
14. If yes, what habitat is targeted? (Coral reef, sand, seagrass, rubble, etc.)
15. What is the soak time for your traps? (Days)
16. How does this change with season or target fish? (e.g., longer in fall, shorter for snapper)
17. Do you use a winch or pot hauler? (Yes / no)
18. Are traps usually hauled and re-set in place or are they moved regularly? (Describe)
19. What do you do if floats are missing or traps are lost? (e.g., use grapple, dive)
20. Do others fish in the same manner as you? (Yes / no)
21. If no, how are they different? How have they changed over time?

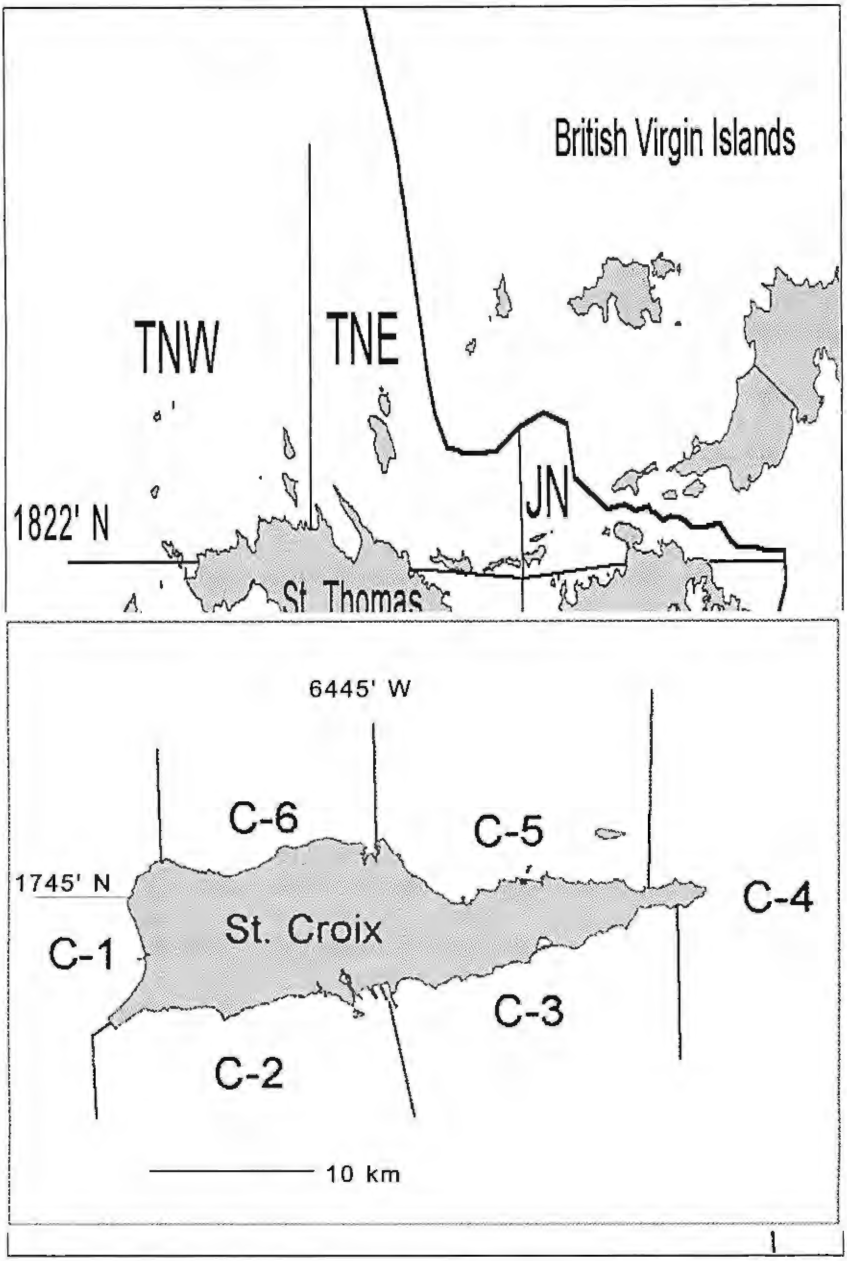


Figure 1. Fishing area codes for the U. S. Virgin Islands.

RESULTS

VIDPNR / NOAA Fisheries Catch Statistics

Data were summarized from 4,866 trip reports (Table 2). A total of 97 fishermen were identified by unique code numbers in the data set, but only 74 were considered full-time. Ten of 41 fishermen from St. Croix and 13 of 56 fishermen from St. Thomas completed ≤ 24 trips per year (or ≤ 2 trips per month) and generally had fewer than 10 traps, thus we consider them to have been either part-time, just starting, or quitting the fishery. We believe that approximately 8,500 traps are fished (1,500 around St. Croix and 7,000 around St. Thomas; VIDPNR Unpubl. data). However, the maximum number of traps in the water during the reporting period was 4,853 (766 from St. Croix and 4,087 from St. Thomas), based on a total of the maximum number of traps reportedly fished by each fisherman. These data suggest that fishermen did not employ all of their traps all the time. Even though each group of fishermen took similar numbers of trips (Table 2), St. Croix fishermen worked significantly fewer traps and spent significantly less time on the water working their traps than did St. Thomas fishermen. Traps were most often fished off southwestern and northeastern St. Croix and western St. Thomas (Table 3, Figure 1).

During the period July 2000 - June 2001, biomass of fish landed in St. Thomas was highest during February but only fell below 80% of the maximum during April (Figure 2). Landings of fish in St. Croix were also relatively steady from month to month, with highest landings in August-September and < 80% of the September maximum only in November and May. Lobster landings were distinctly seasonal, with highest landings in St. Thomas during November - June and in St. Croix during December - April and relatively low landings (35 - 60% of maxima) in other months (Figure 2). Annual landings for the period included over 34,900 kg of spiny lobster and over 193,000 kg of fish. Seven families of fishes comprised over 90% of the landings from each area (Table 2). St. Croix landings were dominated by parrotfishes, then by surgeonfishes, snappers, and grunts, whereas St. Thomas landings were dominated by triggerfishes, then by parrotfishes, snappers, and groupers.

Fisherman Interviews

Assessment of interviews revealed some commonalities and many differences among fishermen from each island (see following sections). Within each island group, all fishermen agreed that others used similar techniques and gear and that fishing methods had not changed recently, although several fishermen thought the number of traps was increasing.

Target Organisms

Nineteen fishermen captured fishes and lobsters, 10 fishermen caught fish only, and one fisherman from St. Thomas caught lobster only. Most St. Croix fishermen (seven of 10) captured fish only, while three of 20 St. Thomas fishermen captured fish only.

Table 2. Island-related differences in trap fishing effort (compared by t-tests) and catch composition (not tested) as estimated from trip reports by USVI trap fishermen during July 2000 - June 2001 (NOAA Fisheries, Miami, FL, unpublished data). St. Croix = 41 fishermen, 2280 trips. St. Thomas (includes St. John) = 56 fishermen, 2,586 trips. t-test df = 95 (annual data not tested).

	St. Croix	St. Thomas	P
Mean (range) dates with trip reports	55 (1-167)	48 (1-169)	0.190
Mean (range) hours / trip	4.3 (1-12)	6.4 (1-16)	<0.001
Mean (range) traps fished / trip	16 (1-81)	53 (1-237)	<0.001
Annual spiny lobster landings (kg)	1,857	33,066	
Annual fish landings (kg)	58,973	134,551	
Fish catch composition (% weight)			
Parrotfishes	38.6	13.9	
Surgeonfishes	15.5	10.9	
Snappers	14.4	13.9	
Grunts	14.4	10.9	
Triggerfishes	8.1	24.4	
Groupers	2.8	12.9	
Porgies	1.9	6.9	
Other	4.3	6.2	

Table 3. Comparison of catch statistics common to both trip reports (St. Croix = 41 fishermen and 2,280 trips; St. Thomas = 56 fishermen and 2,586 trips) and to interviews (St. Croix = 10, St. Thomas = 20). See Figure 1 for location of fishing areas.

Statistic		Trip reports	Interviews
Fishermen landing (%)	Fish + lobster	47.9	63.3
	Fish only	51.1	33.3
	Lobster only	1.0	3.4
St. Croix fishing areas (%)	C-1	< 0.1	0.0
	C-2	32.0	29.3
	C-3	18.4	32.3
	C-4	12.2	23.1
	C-5	37.4	15.2
	C-6	< 0.1	0.0
St. Thomas fishing areas (%)	TNW	29.8	6.4
	TSW	32.5	38.1
	TSE	15.2	27.0
	TNE	4.1	2.2
	JN	0.2	0.8
	JSW	5.2	10.5
	JSE	10.5	11.6
	BVI	2.5	3.4
Mean number of traps	St. Croix	16	32
	St. Thomas	53	231

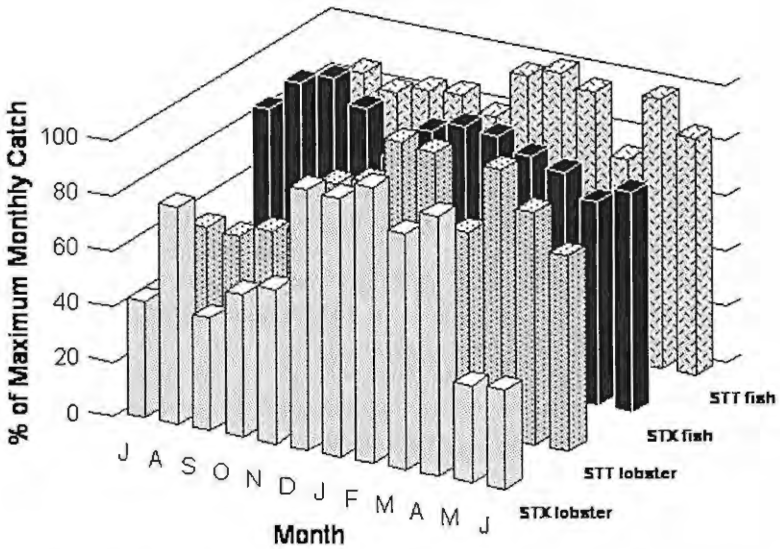


Figure 2. U. S. Virgin Islands trap landings during July 2000 - June 2001 by island group (STT = St. Thomas / St. John, STX = St. Croix). Monthly maxima: STT fish = 14,035 kg, Feb; STX fish = 6,215 kg, Sep; STT lobster = 3,616 kg, Jan; STX lobster = 230 kg, Feb. Data from NOAA Fisheries, Miami, FL.

Fishing Locations

Fishermen did not cross between island groups (St. Croix is 60 km south of St. Thomas / St. John). Interviewed St. Croix fishermen operated 322 traps, approximately 21% of the estimated 1,500 traps fished from that island. St. Croix fishermen placed the largest numbers of traps in areas C-3 and C-2 on the south coast (Table 3), indicating approximately 62% of the total St. Croix effort was expended there. Fewer traps were placed in areas C-4 and C-5 on the east and northeast coasts, and none of the interviewed fishermen placed traps in areas C-1 or C-6 on the west and northwest coasts. The latter trend was borne out by the July 2000 - June 2001 trip reports which indicated only four of 2,280 trips were to areas C-1 or C-6. Shallow shelf waters are relatively narrow in these two areas relative to areas C-2 through C-5. All fishermen operated in either one or two areas. St. Croix fishermen reported mean fishing depths of 17.7 m (range 7.3 - 30.5 m), but nine of 10 fishermen reported minimum and maximum depths were the same.

Interviewed St. Thomas fishermen operated 4,610 traps, approximately 66% of the estimated 7,000 traps fished from that island. St. Thomas fishermen placed the largest numbers of traps in areas TSW and TSE on the southwest and southeast coast of St. Thomas (Table 3), indicating approximately 65% of the total effort was expended there. Moderate numbers of traps were placed in areas JSE and JSW south of St. John and in TNW northwest of St. Thomas. Lowest trap numbers were in areas TNE and JN (Table 3), corresponding to northeast St. Thomas and northern St. John. It is unknown why TNE receives low effort, but JN encompasses Virgin Islands National Park where fishing is restricted. One fisherman reported deploying 160 traps exclusively near Tobago in the British Virgin Islands (north of TNE). Although the modal number of areas fished was two, seven fishermen reported operating in three or four areas, and one fisherman operated in six areas. St. Thomas fishermen reported mean fishing depths of 47.5 m (range 18.3 - 183 m). Only seven fishermen reported a narrow (3 m) depth range fished, whereas most of the other fishermen reported depth range variations exceeding 9 m. Two fishermen reported extreme depth ranges of 27 - 97 m and 55 - 183 m.

Almost all fishermen (27 of 30) reported that they moved their traps on a seasonal basis. However, our survey questions were not detailed enough to capture the nature of these moves so we do not know if moves involved changing depths, changing fishing areas, or both. Movement of target species, weather, or both were most often cited (23 of 30 responses) as reasons for moving traps. Three fishermen cited tides in combination with species movements and weather. One fisherman said he moved traps only when he switched target species.

Fishing Gear

Fishermen interviewed on St. Croix operated fewer traps (mean 32, range 16 - 100) than did fishermen from St. Thomas (mean 231, range 38 - 600) (Table 3). Most St. Croix fishermen (eight of 10) indicated that they had decreased the number of traps fished recently (switching to gillnets), whereas many fishermen from St. Thomas (14 of 20) said their trap counts were stable.

All fishermen said their traps were made of wire or wire and iron rebar, and three fishermen said they also included either wood or plastic in fabrication. Trap specifications were quite variable in St. Croix. Mesh size averaged 4.6 cm with a mode of 3.8 cm and a range of 3.8 - 6.4 cm. Trap length averaged 147 cm, with a mode of 152 cm and a range of 122 - 183 cm. Trap widths were mostly 122 cm, but one fisherman each reported traps of either 91 cm or 117 cm. Traps were all 46 cm high. All St. Thomas fishermen used the same size traps: 5 cm mesh, 122 cm length, 122 cm width, and 46 cm height. While trap length and width are not currently regulated, mesh sizes in USVI waters are restricted to 3.8 cm in St. Croix, to 5 cm in St. Thomas, and to 3.8 cm in Federal waters around all islands. In addition, all traps must have escape panels with biodegradable fasteners, must be inspected by VIDPNR, and must carry numerical identification tags.

Nine of 10 St. Croix fishermen used single traps, each with a single buoy attached. The lone St. Croix fisherman who used trap lines only fished two traps per line, with 45 m of line between traps and both ends buoyed. All of these fishermen set and hauled traps by hand. Conversely, 19 of 20 St. Thomas fishermen used trap lines and mechanized pot haulers, with the remaining individual fishing both single traps and trap lines. Fifteen of these fishermen used buoys on each end of the trap lines, one used a single buoy, three fishermen did not use buoys, and one did not respond. Buoy lines can be used for trap retrieval. Buoys are not required, but if used they must employ color codes assigned by VIDPNR for identification. Trap lines held an average of 13 traps (range 4 - 25) with average 76 m of line between successive traps. All fishermen who used trap lines employed buoyant line to aid in trap retrieval (by grapple).

Soak times were significantly shorter in St. Croix (mean 3.2 d, range 2 - 7 d) than in St. Thomas (mean 7.2 d, range 3.5 - 10.5 d; $t = -6.27$, $p < 0.01$). Six of 10 St. Croix fishermen said their soak times did not change seasonally, whereas 14 of 20 St. Thomas fishermen changed their soak times seasonally (for example, longer in colder water) or with target species (for example, shorter with heavier types of bait). Longer soak times among St. Thomas fishermen were likely related to fishing in deeper waters, operating more traps, and using trap lines.

Traps are usually moved during the fishing operation, as 19 fishermen responded that they moved traps "regularly", and five stated they moved traps short distances or occasionally. Unfortunately, our questions were not structured to reveal whether fishermen using trap lines hauled all traps aboard the boat then moved relatively large distances or just moved traps relatively short distances while working trap lines. It is unlikely that traps are moved large distances if catch rates in a given area are acceptable. However, only five fishermen (four from St. Croix) stated that they hauled and replaced their traps in the same areas.

When fishermen returned to their trap sites and could not locate buoys (i.e., buoys were missing or submerged), eight fishermen (all from St. Croix) stated that they would dive to locate and retrieve missing traps, whereas 21 fishermen (19 from St. Thomas) used grappling hooks to retrieve missing gear. One fisherman did not state how he retrieved missing traps. Grappling was primarily off-bottom (20 of 21 grapple users) and is used to snag buoyant trap lines. Only one fisherman used on-bottom grappling techniques, even though he stated that he used only two traps per line, buoyant trap lines, and two buoys.

Habitats Fished

All fishermen claimed to be familiar with the habitat types they were targeting. Given the depths fished, good visual placement was likely off St. Croix where mean fishing depths were 17.7 m. However, St. Thomas fishermen worked significantly deeper waters (mean 47.5 m, $t = -4.60$, $p < 0.01$; range 18.3 - 183 m) that were often in excess of accurate bottom visibility. Most fishermen (22 of 30) said they fished in more that one habitat type, most often stating that they deployed traps in seagrass (23 responses), sand (19), and coral rubble (12). No one reported fishing in algae, even though both seagrass and algae are common to USVI, so we suspect that fishermen consider both types of plants as the same habitat. Seagrasses are found closer to shore in relatively shallow water (to 20 m), while algal plains are found further from shore and in deeper waters (National Ocean Service 2002). Six of 30 fishermen (all from St. Croix) claimed to be operating in coral reefs, but they represented 142 of the 322 (44%) traps surveyed in St. Croix.

Comparison of Data Sets

There was some overlap in types of data that were collected for this study. The trip report data set consisted of every report filed by fishermen for the period July 2000 - June 2001. Our interviews basically asked 30 fishermen to summarize their typical (annual) habits, and the interviews were conducted in November - December 2001. Therefore, some divergence in results was expected due to both large scale versus small scale data sets as well as to timing of data. Indeed, there were obvious differences along with some similarities (Table 3). For example, about half of the trip reports indicated landing fish only, whereas only one third of the interviews indicated that they fished for fish only. Interviews were more likely to be accurate for target groups, since trip reports do not distinguish between successful and unsuccessful trips (i.e., reporting zero catch of lobsters does not mean lobsters were not targeted along with fish). Trip reports indicated more activity in fishing areas C-5 and TNW, whereas interviews indicated that C-2 and TSE were more important; however, we note that both data sets indicated areas C-3 and TSW as prime fishing locations. In this case, trip reports are likely a better index of actual fishing area pressure. Mean numbers of traps employed by fishermen differed greatly between data sets, but this could be due to capture of daily versus annual use patterns. Again, trip reports were likely to be a more accurate indicator of where fishing pressure is applied. Interviews provided many types of information not available from trip reports such as trap construction and fishing depths.

DISCUSSION

This report provided a detailed description of trap fishing operations in USVI waters. The primary fishing grounds are southern and northeastern St. Croix and southern and western St. Thomas and St. John. St. Croix fisherman work relatively shallow waters, using single traps of varying sizes and construction materials retrieved by hand. St. Thomas fisherman work moderately deep waters, using strings of traps of uniform size and construction retrieved mechanically. Fishermen either dive (St. Croix) or use off-bottom grapples (St. Thomas) to retrieve lost gear. Traps are moved regularly either during fishing operations or in response to weather or target species availability. However, our survey was not designed well enough to get details on these movements such as changes in depth or area. Fishermen most often place traps in vegetated, sand, or rubble habitats, but some St. Croix fishermen report targeting coral habitat. Thus, there is potential for gear impacts to coral habitat in the USVI.

In Puerto Rico, a survey of 47 fishermen from all coastal regions also indicated that coral reefs were not the preferred habitat for trap setting (Schärer at al. 2004). Overall, 60% of Puerto Rican fishermen selected hard-bottom areas, particularly the "rastreal", as the preferred fishing habitat. "Rastreal" is the local name given to a hard bottom of low to medium relief, which may be colonized by gorgonians, algae, sponges, and isolated coral colonies. However, 10 Puerto Rican fishermen did indicate that corals are a targeted habitat.

The effects of trap fishing on bottom habitats are largely unstudied, particularly for coral reefs and reef-associated habitats. Jennings and Kaiser (1998) concluded that static gear such as traps are unlikely to have the widespread habitat impacts of mobile gear such as trawls, although effects may be detected where effort is concentrated or in bottom types supporting long-lived fauna such as corals. Mixed impacts have been reported from lobster and crab traps in European waters: bent and uprooted sea pens, bent but otherwise undamaged sea fans, and living material scraped from hard coral colonies (Eno et al. 2001). Although many of those organisms were not damaged or killed outright, Jennings and Kaiser (1998) postulated that both frequency and intensity of contact may affect coral survival. The Caribbean Fishery Management Council (1998) indicated the potential for damage to coral from traps was slight since "setting traps in coral areas increases the chance of losing traps" and thus traps were likely fished away from corals. However, there are reports beyond our survey that traps are placed in USVI and Puerto Rico corals (Garrison et al. 1998, Quandt 1999, Schärer et al. 2004) and that traps can damage corals (Quandt 1999, Appeldoorn et al. 2000). Movement of traps during haul-back or storms may also induce damage (Jennings and Kaiser 1998). Potential for damage during haul-back in USVI has been lessened by the use of buoyant trap lines which facilitate off-bottom grappling for trap retrieval. However, if currents are strong or trap line reset is delayed while fishing, then traps and lines may be dragged across the bottom. There remains a need to assess the extent and duration of damage to corals from trap fishing and to begin working with fishermen to reduce the potential for habitat disruption.

ACKNOWLEDGMENTS

This project was funded by the NOAA Coral Reef Conservation program. J. Barbel, R. Gomez, W. Tobias, W. Ventura, J. Vasquez, and R. Uwate (VIDPNR) conducted interviews and reviewed this manuscript. J. Bennett (NOAA Fisheries, Miami, FL) provided landings data. G. Matthews (NOAA Fisheries, Galveston, TX) provided graphics. R. Appeldoorn (University of Puerto Rico - Mayagüez) assisted with questionnaire development. E. Cortés (NOAA Fisheries, Panama City, FL) provided the Spanish abstract.

LITERATURE CITED

Appeldoorn, R.S., M. Nemeth, J. Vasslides, and M. Schärer. [2000]. The effect of fish traps on benthic habitats off La Parguera, Puerto Rico. Report to the Caribbean Fishery Management Council. Department of Marine Sciences, University of Puerto Rico, Mayagüez, Puerto Rico. Unpubl. MS. 33 pp.

Caribbean Fishery Management Council. 1998. *Essential fish habitat (EFH) generic amendment to the fishery management plans (FMPs) of the U. S. Caribbean including a draft environmental assessment. Volume I.* Caribbean Fishery Management Council, San Juan, Puerto Rico. 173 pp.

Eno, N.C., D.S. MacDonald, J.A.M. Kinnear, S.C. Amos, C.J. Chapman, R.A. Clark, F.S. P.D. Bunker, and C. Munro. 2001. Effects of crustacean traps on benthic fauna. *ICES Journal of Marine Science* 58(1):11-20.

Garrison, V.H., C.S. Rogers, and J. Beets. 1998. Of reef fishes, overfishing, and in situ observations of fish traps in St. John, U. S. Virgin Islands. *Revista de Biologia Tropical* 46 (Suppl. 5):41-59.

Holthuis, L. B. 1991. *FAO species catalogue. Volume 13. Marine lobsters of the world. An annotated and illustrated catalogue of species of interest to fisheries known to date.* FAO Fisheries Synopsis No. 125, Volume 13. United Nations Food and Agriculture Organization, Rome, Italy. 292 pp.

Jennings, S., and M.J. Kaiser. 1998. The effects of fishing on marine ecosystems. *Advances in Marine Biology* 34:201-352.

National Ocean Service. 2002. *Benthic habitats of Puerto Rico and the U. S. Virgin Islands.* NOAA National Ocean Service, National Centers for Coastal Ocean Science, Biogeography Program, 1305 East West Highway, Silver Spring, MD (available from http://biogeo.nos.noaa.gov).

Quandt, A. [1999]. Assessment of fish trap damage on coral reefs around St. Thomas, USVI. University of the Virgin Islands, St. Thomas, USVI. Unpubl. MS. 11 pp.

Schärer, M.T., M.C. Prada, R.S. Appeldoorn, R. Hill, P. Sheridan, and M. Valdés-Pizzini. 2004. The use of fish traps in Puerto Rico: current practice, long-term changes, and fishers' perceptions. *Proceedings of the Gulf and Caribbean Fisheries Institute* 55:744-756.

Sheridan, P., R. Hill, G. Matthews, and R. Appeldoorn. 2003. The effects of trap fishing in coralline habitats: What do we know? How do we learn more? *Proceedings of the Gulf and Caribbean Fisheries Institute* 54:1-12.

Sheridan, P., R. Hill, G. Matthews, R. Appeldoorn, B. Kojis, and T. Matthews. 2005. Does trap fishing impact coral reef ecosystems? An update. *Proceedings of the Gulf and Caribbean Fisheries Institute* 56:511-520.

History of Surface Longline Fishing Technology in Gouyave, Grenada

SANDRA C. GRANT[1] and ROLAND BALDEO[2]
[1]*University of Manitoba, Natural Resources Institute*
Winnipeg, Manitoba Canada R3T 2N2
[2]*Fisheries Division*
Ministry of Agriculture, Lands, Forestry and Fisheries
Botanical Gardens, St. George's, Grenada

ABSTRACT

Changes in fishing technology are important in assessing fish stocks. However, in many Fisheries Departments, it is rarely documented at the fishing community level. In the case of Gouyave, Grenada, surface longline fishers, they are constantly adapting and changing fishing technology to increase fish catch and income. The objective of this paper is to document the history of surface longline fishing technology (boat and gear), and determine how this technological knowledge, possessed by fishers could be included in fisheries management. Information was obtained from interviews with knowledgeable fishers.

Traditionally, Gouyave fishers were involved in beach seine and '3-line' (hand line) fishing, from non-mechanized wooden sloop canoes. By the 1980s, the Government of Grenada with assistance from the Cuban Government popularized surface longline fishing. Since then, fishers adapted and developed longline boat and gear technology to improve efficiency and effectiveness. Longline technology developed from twisted 2 x 113 kg strain monofilament mainline and droplines stored and deployed from a box, to single monofilament lines stored and deployed from reels. Boat technology developed from mechanized 5 m wooden canoes to 6 - 12 m fibreglass vessels.

KEY WORDS: Fishing technology, Gouyave, surface longline

Historia de la Tecnología de Pesca con Línea Larga en Gouyave, Grenada

Cambios en la tecnología de pesca son importantes para evaluar la reserva pesquera. Sin embargo, en muchos departamentos pesqueros estos cambios son raramente documentados en la pesca a escala comunitaria. En el caso de Gouyave, Grenada, pescadores de línea larga superficial se están adaptando constantemente y cambiando la tecnología pesquera para incrementar la captura de peces e ingresos. El objetivo de este trabajo es documentar la historia de la tecnología de pesca con línea larga superficial (bote y engranaje), y determinar como este conocimiento tecnológico poseído por los pecadores podría ser incluido en el manejo pesquero. La información fue obtenida a través de entrevistas con pescadores de experiencia.

Tradicionalmente los pescadores de Gouyave estaban pescando con red playera y '3-líneas' (línea manual), desde canoas de balandro de madera no mecanizadas. Hacia los anos 80, el Gobierno de Grenada con la asistencia del Gobierno Cubano popularizó la pesca superficial en aguas costeras. Desde entonces, los pescadores de adaptaron y desarrollaron botes con línea larga y tecnología de engranaje para mejorar la eficiencia y efectividad. La tecnología de línea larga se desarrolló de línea principal de mono filamento torzonada de 2 x 113 Kg. de esfuerzo y líneas de fondo guardadas y desplegadas desde una caja, a líneas de mono filamento único guardadas y desplegadas desde carretes. La tecnología de botes se desarrollo pasando de canoas mecanizadas de madera de 5m a navíos de fibra de vidrio de 6-12m.

PALABRAS CLAVES: Tecnología pesquera, Gouyave, línea larga superficial

INTRODUCTION

A new paradigm is emerging in small-scale fisheries management: large volume of scientific data is not necessary to evaluate the status of a fishery - management can work with low inputs of data by including qualitative indicators, proximate variables, and local and traditional knowledge (Pitcher et al. 1998, Charles 1998, Berkes et al. 2001). In recent years, many researchers and practitioners have come to value local and traditional knowledge as reliable, low-input data that could be included in fisheries management (Gadgil et al. 1993, Ruddle 1994, Hanna 1998, Berkes 1999, Johannes et al. 2000, Johannes 2001). The term 'fisher knowledge' and in some instances 'local knowledge' is used here to describe the body of ecological knowledge and management practices on aquatic resources and the environment, evolving by adaptive processes. Traditional knowledge is a cumulative body of knowledge, evolved by adaptive processes and handed down through generations (Berkes 1999).

In the Caribbean, little is known about local and traditional knowledge of natural resources except in the following cases: mangrove conservation in St. Lucia (Smith and Berkes 1993); sustainable extract forest timber in Dominica (Berkes 1999); management of sea urchin resources in St. Lucia and Barbados (Berkes 1999); and using fisher knowledge of sea colour and debris to indicate the presence of flyingfish (*Hirundichtys affinis*) and large pelagic species in the eastern Caribbean (Gomes et al. 1998). In the case of Gouyave surface longline fishery, fishers possess two types of local knowledge: ecological knowledge (species abundance, effects of current, and reproductive and spawning seasonality) (Grant and Berkes 2004); and technological knowledge (gear and boat technology). The objective of this paper is to document technological knowledge possessed by Gouyave fishers and to determine how this knowledge could be included in fisheries management.

METHODS

Fisher technological knowledge of longline gear, boats, and fishing practices was documented during the period December 2002 to March 2004.

A review of available literature and reports was conducted to construct the history of longline development. The authors soon realized that not much information was documented for Gouyave, thus key informant interviews were conducted with over 12 retired and knowledgeable fishers (recommended by fishers, community members, and Fisheries Division staff), and two Fisheries Officers at the Fisheries Division (FD), on the history of longline fishing and longline fishing techniques in Gouyave. One useful technique was to ask fishers to build models of the different longline designs using the same material as in the past, (as much as possible). During interviews with other fishers, model longlines were presented to ensure the researcher and interviewee were discussing the same gear adaptation. It also helped fishers recall how the gear was used and construction techniques, since there were so many versions of the longline gear.

RESULTS

This section documented Gouyave longline fishery and traced the history of longline and boat changes in Gouyave from the 1960s to present. Time periods were arbitrarily chosen based on significant technological changes. Three major periods were identified: pre-longline era (< 1960s - 1978), popularization of longline (1979 - 1999), and present longline (2000 - 2004).

Gouyave Longline Fishery

The fishing community of Gouyave located on the west coast of Grenada (latitude 11°35' and 12°15' north, and longitude 61°35' and 61°48' west). The fishery in Gouyave is small-scale, with three stock types based on fishing methods, and fish type: demersal, inshore pelagic, and the most important - oceanic/large pelagic.

In Gouyave, surface longline (referred to in this paper as longline) construction consisted of: mainline, droplines, hooks, float lines, buoys, flags, and lighted poles. Braided nylon loops were inserted along the mainline onto which droplines of varied lengths were ties during gear set. Buoylines were attached every third dropline. Flags and lighted poles were placed at either end of the mainline to signal boats that a longline was in the area. While fishing, a boat was allowed to drift with the current, while the entire longline was placed in the water. To identify and locate the drifting longline, two flags were placed at each end. Every 60 - 90 minutes fishers patrolled the entire line to check for missing buoys, which signaled that a fish was on the dropline. To retrieve the line, the first end in the water became the starting point (Mitchell 1992).

The longline fishery targeted yellowfin tuna (*Thunnus albacares*) and bycatch such as sailfish (*Istiophorus platypterus*), common dolphinfish (*Coryphaena hippurus*), blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*), swordfish (*Xiphias gladius*), albacore (*Thunnus alalunga*), wahoo (*Acanthocybium solandri*), shark (*Katsuwonus pelamis*), bigeye tuna (*Thunnus obesus*), and fringe tuna (*Auxis thazard*) listed in order of market preference.

Pre-Longline Era (< 1960s – 1978)

Before the 1970s, Gouyave fishers used different traditional fishing techniques. The main gear was beachseine for inshore pelagic species. Others included: 'bazor' and handline for flying fish; touch and 'cali' gear (similar to a dip net) for ballyhoo *(Hemiramphus brasiliensis)*; '3-line' (a handline technique) and 'seche' fishing (specialized handline) for ocean pelagic species; fish pot for demersal; and trammel net for lobster and turtles (personal communication, Osmond Small 2003).

The '3-line' handline fishing technique required three fishers with monofilament line and a single straight hook: a bow-line, the deepest baited with a live flyingfish; a middle-line, constructed with a swivel and lead weight to keep the line suspended in mid-water; and the stern-line, the shallowest, both baited with a piece of fish. Using different depths and placing lines at different sections of the boat prevented the lines from becoming tangled. Some fishers attached the line to a 15 cm bamboo/trap that would 'dance' or signal to fishers that a fish was on the hook. This technique was used to catch the occasional large pelagic species such as marlin and sailfish.

In the early 1970s, fishers observed Venezuelan industrial longline vessels fishing. At times, they lifted lines from the water, to copy the technology, "*we copied as much as was good for us, and we made up [invented] the rest*". Later, two boats started experimenting in secret with a very primitive form of longline, using cord, wire, and 26 straight hooks. Mainline and droplines were made from braided nylon, with twisted copper wires to attach the straight hook, to prevent fish cutting the line when they 'bite' (Figure 1). Fishers would affix the line to the stern of the boat with a 5 - 8 cm tyre trap, drifted with the current and set the line, fishing 11 - 13 hours/day, depending on the wind. The main problems with this technology were the raw-material for line construction was very expensive, and because the line was not allowed to drift it burst continuously because of the tension. With this newly constructed gear, they caught flyingfish, sailfish, marlin, dolphinfish, and kingfish. In terms of performance, this new construct fished 10% better than the '3-line'.

There were two types of vessels: wooden canoes, 4 - 5 m in length, powered by oars (sometimes sail); and sloops or double ender wooden boats, 4 - 6 m in length, powered by oars and sails. By the early 1950s, canoe boats were modified by opening the shaft on the stern to secure the engine. The Wilson's brothers (from the USA), fitted an inboard engine on larger wooden boats, and by the late 1960s, diesel inboard engine was introduced. Boats did not have navigational or safety equipment.

Popularization of Longline (1979 – 1999)

In 1979 the Grenadian Revolutionary Government with assistance from the Cuban government helped to popularized longline. Fishermen were sent to Cuba to be trained, and Cuban master fishermen with fishing equipment (seven fully equipped longline ferro-cement boats) were sent to train fishermen in Grenada. Grenadian fishers were trained in pole fishing ("fly fishing") for skipjack tuna with artificial bait, construction of fish and lobster traps, the art of surface longline, bottom longline for shark, and gillnet for flying fish (personal communication, Johnson St. Louis 2003). Of all the gears, longline had the greatest impact on Gouyave fishers. Boat technology also improved with longline changes over the years. Vessels evolved from wooden canoes to wooden forward cabin pirogues, to fiberglass forward cabin pirogues, to larger fiberglass boats.

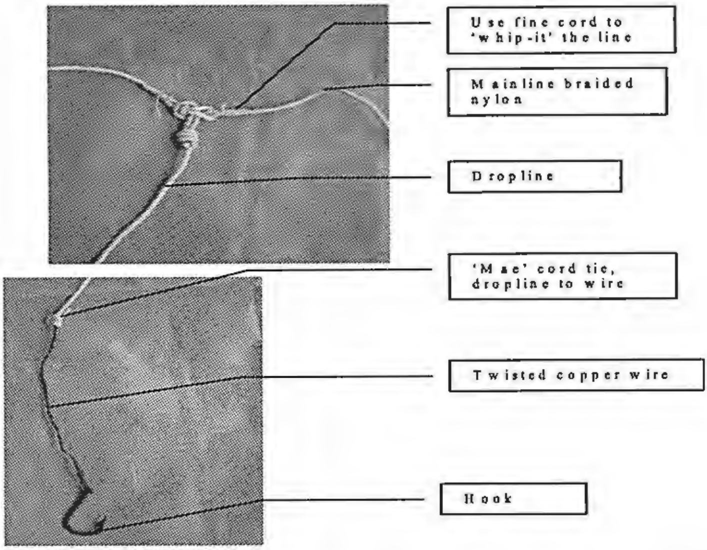


Figure 1. Primitive longline made with braided nylon cord, wire, and straight hook

Cuban design (1980 - 1983) — Popularization of longline started with the Cuban design between 1980 and 1983, using 2 X 113 kg test strain monofilament, drilled and twisted mainline and dropline, stored and deployed from a ply box, using curved 8/0 tuna hooks #9202 (Fig. 2). The distance between droplines on the main was fixed at 18 m apart. Dropline lengths were also fixed at 18, 14, 9, and 4.6 m. Droplines were attached to the mainline, using #18 braided nylon cord/rope, to make a common fisherman's knot. Fishers used 30-50 hooks per line; total length 0.5 km. Main species caught were yellowfin tuna, sailfish, and marlin (Table 1).

The Cuban technology fished 80% better than the primitive longlines, attracting more fishers and investors to fishing. During this time, fishers caught so much fish there wasn't enough freezer storage space; "*at that time the revolution was pretty young and we hadn't enough cold-storage facilities on the island to store tuna and bycatch*" (personal communication, Joseph Taviner 2003). In many instances, fishers had to bury fish because of spoilage.

Fishers were trained on seven Cuban ferro-cement boats, 12 m in length and 4.6 m wide, with two cabins (one in the bow and the other the stern) powered by sails and inboard engines. Four Cuban and four Grenadians were aboard each vessel, working together as a team (a captain, a cook, an engineer, and a fisher); Grenadians learning from Cubans; "... *each Grenadian was given a specific task [on the boat]. We watched what the Cubans were doing* *and learn*" (personal communication, Matthew Duncan 2003). Fishers used boats as the pre-longline era.

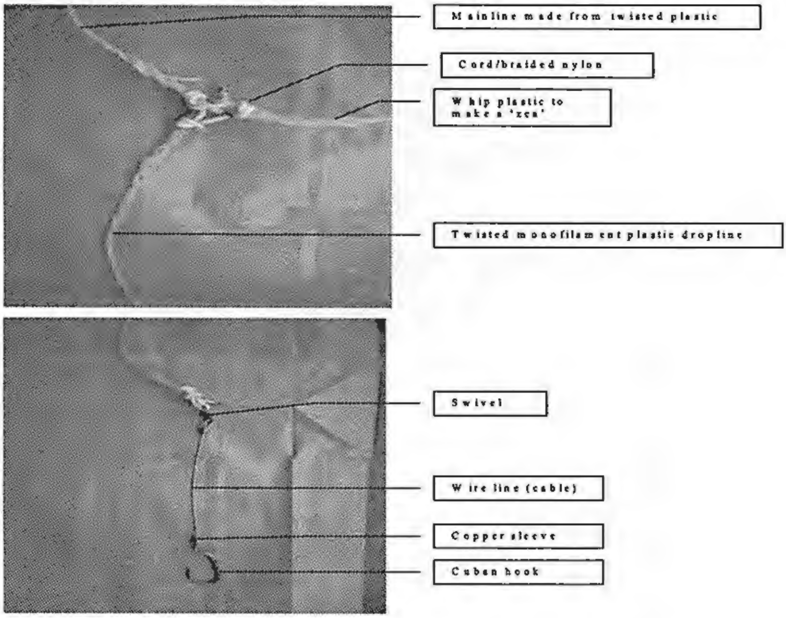


Figure 2. Adapted Cuban design made with twisted monofilament, wire, and curved hook

Early Gouyave Design (1985-1987) — After the revolution, fishers continued using the Cuban technology but with some adaptation. This new adapted version, we term the early Gouyave design. Fishers were still using twisted monofilament mainline, but with single monofilament dropline of 181 kg. Droplines were snapped to mainline, using a branch hanger, and no cable attached to hooks. Main and dropline were stored and deployed from a box. Dropline length varied by boat size: small boats used lengths between 4.6 - 23 m, with 7/0 hooks; while larger boats used 27 - 32 m with 8/0 mustard hooks #7698. Longlines were now using up to 100 hooks (6 - 10 km in length). Main pelagic species caught were yellowfin tuna and sailfish (Table 1).

Over the years, boats increased in length and power. Small canoes, 4 - 5 m in length, were mainly mechanized, with one 25 - 30 hp outboard engine; larger wooden boats, 6.7 - 7 m in length, with two outboard engines (built wider to accommodate two engines). Large wooden boats with inboard engines were still operating.

Table 1: Evolution of the longline gear in Gouyave (1980s to 2004)

VARIABLES	**CUBAN DESIGN (1980-83) A**	**EARLY GOUYAVE DESIGN (1985) B**	**AMERICAN DESIGN (1987/88) c**	**PRESENT GOUYAVE DESIGN (1990s-2004) d**
Boat size (m)	12-14	5-9	9-14	5-12
Monofilament plastic	Splice the ends Used twisted plastic 2X113 kg strain drilled and twisted into a line manual system of deployment tie dropline to mainline Cable used between hook and line	Crimp end with sleeves Manual twisted plastic mainline (2X113 kg) & single dropline 181 kg strain Snap dropline to mainline No cable between hook and line	Crimp end with aluminum sleeves Single monofilament plastic Hydraulic Mainline: 318-363 kg strain Hydraulic and manual dropline 181 kg strain Snap on dropline to mainline No cable between hook and line	Crimp end with aluminum sleeves Single monofilament plastic Mainline 68-227 kg strain Dropline 45-136 kg strain Tie with snap on dropline to mainline No cable between hook and line
Deploy line	Used box to store main & drop lines. Hooks were detached; when setting attached hooks to line.	Used box to store mainline Dropline on reel	Used hydraulic reels to store lines	Small boats, mainline and dropline on manual reel Larger boats, some with hydraulic mainlines
Dropline	Vary dropline 14-18 m Distance between dropline varies from 4.6-23 m Mainline fixed 18 m spacing	Vary dropline from 4.6-23 m Distance between dropline: small boats 4.6-23 m large boats 27-32 m	All dropline the same 14-18 m (some boats) Distance between dropline arbitrary (hydraulic system)	Vary dropline from 2.7-27 m Distance between dropline varies 16-32 m apart
Hooks	Curved hooks 8/0 tuna hook 9202 30 – 50 hooks per line	small boats 7/0 large boats 8/0 mustard hooks 7698 Up to 100 hooks per line	Flat hooks 9/O 7698B 300 hooks per line	Hooks 7/0 or 8/0 100- 500 hooks per line depending on boat size.
Buoyline	Set at 4.6 m depth 1 buoy every 3 hooks	Set at 4.6 m	Lines 14-18 m, others at 18 m 1 buoy every 6 hooks	Set at 1.8-4.6 m 1 buoy every 3 hook
Depth fished	4.6-23 m	4.6-23 m	27-41 m (fishing deep)	23-27 m
Distance	44 hooks set out about 0.5 km	75 hooks set out about 6 km	400 – 500 hooks set out 32 plus km	100-500 hooks set out 3-12 km
Species targeted	Yellowfin Tuna Sailfish Marlin	Yellowfin Tuna Sailfish	Swordfish (using stick lights) Yellowfin Tuna	Yellowfin tuna Sailfish Dolphin Marlin

American design (1987-1989) — In 1988 Government approved foreign fishing licenses for seven US longliners to fish in Grenadian water, with one local fisher onboard as observer (Samlalsingh et al. 1999, Weider 2001). Their technology, which we termed the 'American design', was single 318 - 363 kg strain monofilament mainline, 181 kg strain dropline, stored and deployed from hydraulic reels. All dropline lengths were similar 14 - 18 m. The distances between droplines were arbitrary, as the system was totally dependent on a hydraulic system. Branch hangers were used to attach dropline to mainline. Each longline had about 300 flat 9/0 #7698B hooks. Buoylines lengths were 14 - 18 m, one buoy every six hooks. Lines fished 27 - 41 m deep, with total line length of 32 km. Specie targeted was swordfish, using light stick (Table 1).

The Gouyave design I (1987- early 1990s) — From observing fishing operations on the Cuban and American vessels, reading, along with technical training provided by the FD, fishers started experimenting with different designs to develop a localized system. Fishers Desmond Gill (2003) summarized the changes:

> *"During the period [1988-1990] I had a small wooden canoe boat, about 4.6 m in length, powered by a 15 hp Yamaha engine. It was only two of us [fishers] at the time. We tried using a 36 kg monofilament strain with cable to catch kingfish, blackfin tuna, and barracuda. But big fish burst the line. So we increased the strain to 59 kg, still fish burst the line. So we increased the strain again to 91 kg, and we started catching sailfish and yellowfin tuna. Once we caught six sailfish, we had to tie them to the side of the boat because there wasn't enough space inside the boat. Then we made bigger canoe boats, 5.5-6 m, powered by 40 hp, and increased line strain to 113 kg. Later we increased the strain to 136 kg."*

Mainline and droplines were now made from single monofilament plastic. Reels were introduced to keep the line firm and straight. Fishers also started using sleeves on the line, and increased the number of hooks to about 100 (Samlalsingh et al. 1999).

Small canoes, 5 m long, powered by one 15 hp outboard engine, were still operational. There were also larger wooden boats without forward cabins, powered by one outboard engine; and large wooden boats with forward cabins, powered by inboard diesel engines. In 1986/87 a boat-building company in Mount Moritz fashioned pirogue boats from a Trinidadian mould (Samlalsingh, et al. 1999). They were also fiberglass boats, 9 m long, powered by two 40 - 48 hp outboard engines, with a crew of three fishers.

The present Gouyave design II (late 1990s-1999) — Between 1990-93/94 there was a boom in fiberglass pirogue vessels with forward cabin, powered by 60 - 85 hp engines. By the late 1990s, fishers began noticing a decline in fish stocks and decided they needed boats that could go further offshore and fish longer. Also, the operational cost of the fibreglass pirogue was very high, due to high fuel consumption and cost. According to one fisher, "*Our expense was more than our wages.*" Thus in 1997, fishers and investors came together to design a larger semi-industrial vessel (built in the USA) that was affordable, with relatively low operational cost, and could travel further offshore. With the introduction of these larger vessels, the weight of lines increased, the number of hooks increased, and droplines were set deeper to target swordfish at nights (Table 2).

The 1997 boat census reported Gouyave had 72 vessels: 44 pirogues and 12 canoes involved in longline (Straker, 1997). Later large longline vessels were 10 - 13 m in length, powered by inboard diesel engines, forward cabin (cooking and sleeping accommodations), hydraulic mainline, dropline, and bouyline reels (some boats), and staying three to four days at sea, with safety and navigational equipment (Table 2).

Present Gouyave Longline Technology (2000—2004)

In the last four years, three major technological adaptations were made, adding to the diversity of longline: changes in line construction; changes in the weight of monofilament plastics; and changes in boat construction (Table 2).

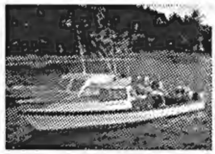
Changes in Line Construction — The length of mainlines ranged from 3 - 10 km, with 136 kg breaking strain. Braided nylon loops 1.5 cm thick were inserted every 18 m along the mainline, onto which droplines are attached by branch hangers during the gear set. Droplines varied in length from 3 - 32 m, using five to eight different lengths, marked by coloured beads (Figure 3). Buoylines, 3 m in length, were attached after every third hook. Mainline and droplines are deployed from separate manual reels with over 300 hooks.

By 2003, there was no standard longline construction. In the past, fishers constructed lines using single monofilament plastic, with dropline lengths ranging from the longest length (23 m) to the shortest length (4.6 m), with 4.6 m increments, e.g., 23, 18, 14, 9, 4.6 m. Fishers changed line construction by mixing dropline length, e.g., 23, 4.6, 11, 2 m, with some fishers having up to ten different dropline lengths.

Changes in Weight of Monofilament Plastic — In the earlier days, fishers used twisted 2 X 113 kg strain monofilament line, however, constant experimentation with lighter breaking strain lines, hooks, and gear design, six longline types have evolved:

i) *Large line* made with 227 kg single strain monofilament line with large buoys; hooks baited with live flying fish; line operated from a hydraulic reel on semi-industrial vessels; and seasonal fishing October to June targeting yellowfin tuna, sailfish, and marlin.
ii) *Regular longline* made with 136 kg strain monofilament line; 7/0 and 8/0 hooks baited with medium and large live jacks (*Selqr crumenonophthalmus*) or flying fish; line operated from manual reel on all vessel types; and fishing year round targeting yellowfin tuna, sailfish, and marlin.
iii) *Light line* made from 91-113 kg strain monofilament line; 7/0 and 8/0 hooks baited with medium and large jacks; line operated from manual

Table 2. Description of three categories of longline vessels in Gouyave (2003).

Variables	Canoe (Small)	Pirogues (Medium)	Semi-industrial (Large)
			
BOAT			
# active boats	67	21	10
Crew	2	2-3	3-5
Boat Size (m)	<5.5 m (open)	6-9 m (forwards cabin)	9-12 m (wheel house)
Boat material	Wood	Wood or fibre	Fibre
Ice	No	No	Yes
Storage	Small	Medium – small cabin	Large – sleeping quarters and fish storage
Water (litre)	19	38	378
Navigational System	Basic	Basic	Advanced navigational system
Numbers of engines	1	2	1
Fuel	Gas; 57 litre/day; 2 tanks	Gas; 113 litre/day; 4 tanks	Diesel; 227 litre/trip; carries up to 757 litre
Power	Outboard 15-75 hp	Outboard 40-90 hp	Inboard 70-350 hp
GEAR			
Gear used	1 manual mainline reel 1 manual dropline reel	1 manual mainline reel 1 manual dropline reel 1 manual bouyline reel	1 hydraulic mainline reel 1 manual dropline reel 1 manual bouyline reel
Longline (Monofilament line)	113-136 kg strain	136-181 kg strain	227 kg strain mainline 204 kg strain dropline 136-204 kg strain buoyline
Length of longline	3-10 km	5-10 km	11 km
Number of hooks	150 hooks; 16 m apart	160-180 hooks; 16-18 m apart	300 plus hooks; 27-32 m apart
FISHING OPERATIONS			
Trips	1 day trip (8 hours)	1 day trip (up to 24 hrs.)	4-5 days trip
Fishing area: distance from shore	11-13 km West	Up to 32 km West	Up to 161 km West
Species targeted	Yellowfin Tuna Blue & White Marlin Dolphinfish Sailfish	Yellowfin Tuna Blue & White Marlin Dolphinfish Sailfish	Yellowfin Tuna Blue & White Marlin Dolphinfish Sailfish Swordfish
Bait	Carry live jacks Catch flyingfish at sea	Carry live jacks Catch flyingfish at sea	Carry live jacks Catch flyingfish at sea dead bait

reel or box on all vessel types (in 2004 semi-industrial vessels started using this line); seasonal fishing targeting yellowfin tuna, sailfish, and marlin.

iv) *Light light line* made from 68-91 kg strain monofilament with small buoys; hooks (7/0) are baited with small live jacks; line operated from a box on canoes and pirogue vessels; seasonal fishing December to February targeting sailfish.

v) *Common Tur line* made from 36-45 kg strain monofilament; hooks baited with small live jacks on canoes only; night fishing operations depending on the phase of the moon, targeting blackfin tuna and sailfish.

vi) *Barracuda line* ("wire line") made from 36-45 kg strain line; dropline has cable near the hook; hooks baited with small dead or live jack bait on canoes and pirogue vessels; line operated from a box; seasonal fishing targeting barracuda, sharks, blackfin tuna.

Many boats had at least two longline weight types, e.g., small canoes had a regular and light line. Use of line was based on availability of fish species and gear performance.

Changes in Boat Construction — With high fuel bills in the 1990s and Hurricane Lenny in 1999 which destroyed 25% of pirogue boats, by 2000, fishers started evaluating the benefits of canoes versus pirogues. Canoes had similar catch rates, low operational cost, and higher incomes, thus more fishers were attracted to this type of operation. This resulted in a decline in pirogue boat operations and an increase in canoes. In 2001 there were 68 longline boats, 40 canoes, 20 pirogues (a decline from 44 in 1997), and eight semi-industrial vessels. By 2003, the number of canoes increased to 67, a 458% increase in canoe longline boats since 1997.

By late 2003, there were three longline boat designs in Gouyave: wooden canoe/multi-purpose boats, operating near-shore; pirogue longline operating mid-shore; and semi-industrial/launcher vessels operating offshore (Table 2). Wooden canoes, totaled 67 were 5.5 m in length, open, eight hour day trips, with one outboard engine, fishing 11 - 13 km from shore, longline carrying 150 hooks, with two crew. Some fishers have further adapted these boats as multi-purpose vessels for longline (removable reels), trolling (bamboo pole fitting), and other fishing gears. Fiberglass pirogue canoes, totaled 21 were 6 - 9 m in length, with forward cabin, up to 24 hour day trips, with two outboard engines, fishing up to 32 km from shore, longline carrying up to 180 hooks, and two crews (reduced crew from three to two). Semi-industrial vessels, totaled 10 were 9 - 12 m in length, with wheel house, fishing trips four to five days, with inboard engine, fishing up to 161 km from shore, longline carrying over 300 hooks, with three to five crew.

Fishers also made changes to boat construction to accommodate the use of live jacks for use as bait. Seasonal availability of bait flyingfish in previous years, restricted longline fishing activities between January to June (Grant and Rennie 2003), but fishers found that with live jacks from the beach seine fishery, they could fish year round. To accommodate live jacks, fishers remodeled boats with bait-wells, which allowed sea water to move in an out through holes in the bottom. This would keep bait alive for the entire fishing trip. 'Bait-wells' were constructed below the engine in wooden canoes, and the center of pirogue boats. In early 2004, two of ten semi-industrial vessels converted an ice-box to a 'bait-well' so they could fish with jacks.

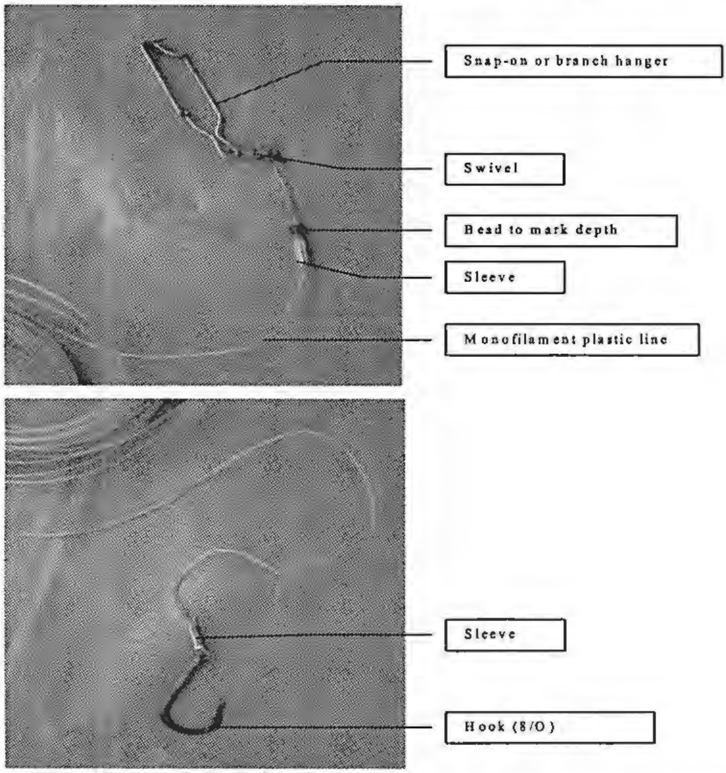


Figure 3. Present dropline design made with single monofilament, straight hooks, sleeves and branch hangers.

DISCUSSION

Over the years, fishers improved longline and boat technology, based on observation, demonstration, and experimentation by trial and error. Is this knowledge important to fishery managers? And, how can fishery managers incorporate such knowledge in fisheries assessment, planning and management?

Is this knowledge important? In comparing data on Gouyave fish landings (Figure 4) and technological information from fishers, there was evidence that knowledge is important. Between 1993 and 2002, the total large pelagic species landings by Gouyave longline fishers, showed an increase from 1993-1995, then a decrease (to 1997), and since 1999, landings increased (Figure 4 continuous line); compared to a gradual increase in national landings (Figure 4 broken line). Between 1993 and 1995, there was an increase in fish landings from 423 MT to 474 MT, which corresponded to the boom in pirogue boats. By 1996 and 1997, there was a sharp decline in landings, which corresponds to fishers noting the decline in near-shore fish stocks and wanting to obtain bigger boats to go further offshore to increase catch. By 1997, they secured larger longliners and by 1998, catch improved. In 1999, there was a decline in fish landing, the lowest it had ever been over the ten-year period (150 MT). This was the year of a fish kill, (origins unknown), and for four months consumers were afraid to eat fish. Then by the end of the year, Hurricane Lenny stopped fishing activities for some time. Since then, fish landings increased, peaking in 2001 (536 MT) and slowing in 2002, which was the period of intense changes and adaptation in fishing technology.

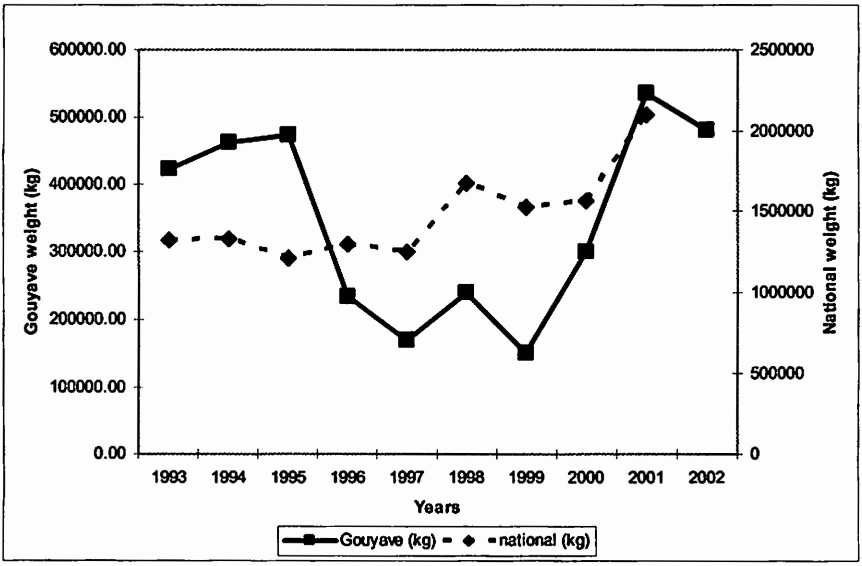


Figure 4. Total large pelagic species caught by Gouyave longline fishers compared to national total (1993 - 2002)

How can this knowledge be incorporated in fisheries assessment, planning and management? Firstly, data collection systems should document fisher technological knowledge, along with catch, effort, and biological data (Berkes et al. 2001). Information on changes in gear construction, fishing operations, and boat adaptation should be documented in detail, to be used later in assessment. Monitoring of data collection activities is essential, as this provides feedback so that changes can be made to the system (e.g., adjusting how gear information is recorded). At the Gouyave Fish Market, staff recorded '*common tur longline*' as handline, and '*regular longline*' and '*light line*' as longline, not making the distinctions between gears.

Secondly, fisheries assessments should somehow take into account technological changes, not just by description but also calculation. Gouyave fishers' decline in landings in 1996 - 1999 was not due to a decline in fish abundance, as other fishing communities were experiencing an increase in fish catch. Thirdly, fishery managers should have confidence in fisher knowledge by including such information in fisheries planning and management. In the future, fishers plan to further improve boat technology and to develop the technology to store bait. Fishery managers' confidence comes by creating policies that support fishers' initiatives.

A fishery system is not static; it is constantly evolving and changing. Gouyave longline fishery is a good example of this changing system. One thing is certain: fishers will continue to experiment, learn from each other, and increase gear effectiveness. Fisheries scientists and managers need to find ways to use technological knowledge to improve fishing techniques, fisheries assessment and management.

ACKNOWLEDGEMENTS

We would like to thank Gouyave fishers, Gouyave Fish Market staff, the Grenada Fisheries Division, and the CARICOM Fisheries Unit. The project has been supported by the International Development Research Centre of Canada (IDRC) and the SSHRC, with grants to Dr. Fikret Berkes.

LITERATURE CITED

Berkes, F. 1999. *Sacred Ecology: Traditional Ecological Knowledge and Resource Management*. Taylor and Francis, Philadelphia, Pennsylvania USA. 209 pp.

Berkes, F., R. Mahon, P. McConney, R. Pollnac, and R. Pomeroy. 2001. *Managing Small-Scale Fisheries: Alternative Directions and Methods*. International Development Research Centre, Ottawa, Canada.

Charles, A.T. 1998. Living with uncertainty in fisheries: Analytical methods, management priorities and the Canadian groundfishery experience. *Fisheries Research* 37:37-50.

Gadgil, M., F. Berkes, and C. Folke. 1993. Indigenous knowledge for biodiversity conservation. *AMBIO* 22(2-3):151-156.

Gomes, C., R. Mahon, W. Hunte, and S. Singh-Renton. 1998. The role of drifting objects in pelagic fisheries in the southeastern Caribbean. *Fisheries Research* 34:47-58.

Grant, S. and F. Berkes. 2004. "One hand can't clap": Combining scientific and local knowledge for improves Caribbean fisheries management. Presented at the 10th biennial conference of the IASCP 2004, Oaxaca Mexico. http://www.iascp2004.org.mx/downloads/paper_106b.pdf

Grant, S. and J. Rennie. 2005. Is CPUE an indicator of stock abundance? Case of Gouyave surface longline fishery. *Proceedings of the Gulf and Caribbean Fisheries Institute* 56:195-212.

Hanna, S.S. 1998. Managing for human and ecological context in the Maine soft shell clam fishery. Pages 190-211 in: F. Berkes and C. Folke (eds.). *Linking Social and Ecological Systems: Management Practices and Social Mechanism for Building Resilience*. Cambridge University Press, Boston Massachusetts USA.

Johannes, R.E. 2001. The need for a center for the study of indigenous fisher's knowledge. *SPC Traditional Marine Resource Management and Knowledge Information Bulletin* **13**:28-29.

Johannes, R.E., M.M.R. Freeman, and R.J. Hamilton. 2000. Ignore fishers' knowledge and miss the boat. *Fish and Fisheries* **1**:257-271.

Mitchell, M. 1992. Special Report: Coastal fishing technology course. Kanagawa International Fisheries Training Centre Japan. 49 pp.

Pitcher, T.J., P.J.B. Hart, and D. Pauly (eds.). 1998. *Reinventing Fisheries Management*. Kluwer, London, United Kingdom.

Ruddle, K. 1994. Local knowledge in the folk management of fisheries and coastal marine environments. Pages 161-206 in: C.L. Dyer and J.R. McGoodwin (eds.) *Folk Management in the World's Fisheries: Lessons for Modern Fisheries Management*. University Press of Colorado, Boulder, Colorado USA.

Samlalsingh, S., H. Oxenford, and J. Rennie. 1999. A successful small-scale longline fishery in Grenada. *Proceedings of the Gulf and Caribbean Fisheries Institute* **46**:3-21.

Smith, A.H. and F. Berkes. 1993. Community-based use of mangrove resources in St. Lucia, West Indies. *Environmental Studies* **43**:123-131.

Straker, L. 1997. Report on the analysis of Grenada fisheries survey data. CFRAMP Report, CFU Belize City, Belize.

Weidner, D.M., G.E. Laya, and W.B. Folsom (eds.). 2001. *An Analysis of Swordfish Fisheries, Market Trends, and Trade Patterns: Past-Present-Future*. World Swordfish Fisheries. US Department of Commerce, NOAA, Silver Spring, Maryland USA.

BLANK PAGE

Shark Fisheries of Trinidad and Tobago: A National Plan of Action

CHRISTINE CHAN A. SHING
Fisheries Division
Ministry of Agriculture Land and Marine Resources.
Port of Spain, Trinidad and Tobago
Current address:
Department of Conservation and Fisheries
Ministry of Natural Resources and Labour
Tortola, British Virgin Island.s

ABSTRACT

Sharks are valued fisheries resources in Trinidad and Tobago ranking fourth in the total estimated landings of the artisanal fishery. They are caught primarily as bycatch of the artisanal gill-net fishery but are landed as by catch of almost all other fisheries such as the artisanal pelagic, and demersal hook and line fisheries for mackerels and snappers, respectively; the beach seine fishery for mackerels and the demersal trawl fishery for penaeid shrimps. There is in addition a small-directed fishery targeting largely the Brazilian sharpnose, *Rhizoprionodon lalandii*. This species is one of the five most important species comprising the artisanal landings, which averages about 800 metric tons per year. Sharks are also an important component of the landings of the small, offshore, semi-industrial pelagic longline fleet for tunas and swordfish. In response to national concerns for the sustainability of shark fisheries, Trinidad and Tobago is developing its National Plan of Action for Sharks under the Food and Agriculture Organization's International Plan of Action (IPOA) for sharks. This poster presents some of the elements of the plan and associated assessment report, namely description of the fishery, brief status of the knowledge of the main species, catch and effort data and the major issues for management as required under the IPOA.

KEY WORDS: Trinidad and Tobago, sharks, National Plan of Action

Piscifactoría de Tiburón de Trinidad y Tobago: Un Plan Nacional de Acción

Los tiburones son recursos de piscifactoría valorados en Trinidad y Tobago la clasificación de cuarto el en general estimó aterrizajes del piscifactoría artisanal. Ellos son agarrados principalmente cuando por - agarran del piscifactoría artisanal neto de papada, pero son conseguidos cuando por agarran de casi todos otros piscifactoría como el gancho artisanal pelágico y profundo y piscifactoría de línea para caballas y castañuelas respectivamente; el piscifactoría de jábega de playa para caballas y el piscifactoría de red de arrastre profundo para camarones peneid. Hay además un piscifactoría pequeño-dirigido que apunta en gran parte el Brasileño sharpnose, *Rhizoprio-*

nodon lalandii. Esta especie es una de las cinco especies más importantes que comprenden los aterrizajes artisanal, que hace un promedio de aproximadamente 800 mt. por año. Los tiburones son también un componente importante de los aterrizajes de la flota pequeña, en el exterior, semiindustrial pelágica longline para atunes y pez espada. En respuesta a preocupaciones nacionales por la sostenibilidad de piscifactoría de tiburón, Trinidad y Tobago desarrollan su Plan Nacional de la Acción para Tiburones bajo el Alimento y el Plan Internacional de la Organización de Agricultura de la Acción (IPOA) para tiburones. Este cartel presenta algunos elementos del plan e informe de evaluación asociado, a saber la descripción del piscifactoría, el breve estado del conocimiento de las especies principales, agarrar y datos de esfuerzo y las cuestiones principales para la dirección como requerido bajo el IPOA.

PALABRAS CLAVES: Trinidad y Tobago, tiburones, Plan Nacional de Acción

INTRODUCTION

Consistent with widespread global trends concerned with the management and sustainable use of shark resources, several countries are proceeding with the analysis of shark fisheries and the development and implementation of National Plans of Action as required under the International Plan of Action (IPOA) for shark conservation and Management (FAO Website). The IPOA Sharks is the outcome of a global response to promote sustainable use of shark resources. Sharks and their relatives exhibit life history characteristics which render them particularly vulnerable to unrestrained exploitation. In addition, there has been a general outcry for the tremendous waste of shark resources through the practice of 'finning', that is removing the fins of captured sharks and discarding the rest of the animal, often alive. In 2000, FAO elaborated precise guidelines for the development and implementation of shark plans and assessment reports at the national regional and international levels (FAO 2000).

Adherence to the requirements of the IPOA Sharks, as well as preparation and implementation of a NPOA, are both voluntary. However, the IPOA Sharks recommends that states adopt a NPOA if their vessels conduct directed fisheries for sharks or regularly catch sharks in non-directed fisheries. Stevens et al. (2000) notes that by-catch makes up about half of the annual global catch of sharks and rays.

Trinidad and Tobago, located on the continental shelf of northeastern South America about eight miles east of Venezuela, is one of the few Caribbean island states where sharks are extensively utilized. Estimated landings of shark rank fourth in volume and value of the species landed by the artisanal fleet. There is also some export of large pelagic sharks and shark fins. As in most parts of the world, the fishery is principally a by-catch fishery with a very limited, seasonal directed component (Shing 1993). The fishery is being analysed and the biological data collected over the period 1985-1986 and 1987, and later are being reviewed in the context of a NPOA.

FISHERY DESCRIPTION

The principal inshore artisanal fishery that catches sharks is the gill net fishery for carite *Scomberomorus brasiliensis* and kingfish *S. cavalla*. This fishery contributes about 60% of the estimated shark landings (Henry and Martin, 1992). Sharks are also caught incidentally by the beach seine fishery, the hook and line (trolling live bait (a la vive) and banking) fishery; the demersal longline or palangue fishery, and the semi-industrial pelagic longline fishery. Of the species of sharks identified from the waters of Trinidad and Tobago about 15 generally comprise the catch.

The artisanal vessels involved in the fishery are either wooden, fiberglass, or fiberglass coated wooden boats between 6.71m. and 9.14m. in length called pirogues. These vessels are equipped with one or two outboard engines, commonly 45 to 75 hp. All operations are manual (Henry and Martin 1992). The semi-industrial vessels are fully equipped for spending up to seven days at sea. Gear used is pelagic longlines.

DATA COLLECTION

Catch and effort data for sharks have been collected since 1962 as part of the onshore data collection system. With this system, data are collected at 31% of the fish landing sites for 20 random days in the month. Data are subsequently raised to account for non-enumerated days and sites. Data collected includes landings and trip details for each vessel. Trends in the landings and standardized effort for some years are examined. These data do not include the offshore semi-industrial fleet. Attempts to record sharks by species is achieving limited success.

Biological data on sharks were collected over the period 1985 - 1986 and later from 1987 - 1989 with some follow up activities intermittently from 1999 - 2000. Samples were obtained largely through a fishery independent survey, which sought to mimic the activities of the inshore artisanal, gillnet vessel on the north and east coasts where sharks were found to be most prevalent in the landings. However, while the typical artisanal gillnet vessels use gillnets of about 4½ in. mesh size, the nets used in the survey were at least 6 inch mesh and deployed specifically for sharks. The species composition of the catch was noted and biological data collected on all species caught. These included sex, total length, weight and stomach contents; for females the width of the shell gland, reproductive state, presence of eggs or pups in the uterus, sex (where possible), and size of pups. For males data collected were clasper length and reproductive state. Some of these data are summarized here for five species.

CATCH AND EFFORT DATA

Between 1962 and 2002 landings averaged about 800 tons. Figure 1 shows estimated landings for this period. Landings peaked in the late 1970s, declined dramatically in these mid-1990s with an increasing trend in 2000s. The variations in landings may be typical of a by catch fishery. It is to be noted however that the peaks in the late 1900s early 2000s are lower than peaks in previous years. CPUE data were standardized for some years between 1972 and 1992 and is shown in Figure 2. The CPUE peaked in the late 1970s declined in the mid-1980s with further increases. However, as with the landings the later peak is at a lower level.

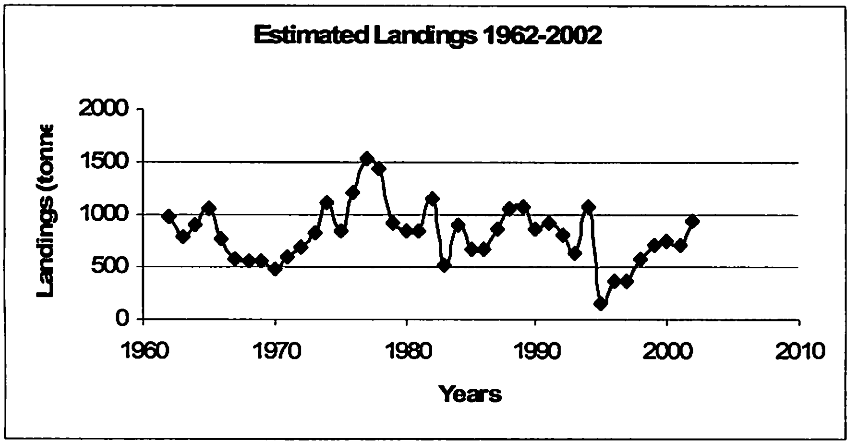


Figure 1. Estimated landings of sharks 1962 - 2002

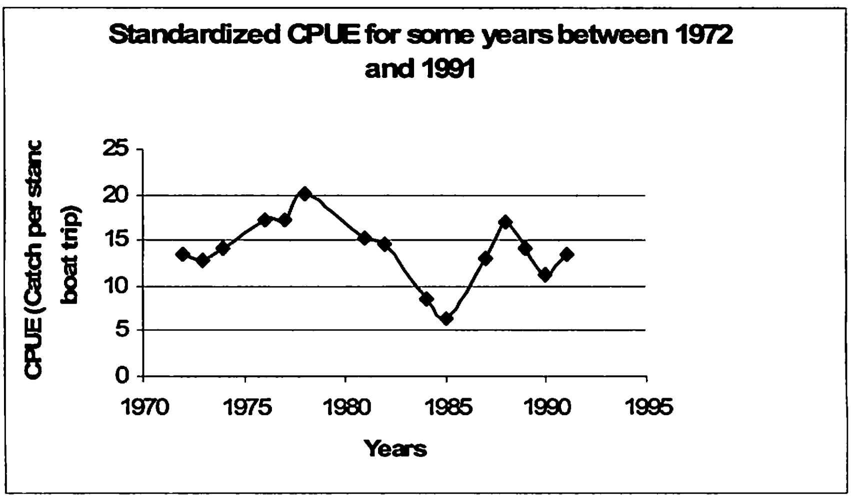


Figure 2. Standardized CPUE (catch per standard boat trip) (Henry and Martin 1992)

SPECIES COMPOSITION OF THE CATCH

Data from the fishery independent survey collected with respect to the fishing grounds on the north and east are presented in Figure 3. It shows that 15 species were most common in the catch. *Carcharhinus porosus* was most abundant followed by *Sphyrna tudes* and *Rhizoprionodon lalandii.*

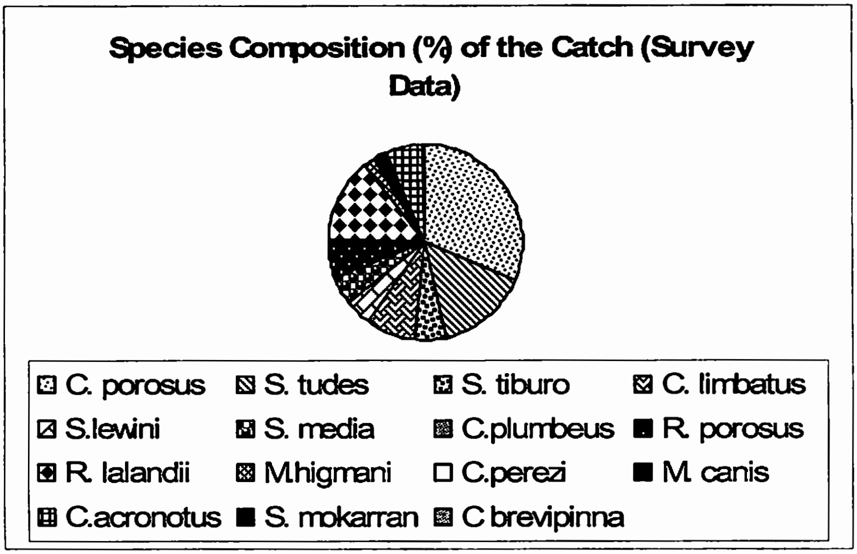


Figure 3: Percentage species composition of the catch (fishery independent survey data)

SUMMARY: BIOLOGICAL DATA AND FISHERY NOTES

Biological Data

Table 1 summarises the biological data based on data collected during fishery surveys (in bold) and data from the literature in italics for comparison. It provides a snapshot of the life history characteristics of the main exploited species. Largely it demonstrates that these species like other chondrichthyians have extended gestation periods, whether they are small or large sharks, produce a limited number of large progeny and are mature at relatively large sizes.

Table 1: Biological data on five species of sharks (*Data in bold is largest specimen in the catch, °data is bold is the smallest female with eggs or pups in the uteri or smallest male with a calcified clasper; pup length in bold in the largest pups observed, Data in italics from Compagno 1984).

Species	Gestation Period	Litter Size	°Age/Size (cm)at Maturity	*Max. Length (cm)	Max. Age	Size at Birth
Carcharhinus porosus	**9-10 months**	**2-7**	**♂ 75-78 ♀ 84**	**150**	**9yrs**	**31-40cm**
C. limbatus	*10-12mths*	*1-10 (4 common)*	*4yrs ♂ 135-180 ♀ 120-190*	*255*	*12yrs*	*38-72*
		4-6	**♂ 106 ♀ 140**	**♂ 167 ♀ 200**		**48cm**
Sphyma tudes	*7-9 mths.*	*6-9*		*150.*		*30cm.*
	7-9 mths	**6-10**	**♀ 765**	**♂ 152 ♀ 118**		**29 -30**
Rhizoprionodon porosus	*10-11*	*2-6*	*♂ 60 ♀ 80*	*110*		*31-39cm.*
		2-8	**♂ 64 ♀ 65**	**♂ 97 ♀ 105**		**34cm**
R. lalandii		*1-4cm*	*40-50cm*	*64cm*		*33-34*
	7mths	**2-4**	**♀ 56cm**	**♀ 71cm**		**32cm**

Fishery Notes

Carcharhinus porosus — The smalltail shark was found to be quite common in the landings as well as in the survey catch. The catch comprised both neonates and immature sharks. Neonates were taken in nets set between 10 to 16 fathoms off the north and east coasts about three to five miles offshore. On the north coast particularly in the months of March to May pregnant females of this species comprised a substantial part of the catch of this shark from the inshore artisanal fishery for mackerels. A preliminary assessment done in 1992 (Walker 1992) with respect to this species concluded that it was not yet at the stage of maximum exploitation. Complimentary assessments done on the target species *Scomberomorus brasiliensis* concluded that this species was at the level of maximum exploitation and management measures were prescribed which included an increase in mesh size and increasing use of lines instead of gillnets.

C. limbatus — The blacktip shark is a favoured species. The inshore artisanal catch of blacktips comprise both neonates and adults depending on the fishing location (distance from shore). Beach seine catches have been observed to land both neonates and older, immature males and females but at different times suggesting that pups may stay in nearshore waters as they develop. The semi-industrial longline fishery also catches mature blacktips.

Sphyrna tudes — The smalleye also known as a golden hammerhead or buttershark has declined in numbers in the landings of the inshore artisanal fishery. This was also evident from a review of the data collected during the fishery survey.

Rhizoprionodon lalandii — The Brazillian sharpnose like the blacktip is also a favoured species given cultural predilection for small sharks. This shark is the focus of a small directed fishery on the north coast of Trinidad. Unfortunately, based on observations of individuals most of the catch comprise females carrying pups. A public awareness programme is focused on restricting the development of this fishery.

R. porosus — The Caribbean sharpnose shark has been observed from the catches of most fishing gears in the artisanal fishery. Generally an inshore species, catches are usually of adult/mature males and females.

ISSUES FOR FISHERY MANAGEMENT

The location, landings and biological and fisheries notes present a number of issues for fishery management:

i) Multispecies nature of the fishery,
ii) Apparent patchy distribution of species,
iii) Landings generally bycatch of more lucrative fisheries,
iv) Inability of field data collectors to reliably record landings by species,
v) Different life history stages of the same species caught by different fisheries.,
vi) Different life history stages of the same species caught by the same fishery,
vii) Females carrying pups found on same fishing ground as target species of some fisheries,
viii) Lack of stock assessments for important coastal species,
ix) Need for collaboration with neighbouring states (transboundary

issues),

x) Shark finning,

xi) Systematic recording of shark catches from all sources,

xii) Framework for identification of threatened species,

xiii) Inappropriate legal framework,

xiv) Public education awareness,

xv) Human resource capability for systematic monitoring of sharks,

xvi) Post harvest practices that contribute to waste of sharks caught,

xvii) Ecosystem impacts as a consequence of shark fishing (directed fishery),

xviii) Further research on shark fisheries biology, age and growth, diet composition and volume of diets contributed by prey species, and

xix) Systematic collection of trade data on sharks.

CONCLUSION

Much remains to be done to complete the assessment report for sharks. The issues identified so far remain to be reviewed and finalized. The continuing challenge is the multi-species, bycatch nature of the fishery. However, the management measures that have been proposed and in some cases implemented with regard to the gillnet fishery, includes gear modifications and promotion of more selective gears. These will have implications for the associated bycatch of sharks.

Further studies on these species will require regional collaboration at least with neighbouring states to ensure compatibility with regard to management approaches.

ACKNOWLEDGEMENTS

The Director of Fisheries Ms. Ann Marie Jobity and the staff of the Marine Fishery Analysis Unit are thanked for providing, respectively, support and assistance for this work. The assistance of Fisheries Officers Lara Ferreira, Louanna Martin and Suzuette Soomai and Mr. Andre Thomas, Systems Manager are gratefully acknowledged. Special thanks is extended to Dr. Jose Castro who provided technical assistance with species identification and biological studies on sharks, Mr. Terry Walker and the FAO Project Team (Mr. Michael Sanders, Team Leader) are gratefully acknowledged for the assessment of *C. porosus*. Special thanks is extended to Ms. Shannon Gore, Marine Biologist at the Conservation and Fisheries Department, British Virgin Islands, for her assistance in compiling the poster and providing advice during the preparation of the document.

LITERATURE CITED

Castro, Jose I. 1983. *The Sharks of North American Waters*. The W.L.Moody Jr., Natural History Series 5. Texas: Texas A&M University Press, College Station, Texas USA.

Chan A Shing, C. 1993. The status of shark resources in Trinidad and Tobago. Trinidad and Tobago: Ministry of Agriculture Land and Marine Resources. Fisheries Division Fisheries Internal Report No. 218 pp.

Compagno, L.J.V. 1984. *FAO Species Catalogue Vol 4. Sharks of the World. An Annotated and Illustrated Catalogue of Shark Species Known to Date. Part 2 – Carcharhiniformes.* UNDP; FAO Species Synopsis Vol. 4 No. 125. Part 2. FAO, Rome, Italy.

Food and Agriculture Organization 2000. *FAO Technical Guidelines for Responsible Fisheries- Fisheries Management –4 Suppl. 1-1 Conservation and Management of Sharks.* FAO, Rome, Italy.

Food and Agriculture Organization Website. 2002. Implementation of the IPOA Sharks. Food and Agriculture Organisation 8th .FAO, Rome, Italy. http://www.fao.org/DOCREP/003/X8692E/x8692e0b.htm

Henry, C. 1989. An exploratory shark fishing survey off the east coast of Trinidad, draft. Ministry of Food Production and Marine Exploitation. Port of Spain, Trinidad and Tobago: *FisheriesTechnical Series No. 3.* 40 pp.

Henry, C. and L. Martin. 1992. Preliminary stock assessment for the Carite fishery of Trinidad. FAO/UNDP Project TRI/91/001. *Technical Report for the Establishment of Data Collection Systems and Assessment of the Fisheries Resources.* Port of Spain, Trinidad and Tobago. 47 pp.

Stevens, J.D., R. Bonfil, N.K. Dulvy, and P.A. Walker. 2000. The effects of fishing on sharks, rays and Chimaeras. (Chondrichthyans) and the implications for marine ecosystems. *ICES Journal of Marine Science* 57 (3):476-494.

Walker, T. I. [undated]. Trinidad and Tobago Shark Stock Assessment Mission Report. FAO, Rome, Italy. 22 pp.

BLANK PAGE

Artisanal Fishing in Jamaica Today: A Study of a Large Fishing Site

ANGINETTE MURRAY and KARL AIKEN
Department of Life Sciences
University of the West Indies
Mona Campus, Jamaica

ABSTRACT

This site is located in the western part of Jamaica and is the third largest fishing community, but before this 2001-2002 study, little was known about this site. Approximately 700 fishers using 120 relatively large (16 m) open boats operate from this relatively well developed site. These boats are all constructed on the beach and are the largest in the island. We investigated selected reef fish species from trap catches, gear distribution, fishing grounds, socio-economic information on fishers as well as attitudes towards potential management measures.

The overfished condition of the reef fish resources targeted by these fishers who operated mainly on Pedro Bank, 100 km to the south, was evident from the high proportion (61%) of "trash" (lower grade) fish in trap landings. Ranked dominant families were Scaridae (parrotfish), 41%, Mullidae (goatfishes (18%), and the Holocentridae (squirrelfishes), 9%. Fish traps with 3.18 cm maximum aperture mesh wire were the predominant gear utilized by 49% of all fishers, with hook and line gear at 37%. Comparisons of estimates of the von Bertalanffy growth parameters for the eleven most abundant reef fish species from seven families, indicated the reef fish populations they represented, were not significantly different from many other Caribbean reef fish populations with high mortality rates. There is a curious interference by dolphins (Mammalia, Delphinidae) with fish traps that will form the basis of another project.

Of the 69 fishers interviewed, 87% were full-time, and 52% were over 40 years old. Most had been fishing from more than 10 years. Most fishers perceived that there was need for management measures such as shorter fishing seasons, introduction of fishery reserves, increasing the minimum size for lobsters, and co-management of the reef fisheries.

KEY WORDS: Fishing gear, reef fish, management, Jamaica

Pesca Artisanal en Jamaica: Un Estudio de un Sitio de Aterriza de Peces Grandes

Whitehouse se esta situado en el occidente de la Jamaica y es el tercer mas grande comunidad de los pescadores. Pero antes de ese estudio desde 2001-2002, se no ha entiende mucho de este lugar. Aproximadamente 700 pescado-res, se utilisando 120 canoas mas grande edasen (18m), pescando desde este lugar mas desarollado. Esos barcos son contruido sobre la playa y se los mas grandes en toda la isla. Hemos investigados los peces arrecifes particulares desde las nasas para peces, el distribucion de artes de pesca, las zonas de pesca, la informacion socio-economico sobre los pescadores, y tambien, opiniones sobre regulaciones del manejo para la pesqueria para el futuro.

El estado de sobrepesca de los peces del arrecife que estaba la objeto de los pescadores, se operan en el Banco Pedro, 100 km al sur de la isla, estaba probado por la proporcion mas grande encontrado en la categoria de menor valor (se llama en ingles"trash") (61%) desde los desembarcaciones de las nasas antillanas.. Las otras familias con las abundancias mas grandes, son, en el orden, Scaridae (loros), (41%), Mullidae (barbas) 18%, y Holocentridae (ojos grandes) 9%. Nasas antillanas con la aperatura maxima de 3.18 cm estaba el arte de pesca mas comun utilizado por 81% los pescadores, y los ansuelos y lineas, 42%. Los parametros de von Bertalanffy se han calculado para 11 especies del arrecifes, se han demonstrado que esos especies no son muy diferente del los otros especies similares de los otros lugares en el Caribe, con ratos grandes de la mortalidad. Se lo ha observado un fenomeno muy interesante que los delfines (Mamalia) jugando con nasas en este region.

Un total de 87% de todos los pescadores estaban pescadores permanentes, y 52% tienen mas que 40 anos de la edad. La majoridad estaban pescando para mas que 10 anos. La majoridad de los pescadores piensan que es necesario los regulaciones de manejo como por ejemplo, vedas, refugios, subiendo a talla minimo para la langosta, y el co-manejo de la pesca del arrecife.

PALABRAS CLAVES: Jamaica, artes de pesca, peces arrecifes, manejo

INTRODUCTION

Jamaica lies to the centre of the southwest Caribbean Sea and is third largest of the Greater Antilles with a total land area of 10,940 km^2, a population of approximately 2.5 million, and a coastline of 885 km. It has many small inlets and bays along this coastline (NRCD 1987). Lying in the path of the northeasterly trade winds, wind speeds exceeding 15 m/sec and associated choppy seas are common, with a calmer period between October and February (Munro 1983, Aiken 1993). Currents in the vicinity of the island are westerly and vary from 0.5 – 1.0 knots per hour. For most of the year tidal effects are slight to nil, although over Pedro Bank they can reverse at ebb tide. The majority of the sea floor on the shelf is seagrass and soft corals over sand and limestone bedrock, with coralline growth usually concentrated at the edges (Aiken 1993, Halcrow 1998). There are muddy areas near the estuaries of several large permanent rivers emptying at the south coast. Much of the south shelf is flat and shallow with a mean depth of approximately 20 m and a maximum width near the middle of it, of approximately 25 km. The north shelf, in contrast, is a narrow 1.6 km band. The larger reefs are found on the eastern portion of the south shelf and are of the fringing and sill types. There is deep water separating the island from all the oceanic banks. The edges of the shelf have a vertical or near-vertical profile into deep water (> 300 m) on all sides. The island and the nine proximal oceanic banks have a total area of 4,170 km^2. An Exclusive Economic Zone established in 1996 has increased

Jamaica's total marine area to 274,000 km^2. Fishing activities from White-house, take place within the national EEZ. This assumption was tested.

Figure 1 shows the location of Whitehouse fishing beach, near the eastern edge of the parish of Westmoreland parish, approximately 180 km from the island's capital of Kingston. It is recorded by the Fisheries Division of the Ministry of Agriculture as having approximately 700 fishers and some 150 boats. There is a large river, the Black River, which empties just to the east of Whitehouse, which provides a large volume of fresh water input into the coastal waters up current of Whitehouse. Whether there is significant siltation effect on corals in nearshore waters near that location is unknown at the present time, but during the two years of study, no significant siltation was observed or reported to us from that river. The shelf near Whitehouse is relatively flat and shallow with a mean depth of approximately 20 m. study. There are actually two (twin) adjoining landing, Whitehouse beach proper which is larger and with a large mooring pier and gear storage, and the slightly smaller, Gillings Gully beach to the west. The active fishers cooperative for the twin beaches, takes it name from this latter site. It is estimated to be the third largest fishing site in Jamaica. The site has a modern pier, freezers, and market area courtesy of Japanese government constructed in 1999. It was thought to be a base for approximately 700 fishers with 150 fishing vessels. It was always thought to be an important landing site, yet little data had been collected there previous to this study.

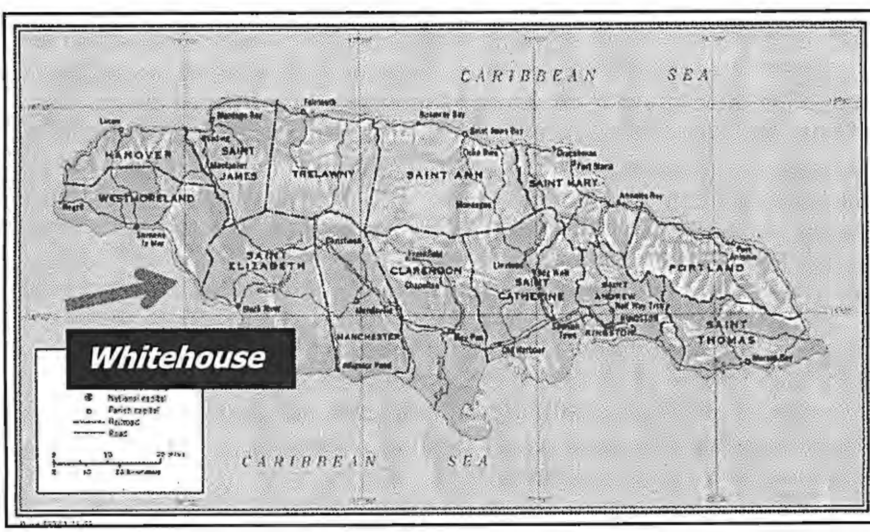


Figure 1. Map of Jamaica showing location of Whitehouse study

The Fishing Industry

The fishing industry is primarily artisanal and small-scale, but is surprisingly diverse and complex (Halcrow 1998). There are at least 15,000 to 20,000 active fishers and at least 3,500 registered fishing vessels operating from 184 landing sites spread relatively evenly around the entire island. The typical vessel is an open canoe (95% of all vessels) that range in size from 4 m wooden dugouts to > 18 m larger fiberglass canoes that fish Pedro Bank 150 km offshore to the south. All larger canoes use large (> 40 hp) outboard engines. There is also a small number of decked, offshore vessels in the 12 m to 20 m size range that are fitted with inboard gasoline or diesel engines that fish adjacent oceanic banks. There is a small fishing port in Kingston that was constructed in 1980 with concrete berths and other facilities for larger decked vessels. It is presently in a somewhat poor condition.

The main landings are of coral reef fishes (Munro 1983, Aiken and Haughton 1987, Koslow et al. 1988, Aiken 1993, Aiken and Kong 2000). Though 445 species of marine bony and cartilaginous fish species have been described by Caldwell (1966), only 96 species of fish and two lobster species have been described from the Port Royal reefs near Kingston by Munro. The main fishing areas are on the island shelf and on the nine small oceanic banks. Pedro bank is a larger oceanic bank that is 5,500 km^2 in area and is to the southwest of Kingston. It is accessible to all larger south coast canoes, and many undertake the perilous, but profitable journey. On the eastern fringe of Pedro bank are three small sandy cays on which fishers reside, fishing and shipping their sorted catches mainly to Kingston, at regular intervals for most of the year. The main fishing gears are fish traps (pots) and beach seine, tangle and gill nets, followed by hand lines, spear fishing and some use of illegal explosives. Since 1980, there has been as steady increase in the number of fishers employing nets of various kinds in an attempt to avoid widespread pot stealing. By 1996, net fishing gears were 40% of all gears employed, equaling the use of pots (Fisheries Division 1997). Large Z-shaped Antillean fish traps (which take crabs and lobsters also) were used by 55% of all fishers and these exploited Pedro Bank resources. A total of 42% of all fishers exploited south coastal shelf resources using traps primarily. These same fishers also traveled to other very small offshore banks that were nearby. Handlines (hook-and-line) were used by 42% of all fishers. Many fishers employ more than one type of gear (Espeut and Grant 1990). North coast fishers are mainly part-time while those on the south coast are mainly full-time. Marketing is by a large diffuse higgler system. This organizational pattern was tested for Whitehouse.

Fish production statistics from the Fisheries Division for 1996 and 1999 suggest that marine catches island wide of all fishable products totaled in those years, 14,400 t and 8,300 t annually, respectively. Old Harbour bay, the country's largest fishing beach produces roughly 33 % of annual production. It was assumed that Whitehouse was the third largest contributor to this total annual fish catch. This assumption was tested.

Fish pot or trap fishing is conducted in two major locations; 1) the island shelf and 2) the offshore banks and their cays. The great majority of fish landings are from reef fisheries, mostly from the southern island shelf. The primary gear is the Jamaican version of the Antillean fish trap, which consists of a hardwood frame over which hexagonal meshwire is stretched in a Z-shape with two horse-necked entrance funnels. These traps are set near, but never on, the fringing reefs at depths between 20 to 40 m on average. They are usually deployed singly, with simple baits for up to six days. Newer pop-up floats are gaining popularity due to increasing fish pot piracy. Traps are retrieved from the seafloor, by hand by a crew of about three persons, operating from an open boat. This fishery produces scalefish, spiny lobsters, crabs, and some octopus. Small quantities of shark and rays are caught in the net fisheries where catches are dominated by scalefish. Nearly 60% of all fishers operate on the south coast.

Offshore, the major activities center on Pedro Bank, which has three sandy cays supporting a maximum of about 150 persons. These fishers use traps, scuba and lines to harvest reef fish, queen conch and spiny lobsters from all over the bank. One thousand fishers and 200 boats are registered with the Fisheries Division as having permits for fishing Pedro Bank and on the much smaller Morant Bank to the southeast of the island. Queen conch is taken by cay-based divers from industrial vessels. The resident cay fishers sell their fish and lobster harvest to larger carrier boats, laden with ice, that take the fish to Kingston. Many larger partly-decked canoes with special insulated ice-holds also travel from south coast beaches to the cays to transport catches back to the island. Fishing patterns at Whitehouse were examined.

The two study hypotheses were tested by collecting a variety of fisheries, biological and sociological data at the study site over a 24 month period. Included in the objectives were the following;

i) Determination of numbers of fishers at WH (Whitehouse),
ii) Determination of number of vessels operating from WH,
iii) Determination of seasonality of fishing at WH,
iv) Description of fishable species composition by gear type landed at WH,
v) Estimation of how many WH fishers fishing on Pedro bank,
vi) Pedro Bank contribution in catches landed at Whitehouse,
vii) Estimation of costs of Pedro bank fishing,
viii) Determination of fishing effort by WH fishers on Pedro bank,
ix) Determination of seasonality of fishing on Pedro bank,
x) Estimation of value of catches landed annually, monthly,
xi) Comparison of project data with data from study site collected and held by Fisheries Division,
xii) Socio-economic characterization of fishers operating at WH,
xiii) Estimation of earnings by fishers,
xiv) Disposal of incomes of fishers,
xv) Problem analysis of fisheries activities,
xvi) Review of regulations affecting fisheries management, and
xvii) Formulation of management plan for fisheries resources landed.

Hypothesis

The following was a general hypothesis, based on the authors own personal observations based on prior knowledge of the study area for 25 years.

H-1

- I) Whitehouse fishing beach is significantly different from other large south coast fishing beaches (fish landing sites)
- II) Whitehouse fishing beach is not significantly different from other large south coast fishing beaches

H-2

- I) Pedro Bank plays an important role in fishing at Whitehouse
- II) Pedro Bank plays no significant role in fishing at Whitehouse.

METHODS

Using mainly random sampling of fishers on the site, we;

- i) Applied questionnaire sampling to a significant percentage (10%) of fishers in order to obtain the following,
- ii) Personal information on fishers (age, years fishing experience, etc.),
- iii) Collected; fishing gear data which will produce as completely as possible, an understanding of the operation of the fishing activities there, especially on a) fish pot fishery, b) net fishing, c) hook and line fishing, d) spear fishing, e) other methods or combinations of methods,
- iv) Data on fishing vessels (numbers, characteristics, places visited to fish, operational costs for vessels, etc.),
- v) Biological data on the fishable resources harvested,
- vi) Data on seasonality (patterns of fishing activity),
- vii) Socio-economic data on operational costs relating to fisheries, such as outboard engine fuel cost, fish pot–building supplies, net costs, ice supply and costs, miscellaneous gear costs, fish prices, etc.),
- viii) Data on marketing (identification of buyers, eventual site of disposal of fish products, ultimate buyers, mark-up prices),
- ix) Data on distributional aspects (transportation costs, types of motorized transport, problems relating to above),
- x) Data on attitude of fishers towards fisheries management by means of suggesting various options for the future,
- xi) Other miscellaneous socio-biological data such as membership in fishers' cooperatives, dependents on fishing, and
- xii) Socio-cultural data (e.g. attitudes to fishing generally, aspirations of fishers' family members, family structure, disposal of incomes).

Data were collected on questionnaires and biological data recording sheets in the field, and those data transposed to commercially available spreadsheet programs and stored in computers at the Department of Life Sciences, UWI, Mona campus. Data were analyzed using fisheries software, especially FiSAT from FAO/ICLARM, spreadsheet statistical packages, and special statistical software (such as Statistica) that were available to the project. FiSAT incorporated several sub-routines for analyses of length-frequency data (e.g. ELEFAN) in order to obtain growth rates and fitting of growth curves, estimates of natural, fishing and total mortality rates. The fieldwork section of the project ran for two calendar years, beginning in January, 2001, and ended at the close of 2002 (24 months). There was a link with the Department of Economics at the UWI, Mona through Dr. Michael Witter, who gave relevant advice.

RESULTS

Whitehouse is located near a part of the larger south shelf, as can be seen in Figure 1, where the shelf narrows. If the findings of the USSR/Jamaica fisheries research programme can be accepted as accurate, then the coastal shelf just off the beach at that location, comprises as we travel from shore outwards to deeper waters as follows; a) clayed silt, b) silty sand, c) old coral reef, followed by d) coral formations (USSR Ministry of Fisheries 1980). Fishers there mainly use traps and do some hook and line fishing at and near the edge of the shelf, seeming to exploit the fishes associated with the coral reefs there. There is a steep drop-off into deep (> 300 m) water at the edge.

Pedro bank has a different benthic habitat sequence. There, the center of the bank is dominated by sand, but as the edge is approached, there are scattered coral heads which increase in density until relatively dense coral growth at the edge is reached (Munro 1983). There is a steep, near-vertical drop-off into very deep oceanic water at the edge of Pedro Bank which is known to have major reef fish resources. The role of Pedro Bank resources in Whitehouse landings was investigated, and we found that Whitehouse fishers harvested fish and lobster from the entire northern edge of Pedro Bank. They tended to prefer, however, the central and eastern parts of the northern edge. Fishers used Z-traps, but about 50% used traps and hand lines in the typical two to three day trips to that area. Another 20% did trolling seasonally as they traveled to and from the Bank to do trap and line fishing. Sixty percent of all Whitehouse fishers depended on Pedro Bank for its resources. The catches from that area were always of greater mean size and weight, was more diverse in fish species and earned more per trip than did catches from the south shelf. We found that there were at least 700 fishers using 120 fishing canoes at Whitehouse in the 2001 – 2002 period of the study. The Antillean Z-trap is the principal gear that impacts reef fish diversity. Contributions of various groups of species were investigated at Whitehouse. The study suggests that the aforementioned hypotheses were correct. Whitehouse beach is significantly larger than Belmont to the west and Scott's Cove to the east. It has many more fishers (17 times and 23 times) and vessels (10 times and 6 times), respectively, than those aforementioned beaches.

Overfished Status of Fishery

The continued overfished status of the shelf fishery resources landed at WH beach was evident from the high proportion of 'trash" fish in the catches. This market category comprised 61% of the total landing over the study period.

Dominant Fish Families and Species

The dominant reef fish family comprising the landings during this study was the Scaridae (parrotfishes) making up 41%, the Mullidae or goatfishes 18% and the squirrelfishes or wenchman family 9%. Figure 2 shows the composition by family of the nine most common reef fish landings.

The dominant reef fish family was the Scaridae or parrot fishes. This group comprised 41% of all reef fish landing observed. The Mullidae or goatfishes, *Pseudupeneus maculatus*, red-spotted goatfish and *Mulloidicthes martinicus*, yellow goatfish or queen mullet, in that order of abundance, comprised 18% of the catch. These two are higher-valued species. But, two low-valued species, Holocentridae (squirrelfishes) and Acanthuridae (doctor fishes) together made up 17% of fish landings. So, three families of lesser value made up 58% of fish catches. Three commercially valuable groups, Mullidae, Serranidae (groupers) and Lutjanidae (snappers) together constituted 31%.

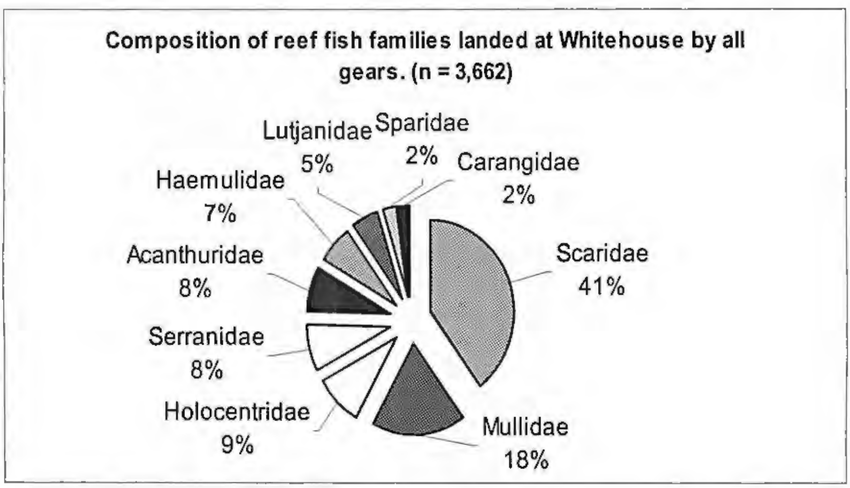
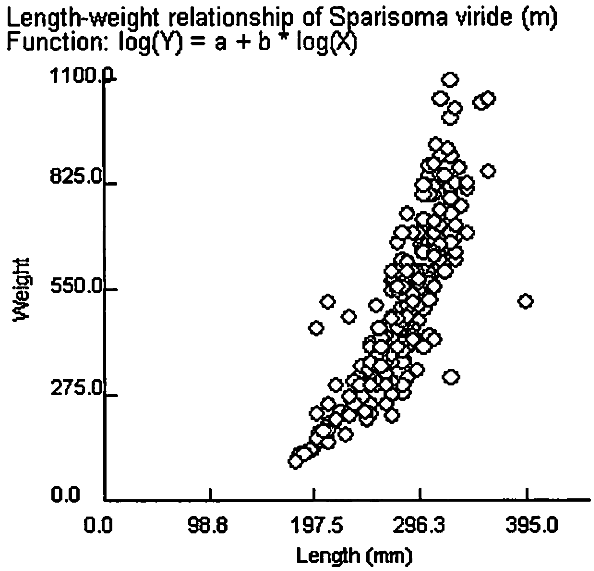


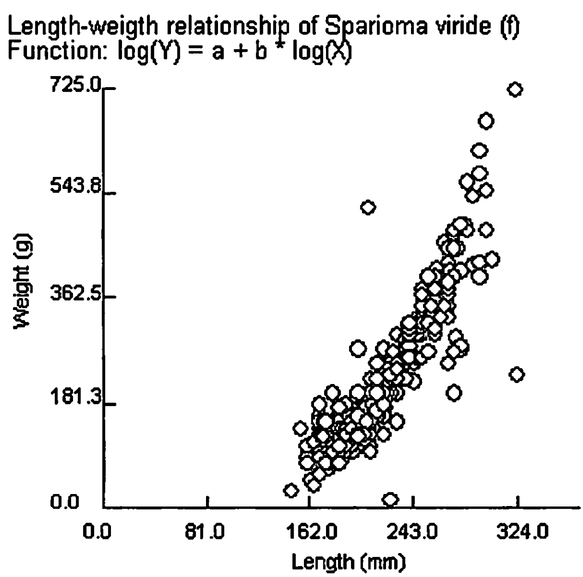
Figure 2. Reef fish family composition of landings at Whitehouse beach, Westmoreland 2001 - 2002

Biology and Population Dynamics of Reef Fish

A total of eleven reef fish species out of at least 30 species observed were investigated. This number chosen was based on higher abundance and regular appearance in fish trap landings at the site during the study period to allow larger sample sizes. A number of biological relationships such as length-weight relationships, and important biological parameters such growth rates, and growth performance index (Ǿ) were investigated. One main example chosen as representative of the reef fish species was the stoplight parrotfish, *Sparisoma viride*, which was very common in fish landings. Figure 3 shows the length-weight relationships estimated for males and females of this species from fish trap catches from both the shelf and Pedro Bank fishing areas.



Length-weight relationship of *S. viride (m)* Wt (g) = 0.0092FL (mm)$^{3.008}$, r^2 = 0.7619. n = 236



Length-weight relationship of *S. viride (f) Wt (g) = 0.0075FL (mm)*$^{3.065}$, r^2 = 0.7711. n = 427

Figure 3. Length-weight relationships for *Sparisoma viride*, stoplight parrotfish, from fish trap catches from shelf and offshore area, landed at Whitehouse.

The length-weight relationship showed that the stoplight male parrotfishes were significantly heavier at any length compared with females. This supported by the length frequency distribution figure for both sexes where there were more larger males than females and that males attained a significantly larger maximum size than females (Figure 4). Length-weight relationships were obtained for all 11 species of fishes investigated, but only one representative example is shown in this paper for the sake of brevity.

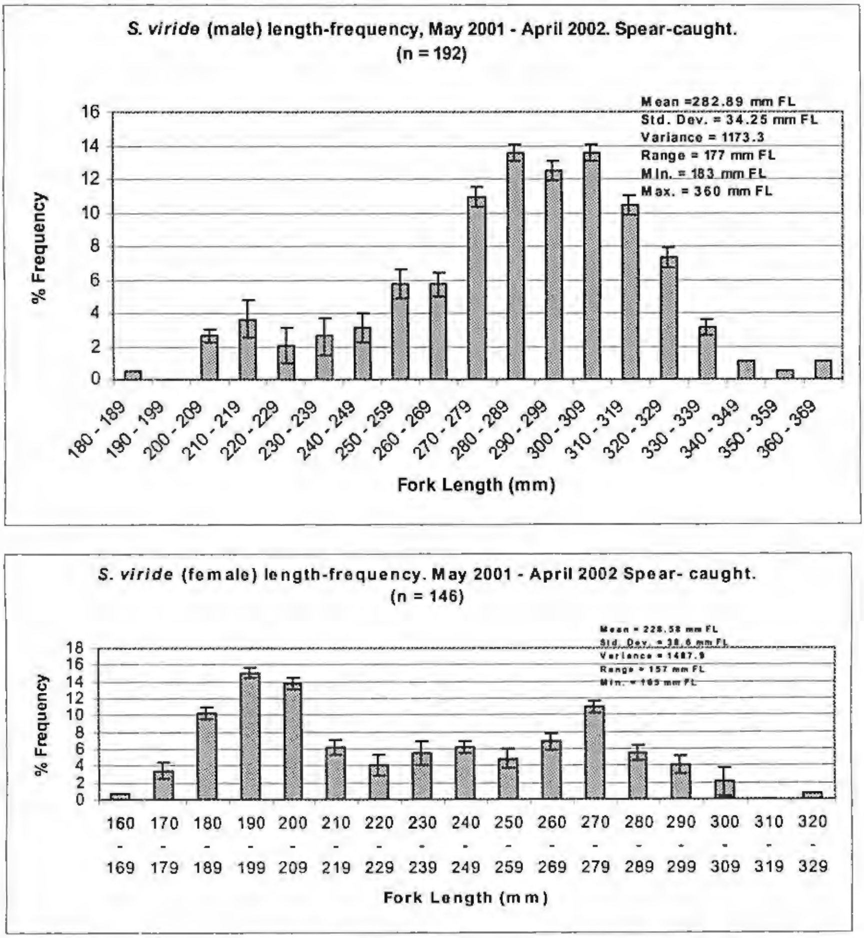
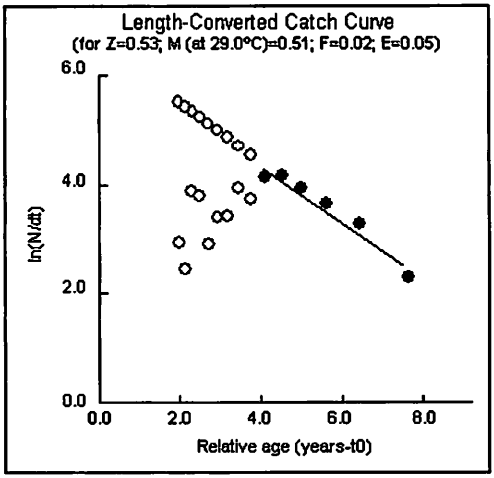
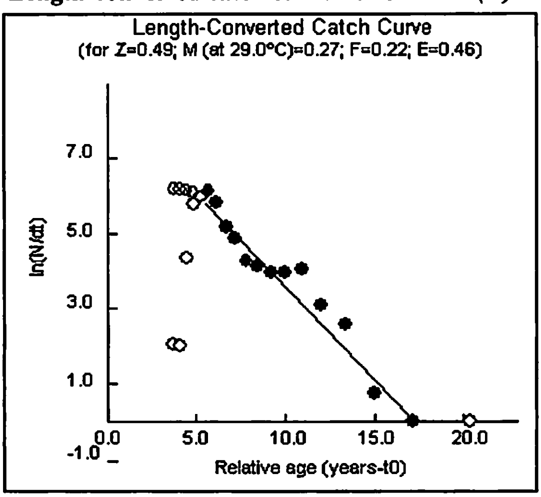


Figure 4. Length-frequency distribution for *S. viride* males and females from trap catches landed at Whitehouse beach.

Figure 4 showed that males obtained by spear fishermen attained a maximum size of just over 360 mm TL while females reached only 320 mm TL. Most males were larger than females with a majority of males in the range 270 – 330 mm TL. Two modes which may represent two year classes are apparent, particularly in the female size distribution. Total mortality estimates for *S. viride* are shown in Figure 5.



Length-converted catch curve for *S. viride (m)*



Length-converted catch curve for *S. viride (f)*.

Figure 5. Total mortality (Z) estimates for *Sparisoma viride* males (Z = 0.53) and females (0.49) from trap catches landed at Whitehouse.

Annual total mortality rate (Z) estimates shown in Figure 5 suggest that male *S. viride* had just slightly higher total mortality rates than females. The stoplight parrot fish is presented as a representative example of the types of results that were obtained for all 11 reef fish species.

Von Bertalanffy growth formula parameters estimated by FiSAT software and based on length-frequency data for eleven reef fish species are summarized in Table 1. The table compares estimates from earlier research on these species including such research as that by Munro and his co-workers (1983).

Table 1. Summary of Von Bertalanffy population parameters for 11 reef fish species landed at Whitehouse, showing present results and those from previous studies.

SPECIES	PREVIOUS STUDIES					PRESENT STUDY				
	L_∞ (mm)	K	Ø'	M	Z	L_∞ (mm)	K	Ø'	M	Z
S. viride (stoplight parrot)	395.00	0.963	2.91	-	-	341.25	0.275	2.46	0.562	0.393
S. aurofrenatum (redband parrotfish)	260.00	0.200	2.13	-	-	246.75	0.730	2.65	1.190	1.269
S. taeniopterus	350.00	-	-	-	-	278.25	0.580	2.65	0.990	1.519
S. chrysopterum	409.00	0.782	3.14	-	-	320.25	0.360	2.57	0.697	0.542
P. maculatus	213.58	0.525	3.88	1.890	1.890	267.75	0.610	2.64	1.034	1.707
M. martinicus (yellow goatfish)	301.60	0.400	2.55	1.700	1.700	362.25	0.130	2.23	0.345	0.587
H. ascensionis	279.45	0.867	2.92	2.873	1.700	246.75	0.520	2.50	0.955	1.421
H. aurolineatum	258.75	0.583	2.27	2.755	-	246.75	0.520	2.42	0.953	1.421
E. fulvus	424.50	0.528	2.50	1.635	1.580	320.25	0.230	2.37	0.519	0.480
E. cruentatus	360.00	0.290	2.52	0.490	-	320.25	0.150	2.19	0.393	0.367
A. chirurgus	355.50	0.279	2.62	1.580	-	278.25	0.390	2.48	0.765	1.359

Table 1 showed that with few exceptions, the maximum lengths found in the present study were slightly smaller than those from earlier studies. The sole exception was *M. martinicus*, yellow goatfish, where the maximum size found was 362 mm FL, which was 61 mm greater than the earlier maximum size found. A comparison of annual growth rates (K) most were the same or slightly less than previous estimates. Stoplight parrot fish showed a much slower growth rate (K = 0.275) compared with earlier studies (0.963), while in contrast, redband parrot fish showed a much greater growth rate (0.730) than earlier studies (0.200). Most of the species in this study showed low natural mortality rates relative to earlier work.

An important part of the present study was an investigation of the attitudes of fishers to potential fishery management measures. The interviews conducted represented approximately 10% of all known fishers. Most (87%) of all fishers had no other occupation, while 12% were part-time. The greatest proportion of fishers were between 40 – 50 years old and 11-20 years fishing experience was the most common group (see Figure 6).

With regard to gear use, the majority of all fishers used fish traps (55% of those using Pedro Bank and 44% of south shelf fishers). The other ranked gear types, were hook-and-line, nets and spears (Figure 7).

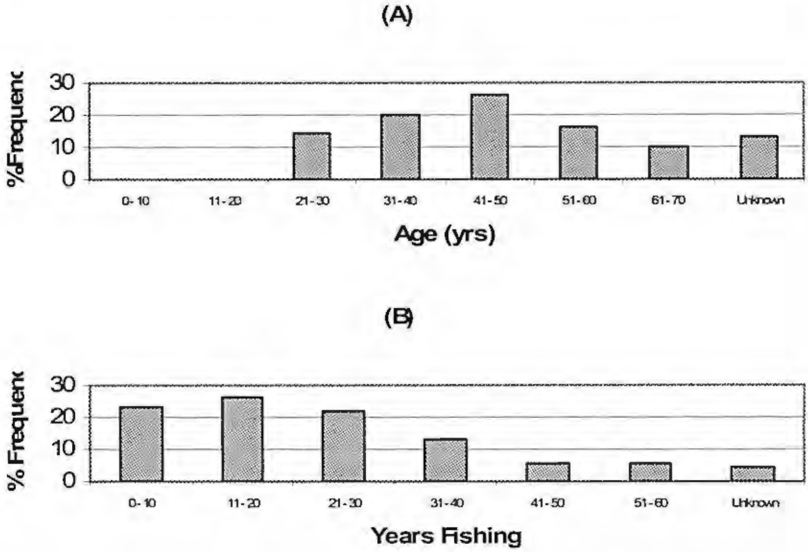


Figure 6. Age structure of Whitehouse fishers (A) and number of years spent fishing (B).

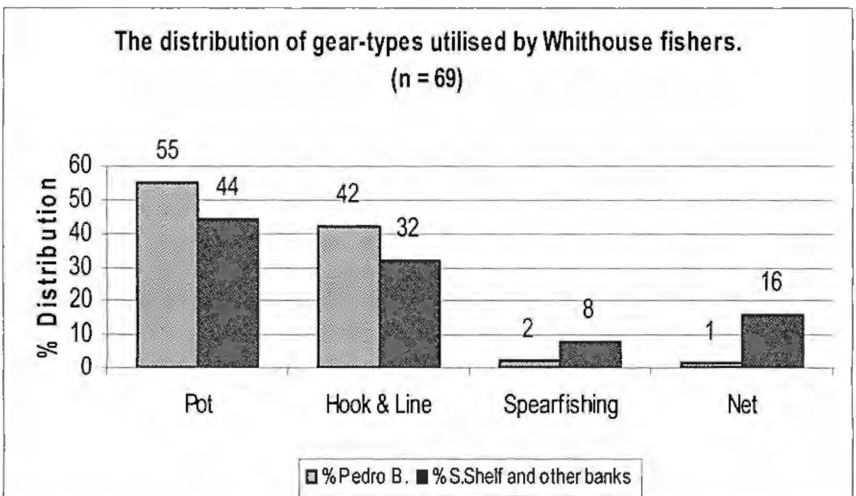


Figure 7. Gear types used on Pedro Bank and the south shelf by Whitehouse fishers.

A number of questions were asked regarding opinions on possible future management measures such as increases in trap meshes, fishing seasons, quotas, introduction of fishery reserves, co-management, increased lobster minimum size, and the use of dynamite. Most fishers disagreed with larger mesh introduction claiming it would result in serious losses of the Mullidae or goatfishes which have a cylindrical body cross section. They also disagreed with a reduced fishing season, quotas for fish, but agreed with introduction of fishery reserves (Figure 8).

Most fishers agreed with an increase in lobster minimum size and with the introduction of co-management, but disagreed with dynamite use and suggested sometimes drastic punishment for fishers using dynamite (Figure 9).

Whitehouse beach has the largest canoes in the entire island with a average length of 15m compared to 10m on most other beaches. Also, nearly all these large boats are constructed by hand on the beach by highly skilled artisans. The number of fishing vessels (open canoes) counted and examined totaled 120. This number is 30 less than that recorded in 1998 (Halcrow 1998). The size range was from 4 m to 16 m and this indicates this beach had the largest canoes in the island (Figure 10).

DISCUSSION

The main fisheries resources are coral reef fishes, spiny lobsters, conch, small coastal pelagic finfish and large offshore pelagic finfish. The reef fish species of major importance come from many families, which include Lutjanidae (snappers), Serranidae (groupers), Carangidae (jacks), Mullidae (goatfishes), Scaridae (parrotfishes), Haemulidae (grunts), Balistidae (triggerfishes), Acanthuridae (doctor fishes), Holocentridae (squirrelfishes), and Holacanthidae (angelfishes). Species composition of landings at Whitehouse was investigated and we found that the dominant reef fish families comprising the fish landings during this study was the Scaridae (parrotfishes) making up 41%, the Mullidae or goatfishes 18% and the squirrelfishes or wenchman family 9%. Thus, two lower–priced fish families, the parrot fishes and the squirrel fishes, together comprised 50% of all fish landings. This is higher than expected and is further confirmation of the relatively high levels of overfishing at the fishing grounds exploited by western Jamaican fishers.

In the 1970s it was reported that there were only 10 species on the south shelf that individually contributed more than 4% by weight to the catch and together these species comprised approximately 42% of the total catch. Spiny lobsters comprised 8% by weight (Munro 1983). In 1996, reef fishes constituted 80% of all landings (Fisheries Division 1997). Recent information on species diversity in reef fish catches (Koslow, et al. 1988, Koslow et al. 1994, Clemetson 1994) can be compared with earlier findings from roughly similar areas made by Munro (1983), Hartsuijker (1982), and Nicholson and Hartsuijker (1983). The Fisheries Division has more data gathered between 1995 and 1998 for various landing sites around the island. Comparisons suggest that since the late 1970s there have been changes in species diversity with loss of the predatory species and replacement by less valuable ones. This is clearly the case in western Jamaican waters.

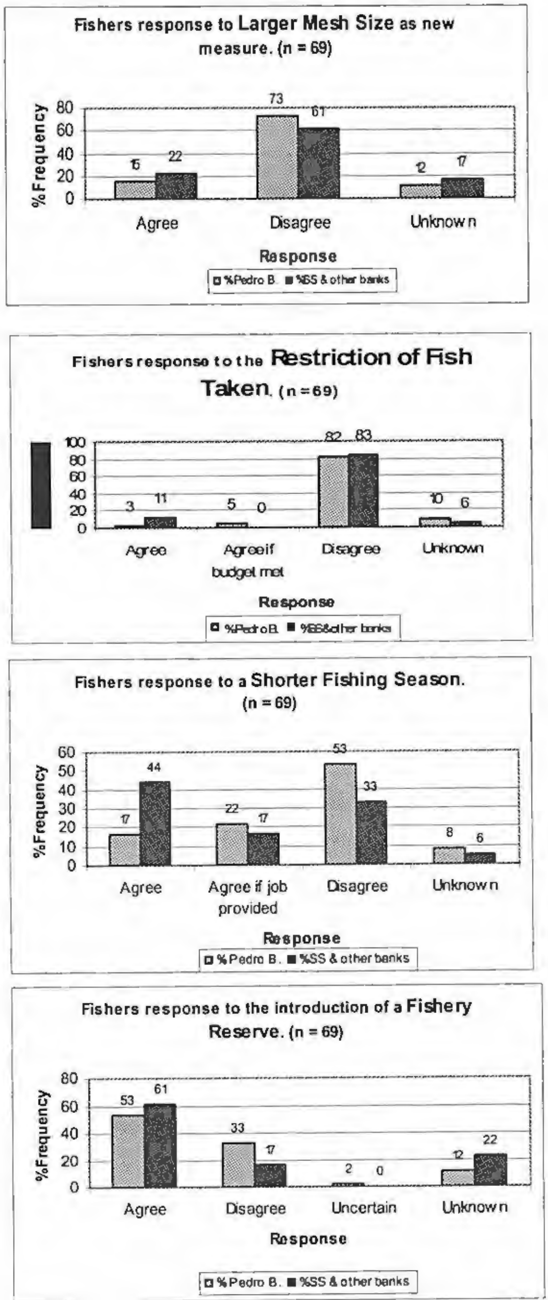


Figure 8. Fishers responses to potential management measures.

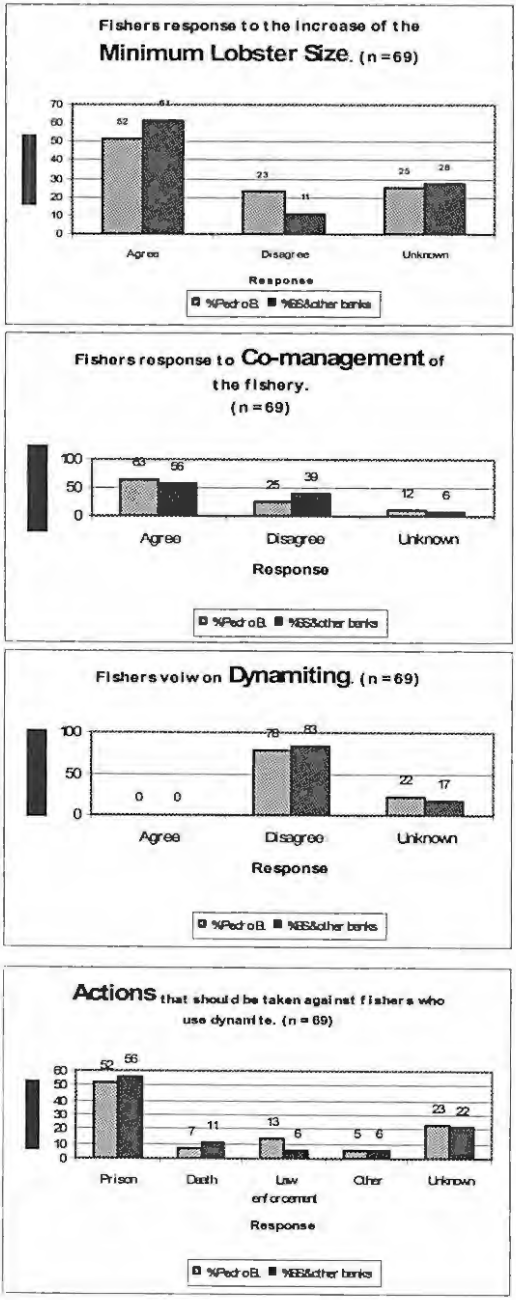


Figure 9. Fishers opinions on minimum lobster size increase, co-management, dynamite use and actions to be taken on dynamiters.

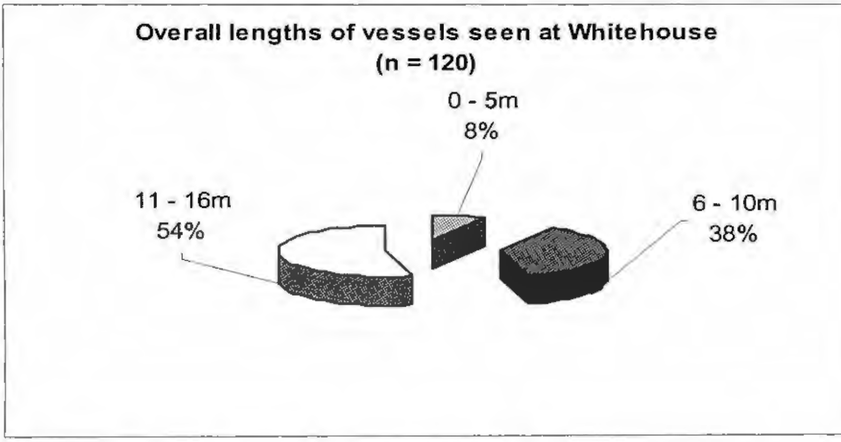


Figure 10. Length (m) overall of canoes at Whitehouse

That the length-weight relationships of males and females of the stoplight parrotfish, *Sparisoma viride* showed that the former were heavier and achieved larger sizes (Figures 3 and 4) was not unexpected. This is because this species (and others in the family Scaridae) show protogynous hermaphroditism where all fish begin as females, and as dominant males are removed by fishing or natural mortality, some of the larger females change sex and become functional males to replace them. Females and to some extent, males, display two modes in their length-frequency distributions (see Figure 4). These two modes probably represent year-classes. The two modes at 190 and 270 mm TL, in the length-frequency distribution of spear-caught *S. viride* females were clearer suggestions of two year-classes. Further, as this species spawns once annually (Munro 1983), then we can derive an annual growth rate of approximately 80 mm TL per year for females. Though these were caught by spears, we assume that the conclusions apply generally to this species both on the island shelf and offshore.

The mainly smaller asymptotic sizes found (Table 1) in the present study may be due to the heavily overfished status of the reef fish resources. In fact, combined with other characteristics such as lower than expected predatory (higher tropic level) fish families which have a higher commercial value, and the higher proportion of lower trophic level families (e.g. parrot fishes and squirrel fishes), we suggest these are the very indicators of the overfished status of the reef fish trap fishery mentioned by other workers (Munro 1983, Nicholson and Hartsuijker 1983, Aiken and Haughton 1987, Koslow et al. 1988). Growth rates (K) values were generally lower than in previous studies as were the natural mortality rates (M). These differences could be due to the relatively short (24 months) duration of the present study relative to the earlier studies.

Generally, fishers' interviews showed that the major fishing ground was Pedro Bank and other much smaller adjacent oceanic banks with a minority of fishers exploiting the south shelf. This was not entirely unexpected, as the shelf resources are known to be more overexploited than offshore banks. Fishers did not support larger meshes, reduced fishing seasons, quotas for fish catches, or use of dynamite, but agreed with fishery reserves, increase of minimum lobster size, co-management, and with severe punishment for dynamiters. The wooden canoes at Whitehouse were remarkable for their large sizes and were at least 3 m larger than the average elsewhere. Also noteworthy was the fact that these large wooden boats were all constructed on the beach by highly skilled artisans. We must note that in contrast to other fishing communities only a minority of the canoes were made of fiberglass. Two to three day (48 - 72 hours) long trips to Pedro Bank were common, and this feature is another one unique to this site, as most other trap canoes operating from the south coast mainland executed round trips of only approximately 8 - 12 hours. Fishers were in middle age (40 – 50 years old) on average with around 10 years of experience. This is in keeping with the findings of the few similar studies done (e.g. Espeut and Grant 1990).

We cannot definitively account for the reduction by 30 of the number of canoes operating from this beach since an estimate was done in 1998 (Halcrow 1998). Perhaps it was due to natural attrition, but this rate would be unusually high. We suggest that it could be a combination of that factor and fishers electing to drop out of the trap fishery since 1998 due to reduced earnings due to overfishing, as most fishers said their incomes had fallen over that period. Another possible factor is the gradual loss of boat-building artisans over time.

Finally, we recorded many reported instances of physical interference with fish traps owned by Whitehouse fishers by dolphins (mammals) both on the south shelf and on Pedro Bank. Traps are apparently overturned, stood on end or toppled into deeper waters, or in some cases had their mesh damaged in apparent efforts to remove the catch trapped inside. This is previously unreported in Jamaica. This unusual phenomenon will be the focus of a subsequent study by the University of the West Indies, Mona campus.

ACKNOWLEDGEMENTS

The authors thank the Research & Publications Committee of the University of the West Indies, Mona campus for small grants received in 2000 and 2001 for this project. We also thank Mr. Havelan Honeghan, chairman of the Gillings Gully Fishers Cooperative Society for allowing us to interview the many fishers, without whose cooperation this work would have been impossible. Finally, we are grateful to the Life Sciences Department of the University of the West Indies, Mona campus, which assisted us with transportation.

LITERATURE CITED

Aiken, K.A. 1993. Jamaica: Marine fishery resources of the Antilles: Lesser Antilles, Puerto Rico and Hispaniola. *FAO Fisheries Technical Papers* 326:1160-1180.

Aiken, K.A. and M.O. Haughton. 1987. Status of the Jamaica reef fishery and suggestions for its management. *Proceedings of the Gulf and Caribbean Fisheries Institute* **38**:469-484.

Aiken, K.A. and G.A. Kong. 2000. The marine fisheries of Jamaica. *Naga ICLARM Quarterly* 23(1):29-35.

Clemetson, A.O. [1994]. An investigation of the Jamaican south shelf coral reef fisheries using catch and effort data. University of the West Indies, Mona, Jamaica. MS Thesis, Unpubl. 136pp.

Espeut, P. and S. Grant. 1990. An economic and social analysis of small-scale fisheries in Jamaica. Institute of Social and Economic Research. University of the West Indies, Mona, Jamaica. 80 pp.

Fisheries Division. [1997]. Fish production survey for 1996. Ministry of Agriculture, Kingston, Jamaica. Unpubl. MS. 35 pp.

Halcrow, W. 1998. Sir William Halcrow & Partners. South coast sustainable development study: Phase 1, Government of Jamaica. Tech. Rep. 2. Marine Resources, Kingston, Jamaica.

Hartsuijker, L. 1982. Report: summary of findings (restricted). FAO/TCP/ Jamaica 8902. 56 pp.

Koslow, J. A., F. Hanley, and R. Wicklund. 1988. Effects of fishing on reef fish communities at Pedro Bank and Port Royal cays, Jamaica. *Marine Ecology Progress Series* **43**:201-212.

Koslow, J.A., K.A. Aiken, S.A. Auil, and A.O. Clemetson. 1994. Catch and effort analysis for the reef fisheries of Jamaica and Belize. *Fisheries Bulletin (US)* **92**:737-747.

Munro, J.L. 1983. *Caribbean Coral Reef Fishery Resources.* ICLARM Studies Review No. 7. 276 pp.

Natural Resources Conservation Department. 1987. Jamaica: country environmental profile, with R.M. Field Associates. Kingston, Jamaica. 362 pp.

Nicholson, W. and L. Hartsuijker. 1983. The state of the fisheries resources of Pedro Bank and the south Jamaica shelf. *FAO Fisheries Reports* **278** (Suppl.):215-254

USSR Ministry of Fisheries/Government of Jamaica. 1980. Report on the main results of the USSR/Jamaica Fishery Research Programme in 1979-1980, AtlantNiro, Kaliningrad, Soviet Union. 80 pp.

BLANK PAGE

Preliminary Observations of Abundance and Distribution of Settlement-Stage Snappers in Shallow, Nearshore Seagrass Beds in the Middle Florida Keys

CLAUDINE T. BARTELS and KAROLE L. FERGUSON
Fish and Wildlife Research Institute
Florida Fish & Wildlife Conservation Commission
2796 Overseas Highway, Suite 119
Marathon, Florida 33050 USA

ABSTRACT

Reef-dwelling snappers support valuable commercial and recreational fisheries. Snappers have been reported to use seagrass habitat as a primary nursery area in south Florida waters, although it is still largely unknown where newly recruited and early-juvenile stages of snappers are settling in the waters of the Florida Keys. Previous studies largely have been unsuccessful in locating and collecting these young-of-the-year fishes in seagrass beds. In order to determine the feasibility of collecting early-life stages of snappers in shallow (< 1.3m depth), nearshore seagrass beds and to describe snapper abundance and distribution, we conducted a six-month (June through November 2003), stratified-random-design pilot study using 21 m seines on the Atlantic side of the Middle Keys. We collected relatively high numbers of snappers (n = 363), of which more than half were settlement-stage individuals, including 69 new recruits ($\leq$ 20 mm SL) and 131 early-stage juveniles (> 20 and $\leq$ 40 mm SL). Mean standard length overall was 36 mm. The most abundant snapper collected was *Lutjanus griseus*. Snappers recruited consistently during the sampling period, and abundance did not significantly differ between months. Recruitment peaked during September, October, and November, suggesting that higher numbers of adult snappers were spawning in late summer and early fall. Snapper abundance differed significantly between sampling sites, most likely due to habitat differences. Abundance was positively and significantly correlated with *Halodule wrightii* cover and negatively correlated with *Thalassia testudinum* cover. Preliminary results indicate that shallow, mixed-species seagrass beds along Atlantic beachfronts in the Middle Keys may constitute an especially important settlement habitat for snappers, particularly *L. griseus*.

KEY WORDS: Seagrass, settlement, snapper

Observaciones Preliminares de la Abundancia y Distribución de Pargos Reclutas y Juveniles en Pastos de Hierbas Marinas Poco Profundo en los Cayos Centros de la Florida

Las especies de pargos arrecifales son muy abundantes y muy valiosos para las pesquerías recreativas y comerciales de los Cayos de la Florida. Se ha reportado que estas especies utilizan los pastos de hierbas marinas como un área primaria de criadero en las aguas del sur de la Florida. Sin embargo, todavía no se conoce donde reclutas nuevos y las etapas tempranas de los juveniles se establecen en las aguas de los Cayos. En estudios anteriores no pudimos localizar pargos juveniles en las praderas de hierbas marinas de poca profundidad (>1.3m) a lo largo de los Cayos. Un estudio piloto se realizo durante seis meses (junio 2003 hasta noviembre 2003) usando redes de cerco con una dimensión de 21metros de cobertura en el lado atlántico de los Cayos. Las áreas de muestreo se seleccionaron utilizando un sistema de estratificación al asar, con el propósito de determinar la viabilidad de recolectar pargos de edades tempranas en pastos de hierbas marinas con profundidades de <1.3 m y para describir su abundancia y distribución. Tuvimos éxito en capturar números relativamente altos de pargos [n = 363; n = 69 reclutas nuevos, $\leq$20 mm SL; n = 200 juveniles, $\leq$ 40 mm SL] en un corto período de tiempo y con solamente 72 caladas. Los tamaños de los individuos capturados fueron entre 10 mm y 190 mm con un promedio de 38 mm. El pargo más abundante fue *Lutjanus griseus*. Pargos se capturan con regularidad durante el verano y otoño; *L. griseus, L. apodus, L. analis, L. synagris,* y *Ocyurus chrysurus* estuvieron presente en los meses de septiembre, octubre, y noviembre. Reclutamiento para *L. griseus* alcanzó a su máximo durante los meses de septiembre a noviembre. Las densidades de pargos fueron estadísticamente diferentes entre los sitios de muestreo, esto es probablemente es debido a diferencias en el hábitat. Las densidades de pargos estuvieron una correlación positiva con la cobertura de *Halodule wrightii* y una correlación negativa con la cobertura de *Thalassia testudinum*. Estos resultados preliminares indican que pastos de hierbas marinas formado por varias especies en aguas poco profundas que se encuentran cerca de la costa en el lado atlántico de los Cayos de la Florida pueden constituir un importante, aunque limitado, hábitat para el reclutamiento de etapas tempranas de las especies de pargo.

PALABRAS CLAVES: Pargos, reclutamiento, asentamiento, hierbas marinas, hábitat

INTRODUCTION

Reef-dwelling snappers (Lutjanidae) are abundant and support large commercial and recreational fisheries in south Florida and the Florida Keys. Snappers occupy a variety of habitats throughout their life cycle. New recruits, juveniles, and young adult snappers have been reported to use inshore seagrass habitats as nursery areas before undergoing ontogenetic migrations to reefs, offshore habitats, and other areas as they approach maturity (Tabb and Manning 1961, Springer and McErlean 1962, Starck 1970, Bortone and Williams 1986, Rutherford et al. 1989, Lindeman et al. 1998, Burton 2001, Mateo and Tobias 2001, Allman and Grimes 2002, Watson et al. 2002). Many studies have examined the abundance and distribution of juvenile snappers, either directly or indirectly, in Florida Bay and the Gulf of Mexico (Odum and Heald 1972, Sogard et al. 1987, Thayer et al. 1987, Hettler 1989, Rutherford et al. 1989, Thayer and Chester 1989, Chester and Thayer 1990, Matheson et al.

1999, Thayer et al. 1999). We have also specifically targeted early-juvenile stages of snapper by conducting extensive sampling with otter trawls, offshore seines, visual censuses, and exploratory surveys throughout various habitats in the Keys and Florida Bay. These studies have collected relatively low numbers of newly settled snappers, despite scientists having used a wide variety of gear and methods. To date, researchers have been unable to determine the settlement locations of snappers in the Florida Keys because they collected insufficient numbers for useful analyses, either because of low abundance of snapper recruits in the areas studied or ineffective sampling gears.

Some studies have suggested that juvenile snappers may preferentially inhabit seagrass beds in shallow waters close to the beachfront shorelines of the Keys. A three-year seine study designed to collect bonefish in such habitats collected relatively high numbers of settlement-stage snappers (n = 222) (Harnden and Snodgrass In review). In addition, a single seining study conducted along a grassy shoreline in the Middle Keys from 1960 to 1961 was particularly successful in collecting even higher numbers of young juvenile snappers (n = 650) (Springer and McErlean 1962). Because of the comparative success of these studies, we established a six-month pilot study using 21.3 m seines in shallow, shorefront seagrass beds on the Atlantic Ocean side of the Middle Florida Keys. The objective of this study was to establish the feasibility of collecting newly settled snappers in numbers sufficient to provide preliminary information on species composition, abundance, size-structure, spatial and temporal distribution patterns, and habitat use.

METHODS

Sampling was conducted for six months from June through November 2003 in nearshore seagrass beds on the Atlantic side of the Middle Florida Keys from Long Key to Bahia Honda Key (Figure 1). A habitat-based, stratified-random-sampling procedure based upon the "Benthic Habitats of the Florida Keys" Geographical Information System (GIS) (FDEP and NOAA, 1998) was used to select sampling sites. In this system, the Keys were divided into one-longitudinal- by one-latitudinal-minute [~1 nautical mile $(nm)^2$] sampling "grids" (Figure 1). All grids touching land containing bottom habitat mapped as "Continuous Seagrass" or "Patchy Seagrass" were included in the sampling universe. Each of these resultant eleven grids (sites) was subdivided into 100 "microgrids" (~0.01 nm^2) (Figure 1). A total of twelve of these microgrids were randomly selected and sampled each month.

Fish collections at each site were made using a 21.3 m center-bag drag offshore seine, constructed of knotless 3.2 mm #35 Delta nylon-mesh and a 183 cm x 183 cm x 183 cm bag. Each seine was hauled in open-water away from the shoreline (> 5 m). The net coverage area was approximately 140 m^2/ haul.

One seine haul was conducted during daylight hours at each site. Hauls were made during high to mid-high tide whenever possible. All snappers were processed in the field, identified to the lowest possible taxon, and enumerated. Any snappers that were $\leq$ 100 mm SL were measured to the nearest mm. As needed, small subsamples of snappers were collected and brought back to the laboratory for identification purposes; all remaining fish were released.

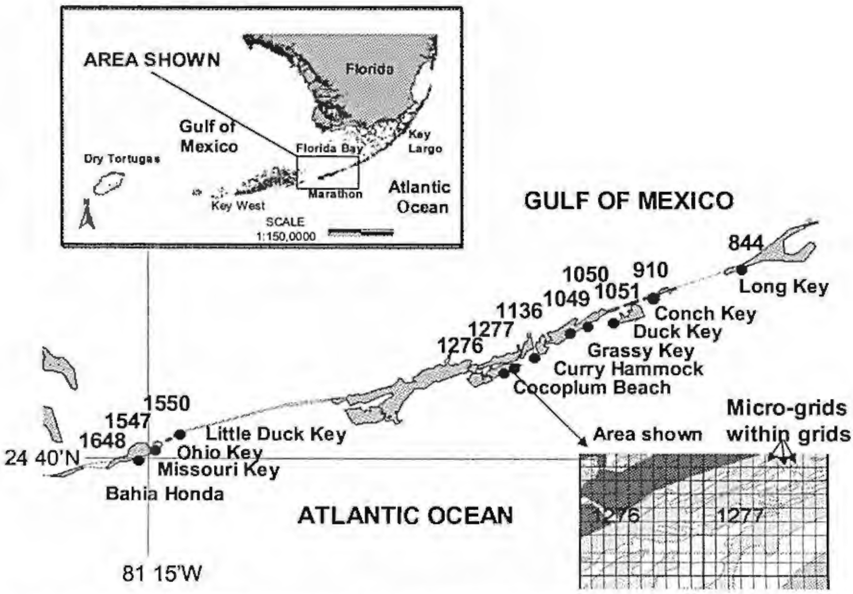


Figure 1. Map of sampling area in the middle Florida Keys showing location of eleven grids and inset of microgrid system.

Hydrographic data, atmospheric and sea conditions, and observations relative to bottom type including water depth, substrate type, submerged aquatic vegetation (SAV) types, and percent bottom cover of SAV were recorded at each site. Water temperature (°C), salinity (‰), dissolved oxygen (mg/L), and pH were measured using YSI water-quality instruments. Turbidity was measured using a secchi disk.

Data were analyzed to describe spatial and temporal patterns of relative snapper abundance, species composition, and size-structure. Data from microgrids were pooled into their respective larger grids for analyses. Variation in snapper abundance between months and sites for all species combined, for abundant snapper species ($n > 50$), and for settlement-stage snappers was analyzed for temporal and spatial differences using the nonparametric Kruskal-Wallis test. The Kruskal-Wallis test was also used to determine if physical parameters and habitat characteristics differed between months and sites. Spearman's rho was used to determine significant relationships between snapper abundance and physical variables or habitat characteristics. All statistical tests were run using SPSS 11.0 for Windows. Results were considered significant at $p < 0.05$.

A total of 363 snappers representing five species (*Lutjanus griseus* [gray snapper], *L. apodus* [schoolmaster snapper], *L. analis* [mutton snapper], *L. synagris* [lane snapper], and *Ocyurus chrysurus* [yellowtail snapper]), were collected in 72 seines from June through November 2003 (Figure 2). The most abundant snappers collected were *L. griseus*, *L. apodus*, and *L. analis* (Figure 2). Additionally, eleven small (10 - 15 mm) snapper recruits could be identified only as *Lutjanus* spp. because meristics overlapped, and their coloration was not yet distinct; however, they were either *L. griseus* or *L. apodus*.

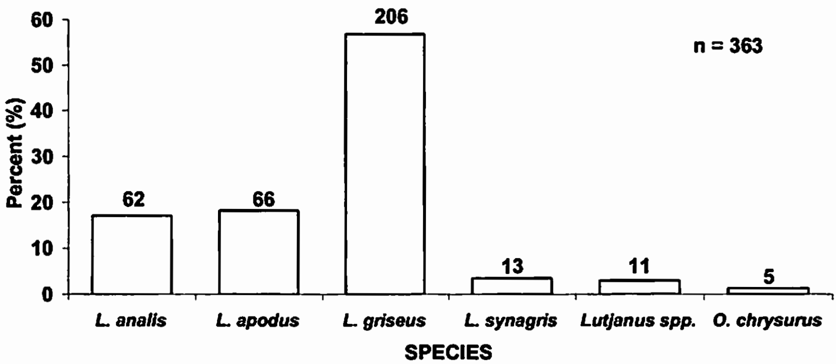


Figure 2. Percentage of the total snapper catch represented by each species. Numbers above bars indicate total number of each species collected.

Approximately 85% (n = 307) of the snappers collected were young juveniles ($\leq$ 100 mm SL) with a mean size of 36mm SL ($\pm$ 1.0 mm SE). More than half of the snappers (n = 200) were settlement-stage individuals ($\leq$ 40 mm SL), including 69 new recruits ($\leq$ 20mm SL) and 131 early-stage juveniles (> 20mm to $\leq$ 40mm SL) (Figure 3a). *Lutjanus griseus* was the only snapper species collected in sizes greater than 100 mm SL (n = 56) during the study. Of the 150 *L. griseus* measured, 68% were settlement-stage individuals with a mean size of 35 mm SL ($\pm$ 1.3 mm SE) (Figure 3b). *Lutjanus apodus* had the greatest mean size of all the snappers (45 mm SL [$\pm$ 2.1mm SE]); 45% were settlement-stage individuals (Figure 3c). The majority (68%) of *L. analis* collected were settlement-stage individuals with a mean size of 36 mm SL ($\pm$ 2.7 mm SE) (Figure 3d). *Lutjanus synagris* averaged 25 mm SL ($\pm$ 2.9 mm SE) in size; 85% of individuals were settlement-stage individuals (Figure 3e). Finally, of the few *O. chrysurus* collected, mean size was 27 mm SL ($\pm$ 4.6 mm SE), and 80% of the individuals were settlement-stage individuals (Figure 3f).

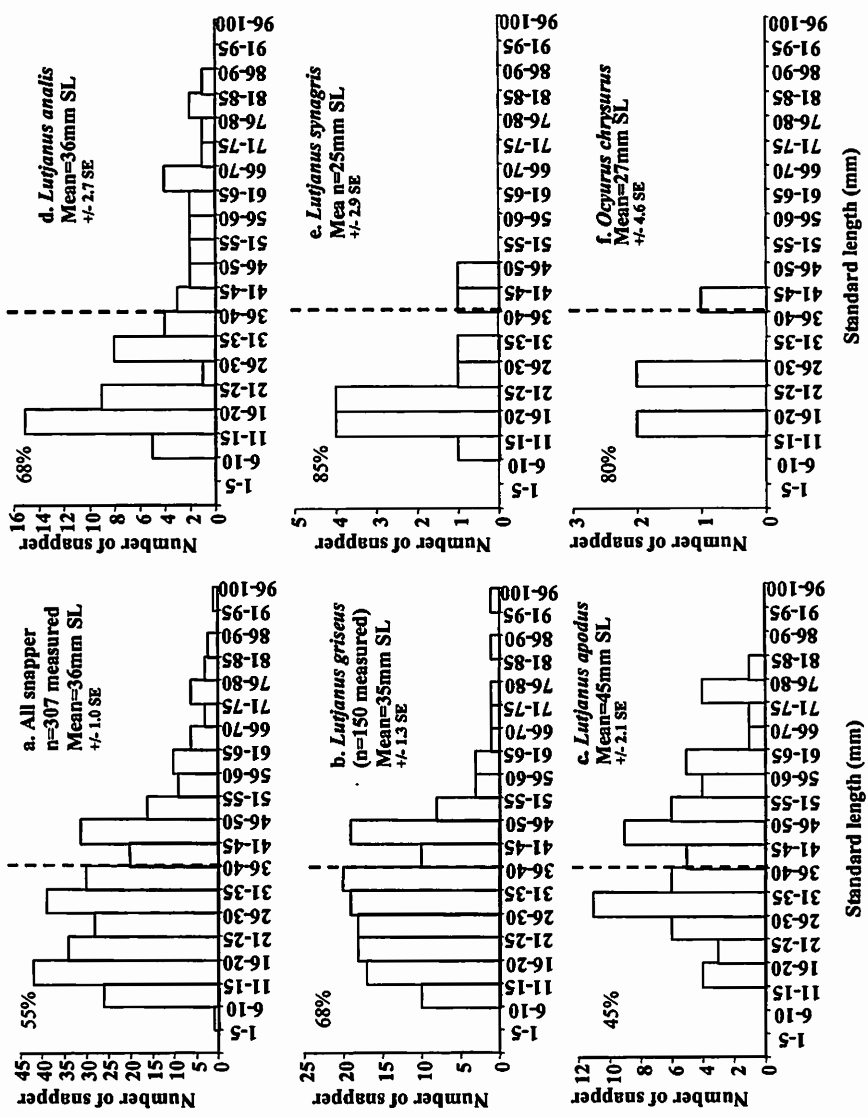


Figure 3. Length-frequency distributions of all snapper species that were measured (≤ 100 mm SL) during the study period. Total percentages of each species that were settlement-stage (≤ 40 mm SL) are indicated to the left side of the black dotted lines.

Abundance of all snappers combined and of *L. griseus*, *L. apodus*, and *L. analis* was not significantly different by month ($p > 0.05$). Statistical tests were not run on *L. synagris* or *O. chrysurus* because the total number collected of each was too low. Snappers were consistently caught throughout the summer-fall sampling period. The lowest mean numbers of snappers were collected in July (1.3 ± 0.8 SE) and the highest in October (10.8 ± 6.5 SE).

Lutjanus griseus, L. apodus, and *L. analis* were caught every month; all five snapper species were collected during September and October (Figure 4). Mean numbers of *L. griseus* were highest during September, October, and November, with a peak in October (7.8 ± 5.5 SE), whereas mean numbers of *L. analis* peaked in August (2.2 ± 1.1 SE; Figure 4). *Lutjanus apodus* were consistently caught throughout the sampling period, averaging 0.9 snappers (± 0.2 SE) per seine (Figure 4). *Lutjanus synagris* and *O. chrysurus* were most abundant in November (Figure 4).

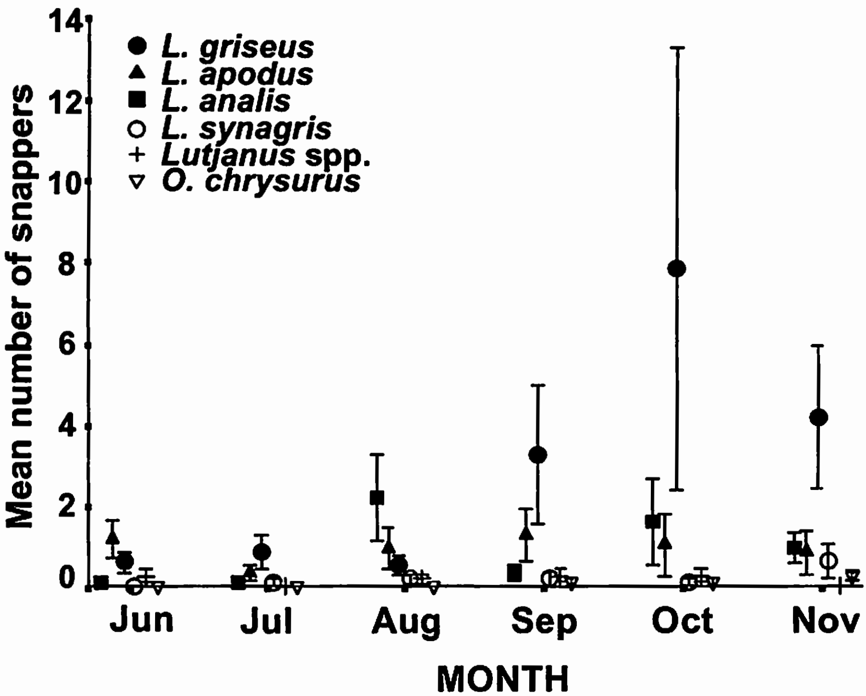


Figure 4. Monthly mean number of each snapper species collected during the study period. Error bars indicate mean standard error.

Abundance of all snappers combined (p = 0.006) and of settlement-stage snappers (p = 0.007) were significantly different between sites (Figure 5a). The majority of snappers (89%) were caught at four sites: 1049, 1050, 1276, and 1136 (Figure 5a). Almost 26 times as many snappers were captured at site 1049 than at sites 1051 or 1547. The lowest mean numbers of all snappers were captured at sites 1051 (0.5 ± 0.3 SE) and 1547 (0.5 ± 0.5 SE) (Figure 5a). A similar trend was observed for settlement-stage snappers, which were most abundant at the same four sites: 1050 (6.2 ± 3.1 SE), 1049 (5.8 ± 1.7 SE), 1276 (5.0 ± 1.7 SE), and 1136 (3.8 ± 1.3 SE) (Figure 5a).

Differences in spatial distribution also appeared to be species-specific. Mean numbers of *L. griseus* were significantly different between sites (p = 0.007); they were highest at sites 1049, 1050, 1276, and 1136 (Figure 5b). *Lutjanus analis* was most abundant at site 1276, whereas catches of *L. apodus* were highest at sites 1049, 1276, and 1050, but these differences in abundance were not statistically significant (p > 0.05; Figure 5b). Finally, mean numbers of *L. synagris* were highest at sites 1136 and 1277, whereas mean numbers of *O. chrysurus* were highest at site 1550 (Figure 5b). Statistical tests were not run on these two species because of low total numbers. The above trends were identical for settlement-stage snappers.

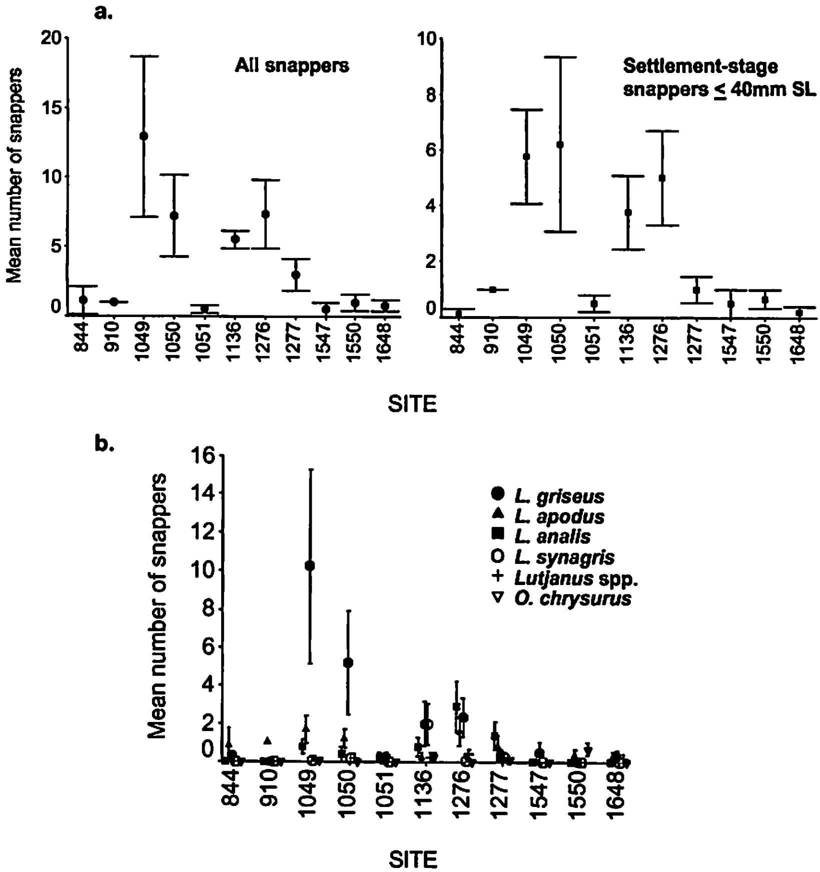


Figure 5. Mean number of all snappers and settlement-stage snappers (a.) and of individual species (b.) at each site during the study period. Error bars indicate mean standard error.

Water depths ranged from 0.3 m to 1.2 m, with a mean depth of 0.65 m (± 0.03 m SE). Physical conditions did not vary temporally or spatially. There were no significant differences in water temperature (°C), salinity (‰), dissolved oxygen (mg/L), and pH among sites (p > 0.05). The abundance of all snappers combined and of individual snapper species was not significantly correlated with water depth or any physical parameters (p > 0.05).

Sampling sites were typically characterized by mixed-species seagrass beds consisting of *Halodule wrightii, Thalassia testudinum, Syringodium filiforme*, or mixed algae (Figure 6). All sites had a high percentage of seagrass cover (mean = 94.1% ± 11.8). There was a significant difference in mean percent cover of *Thalassia* and *Halodule* between sites ($p < 0.001$; Figure 6).

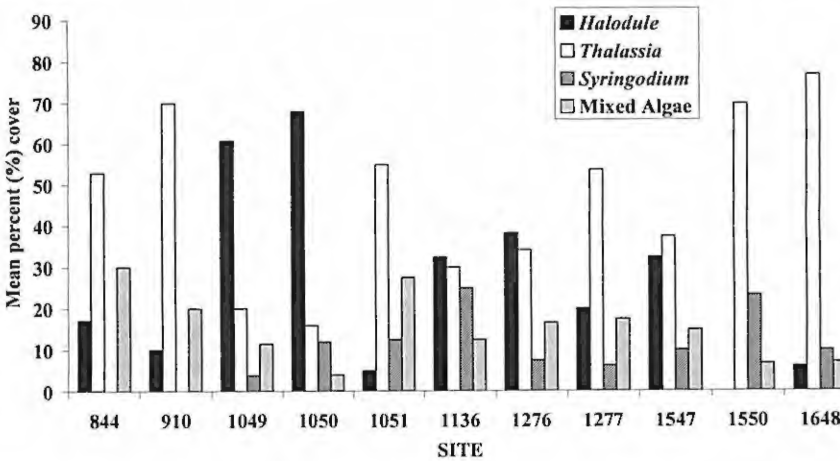


Figure 6. Mean percent bottom cover of submerged aquatic vegetation at each site. Error bars were removed for figure clarity.

Abundance of all snappers combined and of the most abundant snapper species (*L. griseus)* was positively correlated with *Halodule* cover ($p < 0.01$) and negatively correlated with *Thalassia* cover ($p < 0.01$). Mean percent *Halodule* cover was the highest at sites 1050 (68% " 5.7 SE) and 1049 (61% ± 2.6 SE), where mean numbers of snappers were also high (Figures 5a, b), whereas mean percent *Thalassia* cover was the lowest (< 20%) at these sites (Figure 6).

Likewise, mean percent *Thalassia* cover was relatively high at sites 1648 (77% ± 3.2 SE), 1550 (70% ± 3.4 SE), 910 (70% ± 3.0 SE), 1051 (55% ± 1.0 SE), and 844 (53% ± 2.5 SE), where lower mean numbers of snappers were collected (Figures 5a, b; Figure 6). No differences were detected in total percent bottom cover, percent mixed algal cover, or percent *Syringodium* cover between sites ($p > 0.05$; Figure 6).

DISCUSSION

Snappers are extremely valuable to the economy of South Florida. Identifying nursery habitats of settlement-stage snappers and examining recruitment dynamics and the causes of annual variability in fish stocks are crucial for conservation and sound fishery management (Rutherford et al. 1989, Lindeman et al. 1998, Allman and Grimes 2002). Consequently, over the years, FWC and other researchers have conducted extensive surveys throughout the Keys and Florida Bay targeting early-juvenile-stage snappers. During this pilot study, we collected many snappers from shallow, shorefront seagrass beds on the Atlantic side of the Middle Keys. More than half of the snappers caught were young, settlement-stage juveniles, and nearly 25% were newly settled recruits. The high percentage of young snappers collected and small average size confirm that these nearshore seagrass areas serve as important snapper settlement and nursery grounds, particularly for *L. griseus*.

Snappers recruited to our sites throughout the summer-fall sampling period. Abundance of all snappers combined and of individual snapper species did not differ by month. Nevertheless, highest recruitment occurred during September, October, and November, suggesting that higher numbers of adult snappers were spawning during late summer and early fall because larval duration is relatively short (25 - 40 days) in snappers (Rutherford et al. 1989). In other studies, snappers have been similarly observed recruiting to seagrass beds from May through February in Florida (Reid 1954, Tabb and Manning 1961, Springer and McErlean 1962, Rutherford et al. 1989, Allman and Grimes 2002, Watson et al. 2002, Barbieri and Colvocoresses 2003, Harnden and Snodgrass In review). Snapper spawning periods are not necessarily concurrent throughout Florida, and the exact timing of spawning, especially in the Keys, is not well established.

Snapper abundance differed significantly between sites, and differences appeared to be species-specific. A high percentage of the snappers were collected at four sites located in the center of the sampling area. Because seasonal or physical factors were not strongly correlated with snapper abundance, other factors, such as seagrass characteristics (e.g., quality, density, diversity, and species composition) or the proximity of alternative habitats, such as mangroves, hardbottom areas, or coral reefs, may have contributed to the observed patterns of species composition and abundance of settlement-stage snappers. These four sites are all situated along stretches of beachfront in areas far removed from any major channels; additionally, these sites have the largest area of continuous nearshore seagrass in the Middle Keys and are in closest proximity to nearshore coral reefs. Results indicate that the abundance of snappers was positively correlated with *Halodule wrightii* cover, which was most abundant at these four sites. It may be that the complexity and composition of bottom cover in seagrass habitats are the most influential factors determining the diversity and abundance of snappers. A prior study in Florida Bay found similar results in which juvenile *L. griseus* were most abundant in mixed-species seagrass beds with higher densities of *Halodule* and *Syringodium* (Rutherford et al. 1989). In addition, Thayer and Chester (1989) determined that fish species were found in highest abundances and with greatest frequencies in areas of western Florida Bay that have mixed-species seagrass beds containing abundant *Halodule* and *Syringodium*, high sediment organic content, and shallow water. Although we found no significant correlation between fish abundance and water depth or sediment type in our study, the homogeneity of environmental conditions within our study area may have precluded the examination of such effects.

Much debate exists over whether the sizes of adult fish populations are defined by events occurring before, during, or after settlement (Doherty 1991).

Abundance and survival of recruiting fish are most likely influenced by small-scale reef processes, such as predation, competition, presence or absence of conspecifics, density-dependent factors, or habitat preference, and by large-scale stochastic processes of larval supply before settlement (Milicich et al. 1992, Milicich and Doherty 1994, Tolimieri 1995, Danilowicz 1997). Kingsford and Choat (1989) found that distributions of recruiting larvae of some species were influenced by the proximity of reefs. Settling fish may have habitat preferences that direct them to recruit into different areas (Milicich et al. 1992, Lindeman et al. 1998). Research on early demersal habitat use in snapper species in Biscayne Bay found snappers to have species-specific habitat preferences (Lindeman et al. 1998). Newly settled *L. griseus*, as well as early stages of *L. analis*, *L. jocu* (dog snappers), and *L. cubera* (cubera snappers), were found principally in seagrass beds and were rarely recorded from hardbottom, whereas *L. synagris, O. chrysurus*, and *L. apodus* were more opportunistic in their habitat-use patterns, using either seagrass or hardbottom habitats.

Future research will involve larger-scale sampling of Atlantic-shorefront seagrass beds throughout the Keys to more fully determine spatial and temporal distribution patterns and recruitment dynamics of newly settled snappers. We also plan to better characterize the microscale habitat and environmental differences that may influence recruitment in these areas. In addition, we plan to collaborate with NOAA scientists by using microacoustic tags and otolith signatures to analyze early-life-history habitat requirements, site-fidelity, and home ranges of juvenile snappers and to establish the connectivity between nursery and adult habitats. Future research should provide sufficient data to establish recruitment signals that can be used as tuning indices for stock assessment and management of these economically important snappers in the Keys.

ACKNOWLEDGEMENTS

We thank John Hunt, Jim Colvocoresses, Alejandro Acosta, Paul Barbera, Matthew Hoxie, Jeff Simonds, Rich Netro, and Mark Fabyanic for their efforts in the field, laboratory, and office. Funding for this work was supported by State of Florida Saltwater Fishing License monies.

LITERATURE CITED

Allman, R.J. and C.B. Grimes. 2002. Temporal and spatial dynamics of spawning, settlement, and growth of gray snapper (*Lutjanus griseus*) from the West Florida shelf as determined from otolith microstructures. *Fisheries Bulletin* 100:391-403.

Barbieri, L.R. and J.A. Colvocoresses. 2003. Southeast Florida reef fish abundance and biology: Five-year performance report to the U.S. Department of Interior Fish and Wildlife Service F-73. 66 pp.

Bortone, S.A. and J.L. Williams. 1986. Species profiles: life history and environmental requirements of coastal fisheries and invertebrates (South Florida) - gray, lane, mutton, and yellowtail snappers. U.S. Fish and Wildlife Service Biological Reports 82(11.52). U.S. Army Corps of Engineers, TR EL-82-4. 18 pp.

Burton, M.L. 2001. Age, growth, and mortality of gray snapper, *Lutjanus griseus*, from the east coast of Florida. *Fisheries Bulletin* 99:254-265.

Chester, A.J. and G.W. Thayer. 1990. Distribution of spotted seatrout (*Cynoscion nebulosus*) and gray snapper (*Lutjanus griseus*) juveniles in seagrass habitats of western Florida Bay. *Bulletin of Marine Science* 46 (2):345-357.

Danilowicz, B.S. 1997. The effects of age and size on habitat selection during settlement of a damselfish. *Environmental Biology of Fish*es 50:257-265.

Doherty, P.J. 1991. Spatial and temporal patterns in recruitment. Pages 261-293 in P.F. Sale (ed.). *The Ecology of Fishes on Coral Reefs*. Academic Press, Inc., New York, New York USA.

FDEP and NOAA (Florida Department of Environmental Protection and National Oceanic and Atmospheric Administration). 1998. Benthic Habitats of the Florida Keys. Florida Marine Research Institute Technical Report TR-4.

Harnden, C.W. and D. Snodgrass. [In review]. Species composition and recruitment of selected fish species to ocean-side beaches in the Florida Keys. *Bulletin of Marine Science.*

Hettler, W.F., Jr. 1989. Food habits of juveniles of spotted seatrout and gray snapper in western Florida Bay. *Bulletin of Marine Science* 44(1):155-162.

Kingsford, M.J. and J.H. Choat. 1989. Horizontal distribution patterns of presettlement reef fish: are they influenced by the proximity of reefs? *Marine Biology* 101:285-297.

Lindeman, K.C., G.A. Diaz, J.E. Serafy, and J.S. Ault. 1998. A spatial framework for assessing cross-shelf habitat use among newly settled grunts and snappers. *Proceedings of the Gulf and Caribbean Fisheries Institute* 50:385-415.

Mateo, I. and W.J. Tobias. 2001. The role of nearshore habitats as nursery grounds for juvenile fishes on the northeast coast of St. Croix, USVI. *Proceedings of the Gulf and Caribbean Fisheries Institute* 52:512-530.

Matheson, R.E., Jr., D.K. Camp, S.M. Sogard, and K.A. Bjorgo.1999. Changes in seagrass-associated fish and crustacean communities on Florida Bay mudbanks: The effects of recent ecosystem changes? *Estuaries* 22:534-551.

Milicich, M.J., M.G. Meekan, and P.J. Doherty. 1992. Larval supply: a good predictor of recruitment of three species of reef fish (Pomacentridae). *Marine Ecology Progress Series* 86:153-166.

Milicich, M.J. and P.J. Doherty. 1994. Larval supply of coral reef fish populations: magnitude and synchrony of replenishment to Lizard Island, Great Barrier Reef. *Marine Ecology Progress Series* 110:121-134.

Odum, W.E. and E.J. Heald. 1972. Trophic analyses of an estuarine mangrove community. *Bulletin of Marine Science* 22(3):671-738.

Reid, G.K., Jr. 1954. An ecological study of the Gulf of Mexico fishes in the vicinity of Cedar Key, Florida. *Bulletin of Marine Science* **4**:1-94.

Rutherford, E.S., T.W. Schmidt, and J.T. Tilmant. 1989. Early life history of spotted seatrout (*Cynoscion nebulosus*) and gray snapper (*Lutjanus griseus*) in Florida Bay, Everglades National Park, Florida. *Bulletin of Marine Science* **44**:49-64.

Sogard, S.M., G.V.N. Powell, and J.G. Holmquist. 1987. Epibenthic fish communities on Florida Bay banks: relations with physical parameters and seagrass cover. *Marine Ecology Progress Series* **40**:25-39.

Springer, V.G. and A.J. McErlean. 1962. Seasonality of fishes on a south Florida shore. *Bulletin of Marine Science of the Gulf and Caribbean* **12**:39-60.

Starck, W.A. 1970. Biology of the gray snapper, *Lutjanus griseus* (Linnaeus), in the Florida Keys. *Studies in Tropical Oceanography* **10**:1-150.

Tabb, D.C. and R.B. Manning. 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July, 1957 through September, 1960. *Bulletin of Marine Science of the Gulf and Caribbean* **11**:552-649.

Thayer, G.W., D.R. Colby, and W.F. Hettler, Jr. 1987. Utilization of the red mangrove prop root habitat by fishes in south Florida. *Marine Ecology Progress Series* **35**:25-38.

Thayer, G.W., and A.J. Chester. 1989. Distribution and abundance of fishes among basin and channel habitats in Florida Bay. *Bulletin of Marine Science* **44**:200-219.

Thayer, G.W., A.B. Powell, and D.E. Hoss. 1999. Composition of larval, juvenile, and small adult fishes relative to changes in environmental conditions in Florida Bay. *Estuaries* **22**:518-533.

Tolimieri, N. 1995. Effects of microhabitat characteristics on the settlement and recruitment of a coral reef fish at two spatial scales. *Oecologia* **102**:52-63.

Watson, M., J.L. Monroe, and F.R. Gell. 2002. Settlement, movement and early-stage juvenile mortality of the yellowtail snapper *Ocyurus chrysurus*. *Marine Ecology Progress Series* **237**:247-256.

BLANK PAGE

Patterns and Processes of Larval Fish Supply to the Reefs of the Upper Florida Keys

EVAN K. D'ALESSANDRO and SU SPONAUGLE
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149 USA

ABSTRACT

To examine the role of cyclic environmental parameters and stochastic hydrodynamic events on the delivery of fish larvae to shallow coral reefs along a major western boundary current, a series of light traps was deployed over shallow coral reefs along the upper Florida Keys every other night for six months from May-October of 2002 and 2003. Wind speed, current velocity, and water temperature were measured concurrently. In total, 27,649 larval fishes from 55 families, encompassing pelagic, mesopelagic, seagrass and reef species, were collected during the two year time series. Besides small silvery fishes in the families *Clupeidae, Engraulidae,* and *Atherinidae*, the collections were dominated by the families *Pomacentridae, Chaenopsidae, Tripterygiidae, Gerreidae, Labrisomidae, Opistognathidae, Scaridae, Labridae, Scorpaenidae, Lutjanidae, Monocanthidae,* and *Sphyraenidae.* The temporal nature of larval delivery in the study area appears both cyclic and episodic. Physical data indicated that 2 - 3 mesoscale eddies associated with the Tortugas Gyre passed through the study area each year, each with a residence time of several days. Such eddies caused a weakening or reversal of the mean northeast flow. The relative influence of these mesoscale features was taxon specific. Results from this study will improve our understanding of the dynamics of larval fish supply and how it is affected by physical environmental factors.

KEY WORDS: Larval fish, recruitment, Florida Keys

Patrones y procesos de la oferta de larvas de peces en los arrecifes de los cayos superiores de la Florida

Para examinar el papel de parámetros medioambientales cíclicos y de eventos hidrodinámicos estocásticos en la distribución de larvas de peces en arrecifes coralinos someros en cercanías a una corriente importante, se instalaron una serie de trampas de luz a lo largo de los cayos superiores de la Florida cada noche de por medio por un período de seis meses, de mayo a octubre del 2002 y del 2003. Al mismo tiempo se midieron la velocidad del viento y la temperatura. Durante el período de muestreo se recogieron un total de 27 649 larvas de peces pertenecientes a 55 familias, representando especies pelágicas, mesopelágicas, de pastos marinos, y arrecifales. Además de sardinas de las familias *Clupeideae, Engraulidae*, y *Atherinidae*, las colecciones estuvieron dominadas por las familias *Pomacentridae, Chaenopsidae,* *Tripterygiidae, Gerreidae, Labrisomidae, Opistognathidae, Scaridae, Labridae, Scorpaenidae, Lutjanidae, Monocanthidae, y Sphyraenidae.* El carácter temporal de la entrega de larvas en el área de estudio parece ser tanto cíclica como episódica. La información física indica que entre 2–3 eddies asociados con el 'Tortugas Gyre' pasan por el área de estudio anualmente, y se quedan en la zona por varios días. Estos eddies ocasionaron una disminución, o una inversión de la corriente de flujo del noreste. Se encontró que la influencia relativa de estos parámetros de mesoescala fue específica para cada taxa. Se espera que los resultados de este estudio mejoren nuestro entendimiento de la dinámica que controla la oferta de larvas de peces de arrecife y cómo está afectada por los parámetros medioambientales.

PALABRAS CLAVES: Peces en arrecifes coralinos, larvas, cayos superiores de la Florida

INTRODUCTION

The coral reefs of the Florida Keys are located on the western edge of the Florida Current (FC), a major western boundary current with predominantly northeasterly flow. Replenishment processes to the fish populations on these reefs are important due to high natural mortality and recreational fishing pressure. Although the supply of settlement stage fish larvae is a prerequisite of replenishment, very little is known about temporal patterns of larval supply.

The supply of larvae to coral reefs is variable over time and strongly influenced by the physical environment. Cyclic processes such as lunar phase and tidal amplitude may act as cues for settlement while less predictable hydrodynamic variability may affect the delivery of larvae to suitable habitat (Dufour 1991, Thorrold et al. 1994, Sponaugle and Cowen 1996).

Although the FC flows consistently to the northeast, there is considerable variability in flow along its northwestern front where the coral reefs of the Florida Keys are situated. Mesoscale (> 50 km) recirculation features (Tortugas eddies), originating as meanders of the eastern leg of the Loop Current, propagate along this front causing a weakening or reversal of the northeast flow along the shelf. It has been hypothesized that these features enhance delivery of fish larvae to the Florida Keys (Lee and Williams 1999). These eddies are considerably elongated and sheared apart by the time they reach the eastern Straits of Florida and the reefs of the upper Florida Keys. Smaller, faster moving, submesoscale (< 50 km) frontal eddies cause similar current reversals on shorter time scales.

The focus of this study was to measure the effect of cyclic environmental processes and episodic current reversals associated with the Tortugas gyre on the temporal patterns of larval fish supply to the reefs of the upper Florida Keys. The null hypothesis was that larval fish supply to the reefs of the upper Florida Keys is temporally random.

MATERIALS AND METHODS

Light traps modified from Sponaugle and Cowen (1996) were used to measure the temporal pattern of larval fish supply. The design consisted of a cylinder of Nitex netting with three funnel-shaped openings surrounding a submersible fluorescent light. Weather permitting, three replicate traps were deployed on French Reef, Key Largo every other night for two six-month periods (May-October, 2002 and 2003). Traps were attached to Florida Keys National Marine Sanctuary mooring buoys at sunset and retrieved at dawn. Samples were preserved in 95% ethanol for later sorting. Fish larvae were removed and identified to the lowest taxonomic level possible.

Wind and tide data were obtained from the NOAA C-MAN Molasses Reef tower located approximately two km southwest of the study site. Current flow was monitored by two acoustic Doppler current meters fixed to subsurface mooring at 21 and 4 meters depth approximately 4 km northeast of the study site (T. Lee, RSMAS, University of Miami). Prior to analysis, the raw current meter data were broken into V-alongshore and U-cross-shelf components, rotated to standard oceanographic convention, filtered with a low pass 40 hour filter to remove high frequency variability, and regressed against wind data to remove wind induced water flow. Ocean color satellite imagery was provided by the Institute for Marine Remote Sensing at the University of South Florida.

In order to examine possible cycling in the biological data, larvae of all fish taxa (excluding silvery bait fishes of the families *Clupeidae, Atherinidae,* and *Engraulidae*) were grouped together and the mean number of fish larvae per trap per night sampled was calculated. The Autocorrelation Function (ACF), was applied to these data to determine the lag at which the data cycled in time. The entire twelve month time series was then collapsed into a single 30 day lunar cycle with day 1 corresponding to the new moon and day 15 corresponding to the full moon. Raleigh circular statistics were then used to determine if separate taxa were randomly distributed over the lunar cycle. If this test indicated that a taxon was non-randomly distributed over the lunar cycle, the mean day about which the data were centered was calculated. Only taxa in which more than 100 individuals were caught were analyzed in this manner. These were *Stegastes partitus (Pomacentridae), Pomacentridae* (excluding *S. partitus*), *Chaenopsidae, Tripterygiidae, Gerreidae, Labrisomidae, Opistognathidae, Sparisoma spp. (Scaridae), Labridae, Scorpaenidae, Lutjanidae, Monocanthidae,* and *Sphyraenidae.* Because these thirteen taxa comprised almost three quarters of the total number of fish larvae captured (excluding silvery bait fishes), they were considered to be representative of the entire data set. Bray-Curtis cluster analyses were also carried out with these twelve taxa. Data were separated by year and transformed into proportions of the total number of each taxon caught in order to prevent clustering due to overall abundance. Any cycling was then removed from the data set by fitting a sin wave (corresponding to phase of the moon) to the data and obtaining the residuals. The residuals reflected episodic variability that could then be compared to episodic physical features such as passage of mesoscale eddies.

Current meter data as well as ocean color satellite imagery were carefully reviewed to determine periods when mesoscale eddies passed by the study site.

These periods were then compared with the biological data to examine the effects of mesoscale eddies on the supply of fish larvae to the study site.

RESULTS AND DISCUSSION

In total, 154 nights were sampled over the two six-month periods. 496 samples were collected on French Reef yielding 7,791 larval fishes from 55 different families (silvery bait fishes excluded).

The ACF revealed that larval supply of all fish taxa collected was cycling at a lag of approximately 30 days and in synchrony with the lunar/tidal amplitude cycle. Raleigh tests determined that all taxa combined as well as the twelve most abundant taxa separately were non-randomly distributed over the lunar cycle at the $\alpha = .05$ level. All fish combined were centered on a mean lunar day of 27.1 and the mean lunar days about which separate taxa were centered ranged from 24.1 and 1.1, between the third quarter and new moons. The multi-species cyclic nature of these data suggests that the lunar/tidal amplitude cycle is a common cue for a majority of fish larvae captured in the traps. The number of dark hours (hours when the moon is visible over the horizon), as well as the percentage of the moon illuminated, are decreasing during this period and reach a minimum at the new moon. Inversely, the tidal amplitude is increasing to a peak at the new moon during this time. The tidal amplitude and lunar cycle are in phase in the study area and teasing apart the influence of these two cycles is difficult. Because of the large range of mean lunar days for separate taxa, it is likely that both cycles are important and the degree to which each influences larval supply varies among different families.

Examination of current meter data as well as ocean color imagery revealed that three mesoscale eddies passed by the study site during each six month sampling period. Comparison of the residuals (lunar/tidal amplitude cycling removed) of all fish larvae combined and periods where mesoscale eddies passed by revealed that the eddies increased variability in the data when present or up to a week after their passage. The first eddy in 2002 and the first two in 2003 enhanced larval supply to the study site. The remaining three eddies appeared to disrupt larval supply. Whether eddy passage increased or decreased larval supply may depend on when during the lunar cycle eddies were present. Full moon periods consistently had very low larval supply whether or not an eddy passed. Larval supply increased when eddies were present during the period encompassing the third quarter and new moons.

Cluster analyses indicated that the where the influence of the mesoscale eddies was positive, it was also taxon-specific. Because all twelve of the most abundant taxa shared a similar cyclic pattern, the cluster analysis created groups largely due to episodic variability in the data. Three different groups of larvae clustered according to their presence during the three eddies that enhanced larval supply. There was no obvious clustering related to reproductive strategy. The fact that different families were affected differentially by each eddy may simply reflect differential presence in nearshore waters during the eddy's propagation along the reefs.

In conclusion, the supply of fish larvae to the reefs of the upper Florida Keys follows a predictable cyclic temporal pattern which is closely linked to variation in the lunar/tidal amplitude cycles. However, this cycle may be either disrupted or enhanced by the episodic passage of mesoscale frontal eddies.

LITERATURE CITED

Dufour, V. 1991. Variations of fish larvae abundance in reefs: effect of light on the colonization of the reefs by fish larvae. *C.R. Academy of Science* 313(4):187-194

Lee, T.N. and E. Williams. 1999. Mean distribution and seasonal variability of coastal currents and temperature in the Florida Keys with implications for larval recruitment. *Bulletin of Marine Science* 64(1):35-56

Sponaugle, S. and R.K. Cowen. 1996. Nearshore patterns of coral reef fish larval supply to Barbados, West Indies. *Marine Ecology Progress Series* 133(1-3):13-28

Thorrold, S.R., J.M. Shenker, E.D. Maddox, R. Mojica, and E. Wishinski. 1994. Larval supply of shorefishes to nursery habitats around Lee Stocking Island, Bahamas. II. Lunar and oceanographic influences. *Marine Biology* 118:567-578

BLANK PAGE

Whale Sharks (*Rhincodon typus*) in the Northcentral Gulf of Mexico: A Rationale for Research

ERIC R. HOFFMAYER, JAMES S. FRANKS, and JOHN P. SHELLEY
Center for Fisheries Research and Development
Gulf Coast Research Laboratory
The University of Southern Mississippi
P.O. Box 7000
Ocean Springs, Mississippi 39566 USA

ABSTRACT

The whale shark, *Rhincodon typus*, has a circumtropical distribution, excluding the Mediterranean Sea. Internationally, the whale shark is listed as 'vulnerable', however, little is known about this species in the Gulf of Mexico (GOM), and information on whale sharks in the northcentral GOM is especially lacking in the scientific literature. Based on reported sightings and encounters, peak occurrence of whale sharks in the northcentral GOM is June–October, however, the nature of their seasonal occurrence, as well as life history aspects, movement patterns, habitat requirements, and population structure, are virtually unknown for the northcentral GOM. Research needs can be addressed regionally through collaborative research using a combination of questionnaires, aerial surveys, satellite imagery and telemetry, and at-sea research. As a 'first-step' response to the need for comprehensive information, the authors provide an outline of suggested research and describe a recently developed whale shark sightings questionnaire which is provided via the internet or hard copy. Future research will substantially advance understanding of the biology, ecology and behavior of whale sharks in the northcentral GOM.

KEY WORDS: Whale shark, *Rhincodon typus*, northcentral Gulf of Mexico

Tiburones Ballena (*Rhincodon typus*) en la Región Central Norte del Golfo de México: Un Razonamiento para su Investigación

El tiburón ballena, *Rhincodon typus*, presenta una distribución circumtropical, excluyendo el Mar Mediterraneo. Internacionalmente, el tiburón ballena es mencionado en "peligro", sin embargo, poco se sabe acerca de esta especie en el Golfo de México (GM). La información de esta especie en la región central del norte del GM es mínima especialmente en la literatura científica. Basados en reportes de avistamientos y capturas, la ocurrencia máxima del tiburón ballena en la región central del norte del GM es durante Junio - Octubre, sin embargo, la naturaleza de su presencia estacional, así como los aspectos de su historia de vida, patrones de movimiento, requerimientos del hábitat, y su estructura poblacional son virtualmente desconocidos en la región central del norte del GM. La investigación necesaria puede ser desarrollada en colaboración a nivel regional usando una combinación de cuestionarios, observaciones aéreas, imágenes de satélite e telemetría, e investigación marina. Como un "primero-paso" en respuesta a la necesidad de recopilar información detallada, los autores sugieren un plan de investigación y describen el reciente desarrollo de un cuestionario de avistamientos del tiburón ballena. Este cuestionario fue divulgado por ellos en la forma de un documento o en formato digital via internet. La futura colaboración investigativa va a incrementar substancialmente nuestra comprensión de la biología, ecología y comportamiento de los tiburones ballena en la región central de norte del GM.

PALABRAS CLAVES: Tiburones ballena, *Rhincodon typus*, central norte del Golfo de México

INTRODUCTION

The whale shark, *Rhincodon typus*, is an epipelagic shark which has a circumtropical distribution, except for the Mediterranean Sea. It is the world's largest known fish, reaching up to 15 meters (m) and 18 metric tons (Colman 1997), and is generally encountered as single individuals but may form aggregations of up to hundreds of individuals (http://www.fao.org). Whale shark populations have decreased radically in some parts of the world, and the necessity of protecting this species on an international basis is emphasized by its listing as 'vulnerable' by the International Union for the Conservation of Nature and Natural Resources (IUCN, http://www.redlist.org) and its inclusion in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, http://www.cites.org). In the United States, whale sharks are protected from directed commercial fishing, landing or sale in waters of the Gulf of Mexico (GOM) and Atlantic Ocean (http://www.fao.org). Whale sharks are studied by various organizations around the world (e.g., The Marine Conservation Society Seychelles, The Shark Research Institute, The Nature Conservancy, University of York, University of Western Australia), however, little is actually known about the biology and life history of the species. Published scientific information on whale sharks in the GOM is scant, and studies directed at their biology, ecology and migratory behavior in the northcentral GOM are non-existent.

Information on the age, growth and reproduction of whale sharks, worldwide, is scant at best. Size and age at sexual maturity, as well as maximum age, are speculative, but whale sharks may not reach maturity until 30 years of age and longevity could be up to 100 years (Taylor 1994). Interestingly, there are no records of whale sharks between one and four m in length, which could indicate rapid growth at an early age. Pai et al. (1983) reported a mature male which was 8 m in length and three immature females between 8 - 9 m. Wintner (2000) reported three mature males estimated to be between 20 - 27 years of age and an immature female estimated to be 22 years old. It appears that males mature at a smaller size and earlier age than females. Until recent time there was much debate over the reproductive strategy of whale sharks. In 1955 a large egg case containing a whale shark embryo was collected in a shrimp trawl off the Texas coast (Baughman 1955), suggesting oviparity as the mode of development. However, a pregnant female (10.6 m) which was harpooned near Taiwan in 1995 and contained 300 embryos at various stages of development (i.e. egg case, yolksac, free living) revealed that whale sharks utilize yolk-dependent viviparity (Joung et al. 1996). Nothing is known about whale shark age, growth and reproduction in the northcentral GOM.

Whale sharks are considered to be highly migratory (Eckert and Stewart 2001) with movements that appear to be timed to coincide with blooms of planktonic organisms and changes in temperatures of water masses (http:// www.fao.org). In the Western Central Atlantic, specimens tagged off Belize demonstrated movement to Honduras and further northward toward the Yucatan peninsula (Whale Shark News 2001), and one specimen moved from Honduras into the GOM (Alex Antoniou Per. comm.), however, to our knowledge, documentation indicating that whale sharks are a shared, migratory stock between the GOM and Caribbean regions is non-existent. The migratory behavior of whale sharks in the GOM is unknown, and information on its occurrence in the northern GOM is sparse. The northern GOM is considered to be one of twelve regions in the world where whale sharks predictably occur (Whale Shark News 2001), however, with the exception of sightings/encounters recorded during offshore fisheries research activities (the authors) and marine mammal aerial surveys (Childs et al. 2000, K. Mullins, NOAA Fisheries, USA Pers. comm), available information on whale shark occurrence in the northcentral GOM is largely anecdotal and based on sightings reported by offshore recreational anglers, divers, and the offshore petroleum industry (vessels, aircraft, and platforms). The limited available information suggests that whale sharks occur most frequently in the northern GOM during warmer months of the year (May – November), but they have been observed yearound.

Movements and distribution of whale sharks in the GOM may be related to specific biological events and oceanic conditions, such as the Loop Current and northern GOM oceanic frontal features (e.g., convergent zones, upwellings, temperature discontinuities, etc) which represent major pelagic ecosystems and tend to provide optimal conditions for plankton production (Don Johnson, GCRL Per. comm.), a primary food of whale sharks (Colman 1997). Whale sharks also feed on small crustaceans, small fishes, squid and jellyfish (Colman 1997, Heyman et al. 2001), and as reported for other oceans of the world (e.g., Heyman et al. 2001, Graham and Roberts 2003) seasonal aggregations of whale sharks have been associated with mass spawning of corals in the GOM at the Flower Garden Banks National Marine Sanctuary off Texas, USA (Clarke and Nelson 1997). Whale sharks associate with, or attract, other pelagic fishes, including remoras, cobia, jacks, and tunas (Gaertner and Medina-Gaertner 1999), which appear to be feeding on the same resource as the whale shark (Clark and Nelson 1997, Colman 1997, Heyman et al. 2001). Tunas, in particular, are reported to associate with whale sharks (Cropp 1978 - Australia, Iwasaki 1970 - Japan, Baughman 1955 - Honduras, Gudger 1941 and Springer 1957 - U.S. and Mexico, Gulf of Mexico). On September 18, 2002 during a *Sargassum* habitat research cruise in the northcentral GOM, we encountered two whale sharks (~10 m in length) accompanied by large schools of yellowfin, blackfin and skipjack tuna (*Thunnus albacares*, *T. atlanticus*, and *Katsuwonus pelamis*, respectively) which were feeding on small fishes believed to be clupeids that may have been food for the whale sharks as well.

Aggregations of whale sharks have been reported from various locations around the world (e.g., Silas 1986 - Indian Ocean, Wolfson 1986 - Sea of Cortez, Colman 1997 and Taylor 1996 - Ningaloo Reef in Western Australia, Graham and Roberts 2003 - Belize), and offshore anglers periodically observe large aggregations in the northcentral GOM. The significance of the aggregations is unknown, except that Colman (1997) reported that whale sharks may aggregate in areas with dense accumulations of prey. Aggregations in the northcentral GOM typically occurred at or near petroleum platforms located at least 100 km offshore. Whale sharks may be attracted to platforms, which essentially function as fish attracting devices (FAD) (Franks 2000) and may provide foraging opportunities or serve as 'waypoints' or 'meeting points' along migratory routes.

NEEDS AND RATIONALE FOR RESEARCH

The conspicuous lack of scientific information on whale sharks in the northcentral GOM accentuates the need for answers to fundamental questions pertaining to numerous aspects of whale shark biology and ecology in the region. Additionally, research is needed to investigate the north-central GOM as possible whale shark spawning, nursery and juvenile habitat, and to study relationships between seasonal behavior (e.g., short-term and long-term movements) and oceanographic factors. A key factor in the sustainability of the whale shark population in the GOM is a clear understanding of the population dynamics of the animal. Understanding life history aspects of whale sharks and which biotic and abiotic factors affect the abundance, distribution, and seasonal movements of the species in the north-central GOM is important for the development of any future management and/or protection measures for the species and its habitat in the GOM.

A multi-disciplinary approach to research will be required to significantly improve our understanding of whale sharks in the northcentral GOM and will include at-sea studies, aerial surveys, laboratory assessments, questionnaires, oceanographic modeling, genetic analysis, and state-of-the-art technologies, including remote sensing, GIS, and satellite telemetry. Such an approach would necessitate the development of a comprehensive plan with a specific goal and well-defined objectives and would require collaborations among research and academic institutions, fisheries management agencies, fisheries councils and commissions, the offshore petroleum industry, NGOs, the recreational and commercial fishing industries, public education and outreach institutions and organizations, and other pertinent entities. Securing adequate funding will represent a major challenge to the implementation of this plan.

SUGGESTED PLAN OF RESEARCH

The goal is to understand the biology and ecology of the whale shark in the GOM and its role in the pelagic ecosystem of the GOM. Ideally, a regional plan of research to accomplish this goal would initially include input from experts and other informed sources to develop a consensus on needs and priorities for future investigations. In view of the current absence of such a plan and in an effort to initiate, and perhaps stimulate, the planning process, we offer the following brief outline for whale shark research in the northcentral GOM.

Additionally, we recommend that the research be conducted in two phases and suggest specific research topics for inclusion in each phase of the plan.

Outline of Research Plan

Phase 1

A 'first-step' response involves the accumulation and review of *available* recent and historic (surveys, logbooks, etc.) sightings data and information and the development of a sightings database that will benefit future whale shark studies and serve to maximize the success of Phase II activities. The database will provide the following information for whale sharks:

i) Inter-annual abundance and distribution,
ii) Size range,
iii) Behavior, and
iv) Associated pelagic fishes

Phase II

i) Continuation of Phase I efforts,
ii) Estimate relative abundance of individuals through robust, repeatable population surveys (aerial surveys),
iii) Develop a photographic identification library (digital photography and video),
iv) Examine population structure using genetic analysis,
v) Determine critical habitat and environmental preferences using sighting information, at-sea research and satellite imagery,
vi) Investigate movements at regional and oceanic scales using aerial surveys, electronic telemetry (sonic tags, satellite pop-off) and mapping to determine if individuals represent a resident or transient population, or both, and to examine potential threats to migratory behavior,
vii) Determine relationships of abundance, distribution, and movement patterns with oceanic features and localized productivity events using at-sea research and satellite imagery,
viii) Identify food sources and feeding grounds through zooplankton and nektonic sampling during observed feeding events, and
ix) Investigate the association of pelagic fishes with whale sharks through the identification and examination of associated fishes (size range, reproductive condition and stomach contents) and an investigation of the ecological processes in areas where whale sharks and fishes form foraging assemblages.

Initiation of Phase I Activities

Access to information pertaining to future whale shark sightings and encounters is critical to the development of a sightings database and to future whale shark research. In response to this need and in an effort to initiate Phase I activities, we recently developed a succinct sightings questionnaire which is available at http://www.usm.edu/gcrl/whaleshark survey and by hard copy distribution. We are in the process of notifying offshore fishers (recreational and commercial), oil and gas industry personnel, divers, dive boat operators, scientists, and others of its availability and the need for sightings information. Responders can provide information to us by completion of the electronic or paper version of the questionnaire. We will assess the relative value of submitted information as being from either log entry, other documentation or memory. Information greater than two years old will not be included in the database unless sufficient documentation of its validity is provided.

PRELIMINARY FINDINGS

A brief survey conducted by us generated several sightings for 2003 and 2004, the majority of which occurred in areas where whale sharks were historically observed by the U.S. NOAA Fisheries, Marine Mammals Aerial Surveys (W. Driggers, Per. comm.). Many sightings were in offshore waters in the vicinity of the Mississippi River Delta. The majority of sightings involved single whale sharks swimming at the surface, but aggregations were also observed. Whale sharks were observed within the northcentral GOM throughout the year, but most sightings occurred during summer. Because our preliminary data are based on a limited number of opportunistic sightings, we have no insight into whether whale sharks are transients in the northcentral GOM or comprise a resident population. Based on reported estimated sizes, both juvenile and adult sharks occur in the northcentral GOM, suggesting that the area may be an important nursery area. Our data show that pelagic fishes associate with whale sharks in the northcentral GOM, including several species of tuna. We will continue to collect baseline data using the sightings questionnaire and will report detailed findings in future publications.

ACKNOWLEDGMENTS

We thank offshore recreational anglers (J. Roberson, S. Schindler, N. Friedlander, M. Thomas, T. Lipps, B. Lewis, B. Lezina, S. Smith, D. Garstecki, R. Gremillion and R. Howland) and petroleum platform personnel (T. Flowers) for reports of recent whale shark sightings. We are grateful to W. Driggers and K. Mullin, NOAA Fisheries, Mississippi Laboratories, Pascagoula, USA, for data on whale shark sightings collected during marine mammal aerial surveys conducted in the GOM. Regan Hoffmayer provided immeasurable help and guidance during development of the sightings questionnaire. We thank T. Phan for website development and G. Sanchez for Spanish translation. We acknowledge G. Parsons, D. Stanley and S. Diamond who share with us an interest in initiating a whale shark research program for the northern GOM. This paper was made possible, in part, by support from the GCRL Sargassum Research Project (funded by the Mississippi Department of Marine Resources and the U.S. Fish & Wildlife Service, Sport Fish Restoration Program) and the GCRL Pelagic Fisheries Research Program.

LITERATURE CITED

Baughman, J.L. 1955. The oviparity of the whale shark, *Rhincodon typus*, with records of this and other fishes in Texas waters. *Copeia* **1955**:54-55.

Childs, J., C.M. Burks, K.D. Mullin, and J. Hewitt III. 2000 (Abst.). The occurrence and distribution of the whale shark (*Rhincodon typus*) in the northern Gulf of Mexico. Whale Shark Symposium, American Elasmobranch Society, Annual Meeting, La Paz, Mexico, June 2000.

Clark, E. and D.R. Nelson. 1997. Young whale sharks, *Rhincodon typus*, feeding on a copepod bloom near La Paz, Mexico. *Environmental Biology of Fishes* **50**:63-73.

Colman, J.G. 1997. A review of the biology and ecology of the whale shark. *Journal of Fish Biology* **51**:1219-1234.

Cropp, B. 1978. *Shark Hunters*. Harrowood Books, New York, New York USA..

Eckert, S.A. and B.S. Stewart. 2001. Telemetry and satellite tracking of a whale sharks, *Rhincodon typus*, in the Sea of Cortez, Mexico, and the north Pacific Ocean. *Environmental Biology of Fishes* **60**:299-308.

Franks, J.S. 2000. Pelagic fishes at offshore petroleum platforms in the northern Gulf of Mexico: diversity, interrelationships, and perspective. *Colloque Caraibe, Actes de Colloques Ifremer. Aquatic Living Resources* **13**(4):502-515.

Gaertner, D. and M. Medina-Gaertner. 1999. An overview of the tuna fishery in the southern Caribbean Sea. Pages 66-86 in: M.D. Scott, W.H. Bayliff, C.E. Lennert-Cody, and K.M. Schaefer (eds.). *Proceedings of the International Workshop on the Ecology and Fisheries for Tunas Associated with Floating Objects*. February 1992. Inter-American Tropical Tuna Commission Special Report 11. La Jolla, California USA.

Graham, R.T. and C.M. Roberts. 2003 (Abst.). Patterns of movement and site fidelity of whale sharks on the Mesoamerican barrier reef. 6th Congress on Marine Sciences, MarCuba 2003, Havana, Cuba.

Gudger, E.W. 1941. The food and feeding habits of the whale shark (*Rhineodon typus*). *Journal of the Elisha Mitchell Science Society* **57** (1):57-72.

Heyman, W., R. Graham , B. Kjerfve, and R.E. Johannes. 2001. Whale sharks *Rhincodon typus* aggregate to feed on fish spawn in Belize. *Marine Ecology Progress Series* **251**:275-282.

Iwasaki, Y. 1970. On the distribution and environment of the whale shark, *Rhincodon typus*, in skipjack fishing grounds in the western Pacific Ocean. *Journal of the Collections Marine Science Technology, Tokai University* **4**:37-51.

Pai, M.V., G. Nandakumar, and K.Y. Telang. 1983. On a whale shark, *Rhineodon typus* Smith, landed at Karkar, Karnataka. *Indian Journal of Fisheries* 30:157-160.

Springer, S. 1957. Some observations on the behavior of schools of fishes in the Gulf of Mexico and Adjacent waters. *Ecology* 38:166-171.

Silas, E.G. 1986. The whale shark (*Rhincodon typus* Smith) in Indian coastal waters: is the species endangered or vulnerable? Marine Fisheries Information Service, Technical and Extension Series 66, 1-19.

Taylor, G. 1994. Whale sharks, the giants of Ningaloo Reef. Sydney: Angus and Robertson.

Taylor, G. 1996. Seasonal occurrence, distribution and movements of the whale shark, *Rhincodon typus*, at Ningaloo Reef, western Australia. *Marine and Freshwater Research* 47, 637-42.

Whale Shark News. 2001. Newsletter of the UK Darwin Initiative, University of York, 1(1):1-6.

Wintner, S.P. 2000. Preliminary study of vertebral growth rings in the whale shark, *Rhincodon typus*, from the east coast of Africa. *Environmental Biology of Fishes* 59:441-451.

Wolfson, F.H. 1986. Occurrences of the whale shark, *Rhincodon typus*, Smith. Indo-Pacific Fish Biology: Pages 208-226 in: T. Uyeno, R. Arai, T. Taniuchi, and K. Matsuura (eds.). *Proceedings of the Second International Conference on Indo-Pacific Fishes.* Ichthyological Society of Japan, Tokyo, Japan.

Evaluation of the Reproductive Life History of the Sciaenidae in the Gulf of Mexico and Caribbean Sea: "Greater" versus "Lesser" Strategies?

GRETCHEN L. WAGGY, NANCY J. BROWN-PETERSON, and MARK S. PETERSON
Department of Coastal Sciences,
The University of Southern Mississippi
703 East Beach Drive
Ocean Springs, Mississippi 39565 USA

ABSTRACT

There are 54 species of sciaenids in the Gulf of Mexico and Caribbean Sea. Here we review the life histories of the more common sciaenids with an emphasis on reproductive biology. Although all sciaenids have an extended reproductive season and are multiple spawners, analysis using principle component ordination and clustering on eight life history traits resulted in separation of three general groups. Whitemouth croaker (*Micropogonias furnieri*), black drum (*Pogonias cromis*), and red drum (*Sciaenops ocellatus*) are species of high commercial and recreational value, and can be termed "greater sciaenids." These species have a longer life span, larger maximum size, larger size- and age-at-maturity, lower spawning frequency, and lower relative fecundity compared to other sciaenids. In contrast, silver perch (*Bairdiella chrysoura*), cubbyu (*Pareques umbrosus*), and star drum (*Stellifer lanceolatus*) are small sciaenids that are usually caught as trawl bycatch and used as bait or in the aquarium trade, and can be considered "lesser sciaenids." These species have a short life span, small maximum size, small size- and age-at-maturity, short spawning season, high spawning frequency and high relative fecundity. Sharing traits of both groups is an intermediate group typified by moderate size, age and other life history traits.

This group includes ground croaker (*B. ronchus*), sand seatrout (*Cynoscion arenarius*), spotted seatrout (*C. nebulosus*), silver seatrout (*C. nothus*), banded drum (Larimus fasciatus), spot (*Leiostomus xanthurus*), southern kingfish (*Menticirrhus americanus*), gulf kingfish (*M. littoralis*), nothern kingfish (*M. saxatilis*), and Atlantic croaker (*Micropogonias undulatus*). There are commercial fisheries for these species, but most are not typically as economically important as the larger sciaenids. Spotted seatrout and Atlantic croaker have several traits more similar to "greater sciaenids", and historical data suggests overexploitation may have resulted in these species changing groups. Continued exploitation of sciaenids may result in changes to life history shifting traits and thus reclassification into different strategies.

KEY WORDS: Life history, reproduction, Sciaenidae

Evaluación de la Historia Reproductiva de la Vida del Sciaenidae en el Golfo de México y del Mar del Caribe: ¿ Estrategias de "Mayor" contra "Pocos"?

Hay 54 especies de sciaenidos en el Golfo de México y del Mar del Caribe. Aquí repasamos de las historias de la vida de los sciaenidos más comunes con un énfasis en la biología reproductiva. Mientras que todos los sciaenidos tienen una estación reproductiva extendida y desolven múltiples veces cada año, un análisis usando ordenación del componente principal y arracimando en ocho rasgos de la historia de la vida resultó en la separación en tres grupos generales. El ronco blanco (*Micropogonias furnieri*), el tambor negro (*Pogonias cromis*), y la corvineta ocelada (*Sciaenops ocellatus*) son especie del valor arriba comercial y recreacional, y se pueden llamar "sciaenidos mayores". Estas especies tienen una vida más larga, un tamaño máximo más grande, un tamaño y una edad-en-madurez más grande, frecuencias de desolve más bajas, y fecundidades relativos más bajos comparados a otros sciaenidos. En contraste, el ronco amarillo (*Bairdiella chrysoura*), el payasito prieto (*Pareques umbrosus*), y la corvinilla lanza (*Stellifer lanceolatus*) son los sciaenidos pequeños que se cogen como especies accesorias de la red barredera y se utilizan generalmente como cebo o en el comercio del acuario, y pueden ser considerados "sciaenidos pocos". Estas especies tienen una vida corta, un tamaño máximo pequeño, un tamaño y una edad-en-madurez pequeña, frecuencias de desolve altas y fecundidades relativos altos. Compartir características de ambos grupos es un grupo intermedio caracterizado por tamaño, edad y otros aspectos de la historia de la vida moderados. Este grupo incluye el ronco rayado (*B. ronchus*), la corvina pinta (*Cynoscion nebulosus*), la corvina arenera (*C. arenarius*), la corvina plateada (*C. nothus*), el croca (*Leiostomus xanthurus*), el berrugato zorro (*Menticirrhus americanus*), el berrugato del Golfo (*M. littoralis*), y la gurrubata (*Micropogonias undulatus*). Hay industrias pesqueras comerciales para estas especies, pero no son tan importante como los sciaenidos más grandes. *Cynoscion nebulosus* y *M. undulatus* tenga rasgos varios más similares de los "sciaenidos mayores", y los datos históricos sugieren que la explotación demasiado pudo haber dado lugar a estos grupos que cambian de la especie. La explotación continuada de sciaenids puede dar lugar a cambios a los rasgos que cambian de puesto de la historia de la vida y así a la reclasificación en diversas estrategias.

PALABRAS CLAVES : Sciaenidae, historia reproductiva, Golfo de México, Mar del Caribe

INTRODUCTION

Variation in life history traits of fishes is one approach that has been found useful to the development of a better understanding of how species respond evolutionarily to environmental conditions and potentially perturbations. In particular, examination of the reproductive life history of fishes has resulted in the characterization of a series of reproductive guilds that are based on adaptations (i.e., ecological, physiological, etc.) to natural environmental conditions (Balon 1975). This concept of reproductive guilds was further enhanced by Winemiller and Rose (1992) who coupled demographic characters with life history traits. They proposed three primary life history strategies that result from tradeoffs among survivorship, fecundity, and size/age at maturation. The results of these analyses showed convergent evolution in that phylogenetically distinct species with similar reproductive life history traits were grouped together in the same guild or strategy. However, Winemiller and Rose (1992) noted that several of the larger freshwater and marine orders (Clupeiformes, Gadiformes, Perciformes, etc.) showed divergence in placement in any of the three primary life history strategies. For example, there were 71 species of Perciformes examined in their analysis and many life history traits varied widely (standard deviations exceeded the mean values), likely due to family differences within the order. This suggests that a highly specious family may also exhibit variation in reproductive life history traits, even though variation among genera within a family may be less than variation across families within an order.

There are 54 species of sciaenids in the Gulf of Mexico (GOM) and Caribbean Sea (Carpenter 2002). Many of these are prime targets for commercial as well as recreational fisheries (Carpenter 2002). However, little is known of the life history traits, especially reproductive biology, for many tropical sciaenids, even though they are also under fishing pressure. Aspects of the reproductive biology of a species can be used in countless ways to preserve or manage that species more effectively. For example, spawning season, spawning area, age-at-maturity, fecundity, and spawning frequency are important factors employed by fisheries managers to establish catch and size limits as well as the catch season (Everhart et al. 1975, Jennings et al. 2001).

We hypothesize that the Sciaenidae can be separated into different groups based on reproductive life history traits. Therefore, our objectives were to compile the available reproductive life history data on Sciaenidae in the GOM and Caribbean Sea and to analyze these data within a life history framework to identify suites of species exhibiting different reproductive life history strategies. Finally, the results of the analyses are interpreted in light of the impacts of the historic and current fishery practices.

MATERIALS AND METHODS

Literature for this review was searched in a hierarchical manner. First, various ecological and taxonomic guides were examined to determine which species of Sciaenidae inhabit the GOM and Caribbean Sea (Randall 1983, Humann 1989, Böhlke and Chaplin 1993, Hoese and Moore 1998, Smith-Vaniz et al. 1999, Carpenter 2002). Next, we searched Fish Base (http://www.fishbase.org/) for any additional GOM and Caribbean Sea species. Databases using selected keywords (Table 1) were searched in addition to the personal literature of the authors. After all relevant literature was collected, the literature cited section of each reference was checked for additional citations not identified in the procedures mentioned above. These included technical reports, theses and dissertations, older references not incorporated in online databases, grey literature, etc. Finally, general searches were performed in Google (http://www.google.com/) using the keywords in Table 1.

Table 1. List of databases examined during literature search.

Database	Sources	Years	Keywords
Cambridge Scientific Abstracts Database Service	ASFA 1: Biological and Living Resources	1960 - current	genus and common name of each species; Sciaenidae; sciaenid; fish reproduction; gonadosomatic index; drum(s) AND any combination of these words
	Ecology Abstracts	1960 - current	
	Oceanic Abstracts	1960 - current	
	ERIC	1960 - current	
EBSCO Host Research Databases	Biological Abstracts (BIOSIS)	1969- current	
JSTOR	Ecology Section	1913 - 2000	
ISI Web of Knowledge: Web of Science	Science Citation Index Expanded	1994 - 2004	
INGENTA	INGENTA	1900 - current	

From this literature, we documented and tabulated nine traits related to reproduction. Only reproductive information specific for the GOM and Caribbean Sea were included. These nine traits were maximum size (mm total length (TL)), maximum age (yrs), age-at-maturity (yrs), size-at-maturity (mm TL or standard length (SL)), duration of peak spawning (mo), mean peak female gonadosomatic index (GSI, %), spawning frequency (days), relative fecundity (ova/g body weight (BW)), and batch fecundity (ova). Species were included only if some type of female reproductive trait was reported, and were not included if only general biological and non-reproductive information was available. This information was then used in subsequent analyses.

Statistical Analysis

Principle component analysis (PCA) in a two step procedure (Peterson and VanderKooy 1997) was used to compare the reproductive traits between the different sciaenid species. We ordinated species (11 species, 7 genera) based on eight life history traits using PCA of the correlation matrix, with varimax rotation to maximally resolve loadings. A scree test was used to determine the number of meaningful components. Any trait that loaded on a component at an absolute value of ≥ 0.50 was considered to contribute significantly to interpreting that component. Cluster analysis based on the unweighted pair group method with arithmetic mean (UPGMA) procedure was used on fourth- root transformed data to compare reproductive traits among the sciaenid species with the Bray-Curtis similarity coefficient to examine species linkage using PRIMER (PRIMER-E Ltd, Plymouth, UK). The Bray-Curtis similarity coefficient values range from 0 % (no similarity) to 100 % (identical; Clark and Warwick, 2001). For both the PCA and cluster analysis, only species with data in all reproductive trait fields except spawning frequency were included.

RESULTS AND DISCUSSION

Of the greater than 100 literature sources examined, 60 contained complied or unique data used in this review. Sixteen sciaenid species distributed among 10 genera were found to have relevant information pertaining to this review (Table 2). An additional 38 species occur in the study area, but no specific reproductive data were found. Of the 16 species, only 11 were included in the PCA and cluster analysis because of missing reproductive traits. The PCA of the eight traits produced two components which explained 86.08% of the variance (Figure 1). Component 1 (PC I) comprises batch fecundity, relative fecundity, age-at-maturation, size-at-maturation, maximum length, and maximum age which we interpret as aspects of fish size that influence reproduction. Component 2 (PC II) includes duration of spawning season and mean peak GSI, and represents spawning season dynamics. Figure 1 suggests sciaenids have three different reproductive life history strategies. The first consist of whitemouth croaker (*Micropogonias furnieri*), black drum (*Pogonias cromis*), and red drum (*Sciaenops ocellatus*). The next group included ground croaker (*Bairdiella ronchus*), sand seatrout (*Cynoscion arenarius*), spotted seatrout (*Cynoscion nebulosus*), silver seatrout (*Cynoscion nebulosus*), banded drum (*Larimus fasciatus*), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*). The last group was comprised of only one species, silver perch (*Bairdiella chrysoura*). The UPGMA cluster analysis (Figure 2)also identified three groups. Red drum, black drum and white mouth croaker (Group 1) clustered together with 95.82 % similarity. A second group, consisting of ground croaker, sand seatrout, spotted seatrout, silver seatrout, banded drum, spot, and Atlantic croaker (Group 2), were clustered with 90.96 % similarity. Finally, silver perch did not cluster with any other species and only had 82.46% similarity to Group 2. These two analyses support our hypothesis that sciaenids can be divided into different strategies based on reproductive life history traits. We termed these groups "greater", "intermediate", and "lesser" based on a socio-economic-ecological gradient.

Table 2. Life history traits of all sciaenid species included in this review.

Species	Max Age (yrs)	Max Length (mm TL)	Peak Spawning (mo)	Mean Peak GSI (%)	Spawning Frequency (days)	Relative Fecundity (ova/g)	Batch Fe-cundity (ova)	Age-at-Maturity (yrs)	Size-at-Maturity (mm)	References
Bairdiella chrysoura	4 – 5	250	3	12	1.3 – 1.6	151 – 1387	2497 – 50,565	YOY	110 – 120 TL	7, 8, 35
Bairdiella ronchus	2	350	8	2.97 – 5.09		2212	188,964	YOY	158 TL	7, 21, 34
Cynoscion arenarius	3	590	6	4.5 – 5.5	2.8	176 – 1452	25,874 – 432,000	YOY	140 – 180 TL	13, 14, 15, 30, 31, 33, 36
Cynoscion nebulosus	9	700	6.5	~ 8	4 - 5	250 – 650	12,00 – 797,000	1 +	272 TL	5, 6, 7, 24
Cynoscion nothus	2	400	6	3.5		419 – 1336	16,800 – 389,500	YOY	170 – 206 TL	7, 12, 30
Larimus fasciatus	2 – 3	220	4	5.5		1569	12,750 – 320,819	YOY	80 – 150 TL	7, ,29, 32
Leiostomus xanthurus	2 – 3, 5	360	5	~ 4.5		267 – 2948	20,900 – 514,400	1+	127 TL	7, 11, 19 , 28, 30,
Menticirrhus americanus	2 – 3	450 – 500	4					1	150 – 220 TL	1, 7, 17, 18
Menticirrhus littoralis	2	450 – 500	4						210 TL	1
Menticirrhus saxatilis	3	450 – 500	Spring and summer					1		1
Micropogonias furnieri	7	900	7	8.0	3 - 4	52 – 449	17,000 – 3,700,000	2	320 TL	7, 9, 22, 23,

Table 2. Continued.

Species	Max Age (yrs)	Max Length (mm TL)	Peak Spawning (mo)	Mean Peak GSI (%)	Spawning Frequency (days)	Relative Fecundity (ova/g)	Batch Fecundity (ova)	Age-at-Maturity (yrs)	Size-at-Maturity (mm)	References
Micropogonias undulatus	1 – 2, 8	357, 688	7	4.5		519 – 1581	27,300 - 1,075,600	YOY	140 – 170 TL	2, 20, 28, 30, 38
Pareques umbrosus		200	3		1.4 – 2.3		2000 eggs / spawn	Over 1 yr-captivity	150 mm SL in captivity	4, 7, 19
Pogonias cromis	43	1500	4	9 – 14	3 - 4	67 – 793	510, 000 – 3,800,000	5	600 – 649 FL	3, 7, 16, 26, 27
Sciaenops ocellatus	35	1600	4	4 – 8	2 - 4	42 – 447	160,000 – 3,270,000	3 – 6	550 – 899 FL	7, 10, 25, 26, 39
Stellifer anceolatus	2.5 (A)	200	3					YOY (A)	80 – 100 TL (A)	7, 17, 37

References: 1 = Armstrong and Muller (1996); 2 = Barger (1985); 3 = Beckman *et al.* (1990); 4 = Böhlke and Chaplin (1993); 5 = Brown-Peterson (2003); 6 = Brown-Peterson *et al.* (2002); 7 = Carpenter (2002); 8 = Chavance *et al.* (1984); 9 = García-Cagide *et al.* (2001); 10 = Comyns *et al.* (1991); 11= Cowan and Shaw (1988); 12 = DeVries and Chittenden (1982); 13 = Ditty (1986); 14 = Ditty *et al.* (1988); 15 = Ditty *et al.* (1991); 16 = Fitzhugh *et al.* (1993); 17 = Gunter (1938); 18 = Harding and Chittenden (1987); 19 = Holt and Riley (1999); 20 = Kobylinski and Sheridan (1979); 21 = Louis (1985); 22 = Macchi *et al.* (2003); 23 = Manickchand-Heileman and Kenny (1990); 24 = Murphy and Taylor (1994); 25 = Murphy and Taylor (1990); 26 = Dave L. Nieland

(A) = Data for Atlantic Ocean

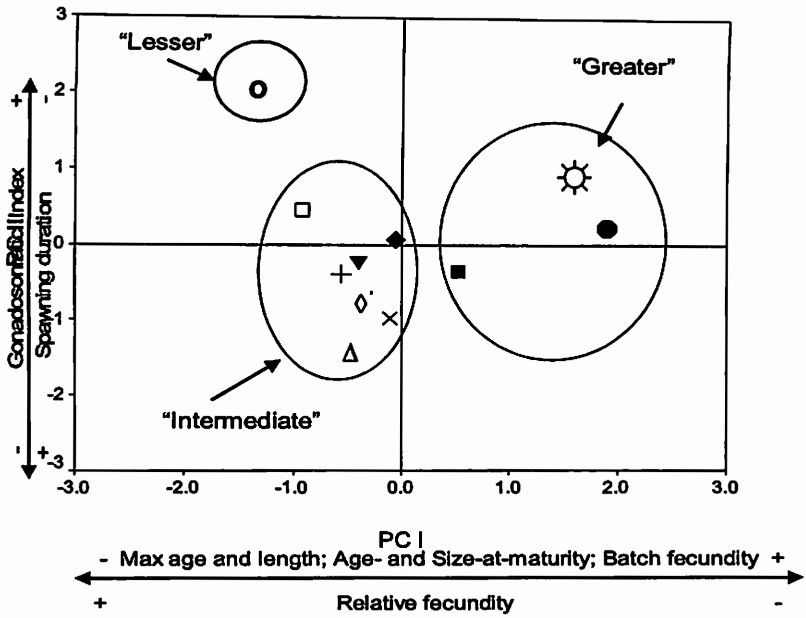


Figure 1. Plot of principle components I and II illustrating the distribution of sciaenid species relative to life history traits. "Greater": ■ = *Micropogonias furnieri*; ☼ = *Pogonias cromis*; ● = *Sciaenops ocellatus*; "Intermediate": Δ = *Bairdiella ronchus*; ▼ = *Cynoscion arenarius*; ♦ = *C. nebulosus*; ◊ = *C. nothus*; □ = *Larimus fasciatus*; + = *Leiostomus xanthurus*; X = *M. undulatus*; "Lesser": O = *B. chrysoura*

"Greater Sciaenids"

The three species included as "greater sciaenids" were whitemouth croaker, red drum, and black drum. This group has a longer life span, larger maximum size, larger size- and age-at-maturity, lower spawning frequency, and lower relative fecundity compared to other sciaenids (Table 3). These species are of high commercial and recreational value. All three species spawn offshore but are estuarine dependent and use estuaries as nursery habitat (Pattillo et al. 1997). Whitemouth croaker ranges from the Caribbean Sea into the southern Atlantic along the coast of South America (Carpenter 2002) and are one of the most economically important demersal fish in Trinidad (Manickchand-Heileman and Kenny 1990), Guianas and possibly Cuba (Carpenter 2002). Juveniles compose a significant portion of bycatch from shrimp trawlers (Manickchand-Heileman and Kenny 1990). Red drum and black drum are commercially and recreationally exploited. Red drum are found only in the GOM and along the Atlantic coast of the United States (U.S.). Black drum range from the Atlantic coast of the U.S. to the northern and western coasts of the GOM, throughout the Caribbean to the Atlantic coast of South America (Hoese and Moore 1998, Carpenter 2002). While all of the greater sciaenids have longer life spans and larger maximum sizes than the other sciaenids, whitemouth croaker are much smaller and have a shorter life span than red drum and black drum, although whitemouth croaker may reach seven years of age (Manickchand-Heileman and Kenny 1990) and 900 mm TL (Carpenter 2002). Red drum have been reported to reach a maximum age of 35 yrs (Murphy and Taylor 1990) and maximum size of 1600 mm TL (Carpenter 2002), while black drum attain 1500 mm TL (Carpenter 2002) and 43 yrs of age (Beckman et al. 1990).

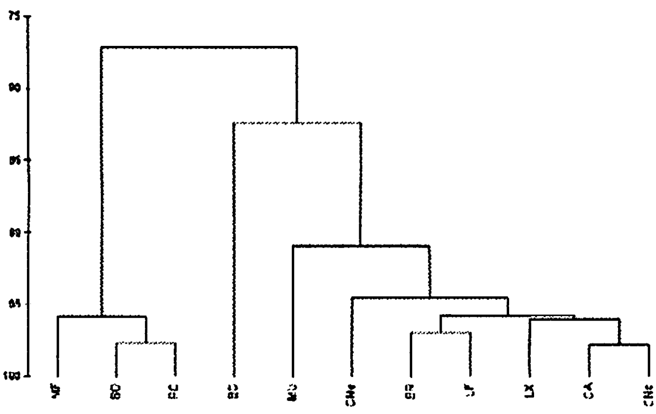


Figure 2. The UPGMA cluster analysis of sciaenid species based on Bray-Curtis similarity of eight reproductive traits. "Greater": MF = Micropogonias furnieri; PC = Pogonias cromis; SO = Sciaenops ocellatus; "Intermediate": BR = Bairdiella ronchus; CA = Cynoscion arenarius; CNe = C. nebulosus; CNo = C. nothus; LF = Larimus fasciatus; LX = Leiostomus xanthurus; MU = M. undulatus; "Lesser": BC = B. chrysoura

In general, the "greater sciaenids" have a greater size- and age-at-maturity then the other groups. Red drum and black drum both mature at an older age and larger size than the aforementioned species. Red drum mature between three and six years of age and 550 – 899 mm fork length (FL) (Murphy and Taylor, 1990; Wilson and Nieland, 1994), and black drum mature at 640 – 649 mm FL and five years of age (Nieland and Wilson 1993). In contrast, whitemouth croaker females mature by age two at 320 mm TL (Manickchand-Heileman and Kenny 1990). Whitemouth croaker spawn most actively from February to August (seven months) in the Caribbean, with maximum mean female GSI values of 8 % and a spawning frequency of 3 – 4 d (Manickchand-Heileman and Kenny 1990, García-Cagide et al. 2001, Macchi et al. 2003). Red drum spawn from August to November (4 mo) with a GSI peak in September of 4 – 8 % and a spawning frequency of 2 – 4 d (Murphy and Taylor, 1990; Comyns et al. 1991, Wilson and Nieland 1994). Black drum spawn for four months in the northern GOM (January – April) with GSI peaks in February and March of 9 – 14 % and a spawning frequency of 3 – 4 d (Fitzhugh et al. 1993, Nieland and Wilson 1993).

Batch fecundity within the "greater sciaenids" is generally higher compared to other sciaenids while relative fecundity is lower (Table 3). Batch fecundity is positively related to fish size, but size explains no more than 44 % (Sheridan et al. 1984, Nieland and Wilson 1993, Brown-Peterson, 2003) of the variation in fecundity for any species. The ranges in batch fecundity for the "greater sciaenids" are listed in Table 2.

Table 3. Summary of mean values of life history traits in each group with the "intermediate" group calculated with and without Atlantic croaker and spotted seatrout. N = number of species; MA = maximum age; ML = maximum length; PS = peak spawning; SF = spawning frequency (number of species); BF = batch fecundity; RF = relative fecundity; AM = age-at-maturity; SM = size-at-maturity; MG = mean maximum GSI.

	N	MA	ML	PS	SF	BF	RF	AM	SA	MG
Greater	3	28	1273	5	3 (3)	1,909,500	225	4	549	9
Intermediate	7	4	468	6	3.6 (2)	255,259	1208	1	166	5
Lesser	1	5	250	4	1.6 (2)	20,181	769	1	115	12
Intermediate without CNe and MU	5	3	382	6	2.8 (1)	210,409	1386	1	147	4.8
Atlantic Croaker (MU)	-	2	357	7	-	551450	1050	1	155	4.5
Spotted seatrout (CNe)	-	9	700	7	4.5	183,316	474	2	272	8

"Lesser Sciaenids"

In contrast to the "greater sciaenids", "lesser sciaenids" are small sciaenids that are usually caught as trawl bycatch, used as bait, or in the aquarium trade. Members of this group are species which inhabit estuaries and reefs. There is a limited amount of life history information available for "lesser sciaenids", and the suite of reproductive life history traits used to define this group is based on a single species, silver perch. However, we were able to place the star drum (*Stellifer lanceolatus*) and cubbyu (*Pareques umbrosus*) in this group based on comparison of the limited information on their reproductive traits (Table 2) to those of the "lesser sciaenids" (Table 3). As a whole, these "lesser sciaenids" appear to have a short life span, smaller maximum size, small size- and age-at-maturity, shorter spawning season, high spawning frequency, and high relative fecundity.

Silver perch are one of the top five most abundant species of sciaenids in estuaries along the GOM and the Atlantic coast of the U.S. (Chao and Musick 1977, Rooker et al. 1998, Gelwick et al. 2001), and support a small commercial fishery in the southern GOM (Ocaña-Luna and Sánchez-Ramírez 1998). Star drum is very similar in appearance to silver perch, but is not as abundant in estuaries. It is also caught as bycatch in bottom trawls and is found in the

GOM and along the Atlantic coast of the U.S. (Hoese and Moore 1998, Carpenter 2002). There is limited information on star drum in the GOM.

The cubbyu is another small sciaenid with little information available about its life history. This fish is found from Chesapeake Bay into the GOM and along the Atlantic coast of South America (Randall 1983, Böhlke and Chaplin 1993, Carpenter 2002) and is taken as bycatch in trawl fisheries (Carpenter 2002). In addition to the cubbyu, other small reef sciaenids such as the highhat (*Pareques acuminatus*), jack-knife fish (*Equetus lanceolatus*) and spotted drum (*Equetus punctatus*) are sought after in the aquarium trade (Smith-Vaniz et al. 1999, Carpenter, 2002). However, there is no reproductive biology information available regarding these and other small sciaenid species. It is unknown if they can be classified as "lesser sciaenids".

Silver perch reach a maximum size of 250 mm TL (Carpenter 2002) and in the GOM, a maximum age of four to five years (Waggy 2004). Star drum are similar and may attain 200 mm TL (Carpenter, 2002) and 2.5 years of age on the Atlantic coast (Welsh and Breder 1923). Cubbyu, smallest of the three, may reach 200 mm TL (Böhlke and Chaplin 1993, Carpenter 2002), but maximum age is unknown.

"Lesser sciaenids" mature at a young age and small size (Tables 2 and 3). Silver perch mature just before their first birthday between 91 and 95 mm SL (Waggy 2004), and star drum at one year of age and 80 mm – 100 mm TL (Welsh and Breder 1923, Hildebrand and Cable 1934). Holt and Riley (1999) observed cubbyu in captivity to spawn when they were 150 mm SL and over one year old.

Silver perch and star drum are spring – summer spawners. Silver perch spawning from March – May with mean peak GSI values of 12 % in April (Waggy 2004). Spawning occurs in star drum from April – June (Gunter 1938). The spawning season for cubbyu is unknown, however Holt and Riley (1999) observed captive cubbyu to have a spawning frequency of 1.4 – 2.3 d (three to five times a week). In comparison, silver perch spawn almost daily (Waggy 2004). The spawning frequency for star drum is unknown.

The "lesser sciaenids" have the lowest batch fecundity of the groups, but mean relative fecundity is higher than that of the greater sciaenids (Table 3). Relative fecundity of silver perch was estimated from data presented by Chavance et al. (1984), and was found to be between 151 and 1387 ova / g BW, and batch fecundity was estimated to be between 2497 – 50,565 ova. Cubbyu spawning in captivity released a mean of 2000 eggs per spawning event (Holt and Riley 1999). Information for star drum is unavailable.

"Intermediates"

Sharing traits of both the "greater" and "lesser" sciaenids is an intermediate group which is typified by moderate size, age, and other life history traits. Some members of this group support commercial fisheries, and although they are generally not as important as the larger sciaenids, they are more economically valuable than the "lesser sciaenids." Many of these species are caught as bycatch, and most are sought by recreational fishermen.

The species in this group cover a wide range in the western Atlantic, GOM and Caribbean. Atlantic croaker occur from the Gulf of Maine to southern

Florida, in the GOM, and down to Argentina. Spot, banded drum, silver seatrout and spotted seatrout are found along the coast of the western Atlantic and in the GOM (DeVries and Chittenden 1982, Sheridan et al. 1984, Pattillo et al. 1997, Hoese and Moore 1998, Carpenter 2002). Sand seatrout are similar in appearance and life history to silver seatrout; however, they live only in the GOM (Hoese and Moore 1998, Carpenter 2002). Ground croaker inhabit the Caribbean Sea and southward along the coast of South America (Carpenter 2002). In addition to these seven intermediate species with well documented reproductive life history traits, three species of *Menticirrhus* can be added to this group based on available information (Table 2). The northern kingfish (*M. saxatilis*), southern kingfish (*M. americanus*) and Gulf kingfish (*M. littoralis*) are all found along the coast of the western Atlantic and GOM, with the southern and Gulf kingfish extending along the coast of South America (Hoese and Moore 1998, Carpenter, 2002).

Most sciaenids in the intermediate group reach a maximum size ≤ 500 mm TL and a maximum age of two to three years (Tables 2 and 3). Spot reach 360 mm TL in size (Carpenter, 2002) and have a life span up to five years (usually two to three years) (Pattillo et al. 1997). Banded drum achieve a maximum length of 220 mm TL (Carpenter, 2002) and have a life span of two to three years (Standard and Chittenden 1984). Sand seatrout attain a size of 590 mm TL (Trent and Pristas 1977) and a maximum age of three years (Shlossman and Chittenden 1981). Silver seatrout reach 400 mm TL (Carpenter, 2002) with an estimated maximum life span of two years (DeVries and Chittenden 1982). Ground croaker grow to a maximum size of 350 mm TL (Carpenter 2002) and have a life span of two years (Louis 1985). Southern kingfish, Gulf kingfish and northern kingfish all have a maximum size of 450 – 500 mm TL and may have a life span of three to four years (Harding and Chittenden 1987, Amstrong and Muller 1996). However, Atlantic croaker and spotted seatrout are larger and older than the other "intermediate" sciaenids." Atlantic croaker may attain a size of 668 mm TL and maximum age of eight years in the GOM (Barger 1985, Pattillo et al. 1997). However, specimens from the north-western GOM (TX, LA) have been reported to have life spans of only one to two years and a maximum size of 357 mm TL (White and Chittenden 1977, Sheridan et al. 1984). In the GOM, spotted seatrout may attain an age of nine years (Murphy and Taylor 1994) and a size of 700 mm TL (Carpenter 2002).

All "intermediate sciaenids" reach sexual maturity in their first year of life at relatively small sizes (Table 2). In Atlantic croaker, maturation occurs near the end of their first year of life at 140 – 170 mm TL (White and Chittenden 1977, Sheridan et al. 1984). Spotted seatrout reach sexual maturity after their first birthday at around 250 mm SL (Brown-Peterson 2003). Female spot mature at 127 mm SL and age 1 in the GOM (Sheridan et al. 1984). Standard and Chittenden (1984) found banded drum to mature in their first year of life between 80 – 130 mm SL. Sand seatrout mature between 140 and 180 mm TL as young-of-the-year fish just before their first birthday (Shlossman and Chittenden 1981, Ditty et al. 1991, Brown-Peterson et al. In prep.) as do silver seatrout which mature at 140 – 170 mm SL (DeVries and Chittenden 1982, Sheridan et al. 1984). Ground croaker mature at about 158 mm TL (Torres-Castro et al. 1999); age at maturation is unavailable. Southern kingfish mature at age 1 and between 150 – 220 mm TL (Harding and Chittenden 1987). Limited information is available for both the northern and Gulf kingfish; however, they appear to have a similar size- and age-at-maturation (Armstrong and Muller 1996).

While spawning season varies within the "intermediate sciaenids", duration of spawning is similar. Atlantic croaker exhibit a protracted spawning season from September through March peaking in October with GSI values of 4.5 % (White and Chittenden 1977, Sheridan et al. 1984, Pattillo et al. 1997). Spot spawn from November through March in the northern GOM with maximum mean GSI values of 4.5 % (Sheridan et al. 1984, Cowan and Shaw 1988) with the season becoming more prolonged as latitude decreases (Pattillo et al. 1997). Spotted seatrout spawn from April to September in the GOM (Brown-Peterson 2003) with maximum GSI ranging from 5 – 14 % (Brown-Peterson et al. 2002). They spawn every four to five days (Brown-Peterson, 2003). Banded drum are generally fall spawners (September – November) with a minor spring period from April – June in the GOM with mean peak GSI values of 5.5 % (Ross 1984, Standard and Chittenden 1984). Sand seatrout display two distinct spawning peaks during a seven month reproductive period, a spring (March – May) peak and a late summer peak (August – September) with mean peak GSI values of 4.5 – 5.5 % (Shlossman and Chittenden 1981, Sheridan et al. 1984, Ditty 1986; Ditty et al. 1988, Brown-Peterson et al. In prep.). Sand seatrout display spawning frequencies of 2.8 d during peak spawning times (Brown-Peterson et al. In prep.). Silver seatrout spawn throughout the late spring and summer (March – October) with two distinct peaks in spawning and maximum mean GSI values of 3.5 % (DeVries and Chittenden 1982, Sheridan et al. 1984). Spawning of ground croaker occurs from March to October in the Caribbean with GSI values ranging between 3.0 – 5.1 % (Louis 1985, Torres-Castro et al. 1999). Southern kingfish spawn in two peaks from February – November (spring and late summer peak) (Gunter 1938, Harding and Chittenden 1987). Northern kingfish and Gulf kingfish are also reported to spawn in the spring and late summer (Armstrong and Muller 1996). The spawning frequency for Atlantic croaker, spot, banded drum, silver seatrout, northern kingfish, southern kingfish, Gulf kingfish, and ground croaker is unknown.

Batch and relative fecundity of the "intermediate sciaenids" were similar among all species (Table 2). The relative fecundity of Atlantic croaker, spot, sand seatrout, and silver seatrout was estimated from data presented by Sheridan et al. (1984), and banded drum relative fecundity was estimated from Standard and Chittenden (1984). Batch fecundity and relative fecundity for the three species of kingfish is unknown.

Many reproductive life history traits of Atlantic croaker and spotted seatrout have a stronger affinity with the "greater sciaenid" group than the "intermediate" group (Table 3). Indeed, prior to analysis, we assumed spotted seatrout to be a "greater sciaenid" based on maximum age, spawning frequency, relative fecundity, and their commercial and recreational importance. The commercial fishery for spotted seatrout has been closed in some of the coastal states along the GOM in the U.S. due to decreased landings from overexploitation and habitat destruction (Pattillo et al. 1997). However, spotted seatrout are still greatly sought after and heavily fished recreationally along the GOM (Pattillo et al. 1997), where they are one of the primary target species of anglers (VanderKooy and Muller 2004). Analysis of otoliths from prehistoric populations of spotted seatrout in Texas (800 – 5,000 years ago) suggest there was a greater percentage of the oldest (age 9) spotted seatrout in prehistoric times and that contemporary populations grow faster than prehistoric populations (Colura and Vickers 1998). Colura and Vickers (1998) note that the percentage of older age fish (not only spotted seatrout, but also Atlantic croaker, red drum, and black drum) was greater in prehistoric times, demonstrating the impact modem fishing pressure has on the populations of these sciaenids. Thus, spotted seatrout may have been considered a "greater sciaenid" historically, but life history adaptations due to heavy fishing pressure (ie., faster growth, smaller size/age at maturation, reduced batch fecundity) which may be related to decreases in population size (Brown-Peterson and Warren 2001), could explain the current inclusion of this species in the "intermediate sciaenid" category.

The historical change in life history traits of Atlantic croaker is even more striking than that for spotted seatrout. In prehistoric times, Atlantic croaker from St. Augustine, FL reached 15 years of age (Hales and Reitz 1992), and prehistoric Atlantic croaker populations in Texas were older than contemporary populations (Colura and Vickers 1998). Due to overfishing in some areas, Atlantic croaker has decreased in maximum size and age, age- and size-at-maturity (Diamond *et al.* 2000) and is considered overexploited in the GOM (Pattillo et al. 1997). While large (668 mm TL, Pattillo et al. 1997) and old (eight years, Barger 1985), Atlantic croaker have been reported from the GOM, current trends indicate ages 0 and 1 fish (<366 mm TL) are most commonly captured (White and Chittenden 1977, Colura and Vickers 1998). Thus, Atlantic croaker appear to be correctly classified as "intermediate sciaenids" based on current reproductive life history traits (Table 3). However, historically this species was older, larger, and supported an extensive commercial fishery in the GOM (Diamond et al. 1999), and could have been considered a "greater sciaenid" at that time.

CONCLUSIONS

We have found that the Sciaenidae indigenous to the GOM and Caribbean Sea can be divided in to three reproductive life history strategies. "Greater sciaenids" have a long life span, larger maximum size, larger age- and size-at-maturity, lower spawning frequency, high batch fecundity, and low relative fecundity compared to the other sciaenids. The "lesser sciaenids" mature quickly with low batch fecundity, a shorter spawning season, high spawning frequency, and high relative fecundity. "Intermediate sciaenids" are between these groups with more moderate traits. The "greater" and "intermediate" sciaenids fall into the periodic strategy proposed by Winemiller and Rose (1992), whereas the traits of "lesser sciaenids" are more similar to the opportunistic strategists. Periodic strategists delay maturation to attain a sufficient size for large clutch (batch fecundity) production with synchronous spawning, and opportunistic strategists mature at small sizes and have small clutch sizes but high relative reproductive effort (Winemiller and Rose 1992). Pianka (2000) also described reproductive strategies, but in terms of the r – K selection continuum based on the maximal instantaneous rate of increase (r_{max}), which takes into account the simultaneous processes of birth and death. Small organisms have higher r_{max} values corresponding to shorter generation times and high reproductive effort (r strategists). Larger organisms tend to delay reproduction (i.e., greater size-at-maturity) which results in reduced r_{max} values (K strategists) (Pianka 2000). Overall, the "greater sciaenids" appear to exhibit a k-selected life history, while the "lesser sciaenids" seem to be r-selected. These attributes may play a significant role in the sustainability of the species under various scenarios of overfishing in the GOM and Caribbean Sea.

Management of species groups is complex; even those classified together may have subtle differences within their reproductive life histories. Thus, a management strategy may work with one species, but negatively affect others in the same group (Winemiller and Rose 1992). Additionally, latitudinal differences within the same species cause deviations in life history traits (Snyder and Peterson 1999, Brown-Peterson et al. 2002), and management strategies should be adjusted accordingly. Overexploitation can change life history traits and demographics of a species, resulting in changes in ordination space and shifting the species along the gradient, resulting in possible classification into a different group. This appears to be the case with Atlantic croaker. Furthermore, our analysis, in conjunction with historical data and current fishery practices, suggest the shift of spotted seatrout from the "greater" to the "intermediate" group is a recent occurrence. Continued exploitation may result in other species shifting among reproductive life history strategies.

ACKNOWLEDGEMENTS

We would like to thank Cathy Schloss, Joyce Shaw, and Margie Williams of the Gunter Library at the Gulf Coast Research Laboratory for their assistance in literature collection. Special thanks to Dave Nieland for sharing his data on red and black drum so freely. Thanks also to Jim Franks for access to his personal literature collection.

LITERATURE CITED

Armstrong, M.P. and R.G. Muller. 1996. A summary of biological information for southern kingfish (*Menticirrhus americanus*), Gulf kingfish (*M. littoralis*), and northern kingfish (*M. saxatilis*) in Florida waters. *Florida Marine Research Institute Report Series* IHR 1996-004.

Bager, L.E. 1985. Age and growth of Atlantic croakers in *the* northern Gulf of Mexico, based on otolith sections. *Transactions of the American Fisheries Society* 114:847-850.

Balon, E.K. 1975. Reproductive guilds of fishes: a proposal and definition. *Journal of the Fisheries Research Board of Canada* 32:821-864.

Beckman, D.W., A.L Stanley, J.H. Render, and C.A. Wilson. 1990. Age and growth of black drum in Louisiana USA water of the Gulf of Mexico. *Transactions of the American Fisheries Society* 119:537-544.

Böhlke, J.E. and C.C.G. Chaplin. 1993. *Fishes of the Bahamas and Adjacent Tropical Waters, 2nd Edition*. University of Texas Press. Austin, Texas USA. 771 pp.

Brown-Peterson, N.J. 2003. The reproductive biology of the spotted seatrout. Pages 99-133. in: S. Bortone (ed.). *The Biology of the Spotted Seatrout*. CRC Press. Boca Raton, Florida USA.

Brown-Peterson, N.J. and J.R. Warren. 2001. The reproductive biology of spotted seatrout, *Cynoscion nebulosus*, along the Mississippi gulf coast. *Gulf of Mexico Science* 1:61-73.

Brown-Peterson, N.J., M.S. Peterson, D.L. Nieland, M.D. Murphy, R.G. Taylor, and J.R. Warren. 2002. Reproductive biology of female spotted seatrout, *Cynoscion nebulosus*, in the Gulf of Mexico: differences among estuaries? *Environmental Biology of Fishes* 63:405-415.

Brown-Peterson, N.J., G.L. Waggy, and J.R. Warren. [In prep.]. Life history characteristics of sand seatrout *Cynoscion arenarius* in Mississippi coastal waters.

Carpenter, K.E. 2002. *The Living Marine Resources of the Western Central Atlantic. Volume 2: Bony fishes part 2 (Opistognathidae to Molidae), sea turtles and marine mammals*. Pages 1375-2127 in: FAO Species Identification Guide for Fishery Purposes. FAO, Rome, Italy.

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. *Fisheries Bulletin* 75:656-702.

Clark, K.R and R.M. Warwick. 2001. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation, 2nd Edition*. PRIMER-E, Plymouth, United Kingdom.

Colura, R.K. and R. Vickers. 1998. Estimation and comparison of age and growth of prehistoric populations of Texas marine fishes with recent populations. Final Report, Federal Aid in Sport Fish Restoration Act. Grant F-36-R 22. Texas Parks and Wildlife Dept., Austin, Texas USA. 22 pp.

Comyns, B.H., J. Lyczkowski-Shultz, D.L. Nieland, and C.A. Wilson. 1991. Reproduction of red drum, *Sciaenops ocellatus*, in the north-central Gulf of Mexico: seasonality and spawner biomass. Pages 17-26. in: R.H. Hoyt (ed.). *Larval fish Recruitment and Research in the Americas: Proceedings of the Thirteenth Annual Fish Conference*; 21-26 May 1989, Merida, Mexico. NOAA Tech. Rep. NMFS 95. 17-26.

Cowan, J.H., Jr. and R.F. Shaw. 1988. The distribution, abundance, and transport of larval sciaenids collected during winter and early spring from the continental shelf water off west Louisiana. *Fisheries Bulletin* 86:129-142.

DeVries, D.A. and M.E. Chittenden, Jr., 1982. Spawning, age determination, longevity, and mortality of the silver seatrout, *Cynoscion nothus*, in the Gulf of Mexico. *Fisheries Bulletin* 80:487-498.

Diamond, S.L., L.B. Crowder, and L.G. Cowell. 1999. Catch and bycatch: the qualitative effects of fisheries on population vital rates of Atlantic croaker. *Transactions of the American Fisheries Society* 128:1085-1105.

Diamond, S.L., L.G. Cowell, and L.B. Crowder. 2000. Population effects of shrimp trawl by catch on Atlantic croaker. *Canadian Journal of Fisheries and Aquatic Sciences* 57:2010-2021.

Ditty, J.G., G.G. Zieske, and R.G. Shaw. 1988. Seasonality and depth distribution of larval fishes in the northern Gulf of Mexico above latitude 26°00'N. *Fisheries Bulletin* 86:811-823.

Ditty, J.G., M. Bourgeois, R. Kasprzak, and M. Konikoff. 1991. Life history and ecology of sand seatrout *Cynoscion arenarius* Ginsburg, in the northern Gulf of Mexico: a review. *Northeast Gulf Science* 12:35-47.

Ditty, J.G. 1986. Ichthyoplankton in neritic waters of the northern Gulf of Mexico off Louisiana: Composition, relative abundance, and seasonality. *Fisheries Bulletin* 84:935-946.

Everheart, W.H., A.W. Eipper, and W.D. Youngs. 1975. *Principles of Fishery Science.* Cornell University Press, Ithaca, New York USA. 288 pp.

Fitzhugh, G.R., B.A. Thompson, and T.G. Snider, III. 1993. Ovarian development, fecundity, and spawning frequency of black drum *Pogonias cromis* in Louisiana. *Fisheries Bulletin* 91:244-253.

García-Cagide, A., R. Claro, and B.V. Koshelev. 2001. Reproductive Patterns of Fishes of the Cuban Shelf. Pages 73-114. in: R. Claro, K.C. Lindeman, and L.R. Parenti (eds.). *Ecology of the Marine Fishes of Cuba.* Smithsonian Institution Press, Washington, D.C. USA.

Gelwick, F.P., S. Arkin, D.A. Arrington, and K.O. Winemiller. 2001. Fish assemblage structure in relation to environmental variation in a Texas gulf coastal wetland. *Estuaries* 24:285-296.

Gunter, G. 1938. Seasonal variations in abundance of certain estuarine and marine fishes in Louisiana, with particular reference to life histories. *Ecological Monogrographs* 8:315-345.

Hales, L.S., Jr. and E.L. Reitz. 1992. Historical changes in age and growth of Atlantic croaker, *Micropogonias undulatus* (Perciformes: Sciaenidae). *Journal of Archaeological Science* 19:73-99.

Harding, S.M. and M.E. Chittenden, Jr. 1987. Reproduction, movements, and population dynamics of the southern kingfish, *Menticirrhus americanus,* in the northwestern Gulf of Mexico. NOAA Tech. Rep., NMFS 49. 21 pp.

Hildebrand, S.F. and L.E. Cable. 1934. Reproduction and development of whitings or kingfishes, drums, spot, croaker, and weakfishes or seatrouts, family Sciaenidae, of the Atlantic coast of the United States. *Bulletin of the U.S. Bureau of Fisheries* 48:41-117.

Hoese, H.D., and R.H. Moore. 1998. *Fishes of the Gulf of Mexico, Texas, Louisiana, and Adjacent Waters, 2nd Edition.* Texas A&M University Press, College Station, Texas USA. 422 pp.

Holt, G.J. and C.M. Riley. 1999. Larval and juvenile development of the cubbyu *Pareques umbrosus* with notes on the high hat *Pareques acuminatus* larvae. *Bulletin of Marine Science* 65:825-838.

Humann, P. 1989. *Reef Fish Identification: Florida, Caribbean, Bahamas.* New World Publications, Orlando, Florida USA. 271 pp.

Jennings, S., M.J. Kaiser, and J.D. Reynolds. 2001. *Marine Fisheries Ecology.* Blackwell Science, Malden, Massachusetts USA. 417 pp.

Louis, M. 1985. Reproduction et croissance de *Bairdiella ronchus* (Poisson Sciaenidae) dans les mangroves de Guadeloupe (Antilles françaises). *Revue d'Hydrobiologie Tropicale* 18:61-72.

Macchi, G.J., E.M. Acha, and M.I. Militelli. 2003. Seasonal egg production of whitemouth croaker (*Micropogonias furnieri*) in the Rio de la Plata estuary, Argentina-Uruguay. *Fisheries Bulletin* 101:332-342.

Manickchand-Heileman, S.C. and J.S. Kenny. 1990. Reproduction, age, and growth of the whitemouth croaker *Micropogonias furnieri* (Desmarest 1823) in Trinidad waters. *Fisheries Bulletin* 88:523-529.

Murphy M.D. and R.G. Taylor. 1990. Reproduction, growth, and mortality of red drum *Sciaenops ocellatus* in Florida waters. *Fisheries Bulletin* 88:531-542.

Murphy M.D. and R.G. Taylor. 1994. Age, growth, and mortality of spotted seatrout in Florida waters. *Transactions of the American Fisheries Society* 123:482-497.

Music, J.L., Jr. and J.M Pafford. 1984. Population dynamics and life history aspects of major marine sportfishes in Georgia's coastal waters. Dept. Nat. Res. Coastal Res. Div. Contr. Ser. # 38. Brunswick, Georgia USA. 382 pp.

Nieland, D.L and C.A. Wilson. 1993. Reproductive biology and annual variation of reproductive variables of black drum in the Northern Gulf of Mexico. *Transactions of the American Fisheries Society* 122:318-327.

Ocaña-Luna, A. and M. Sánchez-Ramírez. 1998. Feeding of sciaenid (Pisces: Sciaenidae) larvae in two coastal lagoon of the Gulf of Mexico. *Gulf Research Reports* 10:1-9.

Pattillo, M.E., T.E. Czapla, D.M. and M.E Monaco. 1997. *Distribution and Abundance of Fishes and Invertebrates in Gulf of Mexico estuaries, Volume II: Species life history summaries.* ELMR Rep. No. 11. NOAA/NOS Strategic Environmental Assessment Division, Silver Spring, Maryland USA. 377pp.

Peterson, M.S. and S. J. VanderKooy. 1997. Distribution, habitat characterization, and aspects of reproduction of a peripheral population of bluespotted sunfish *Enneacanthus gloriosus* (Holbrook). *Journal of Freshwater Ecology* 12:151-161.

Pianka, E.R. 2000. *Evolutionary Ecology, 6th Edition.* Addison Wesley Educational Publishers, San Francisco, California USA. 512 pp.

Randall, J.E. 1983. *Caribbean Reef Fishes, Revised Edition.* T.F.H. Publications, Neptune City, New Jersey USA. 350 pp.

Rooker, J.R., S.A. Holt, M.A. Soto, and G.J. Holt. 1998. Postsettlement patterns of habitat use by Sciaenid fishes in subtropical seagrass meadows. *Estuaries* 21:318-327.

Ross, S.W. 1984. Reproduction of the banded drum, *Larimus fasciatus*, in North Carolina. *Fisheries Bulletin* 82:227-235.

Shlossman, P.A. and M.E. Chittenden. 1981. Reproduction, movement, and populations dynamics of the sand seatrout, *Cynoscion arenarius*. *Fisheries Bulletin* 79:649-669.

Sheridan, P.F., D.L. Trimm, and B.M. Baker. 1984. Reproduction and food habits of seven species of northern Gulf of Mexico fishes. *Contributions in Marine Science* 27:175-204.

Smith-Vaniz, W. F., B.B. Collette, and B.E. Luckhurst. 1999. *Fishes of Bermuda: History, Zoogeography, Annotated Checklist, and Identification Keys*. Allen Press, Lawrence, Kansas USA.

Standard, G.W. and M.E. Chittenden, Jr. 1984. Reproduction, movements, and population dynamics of the banded drum, *Larimus fasciatus*, in the Gulf of Mexico. *Fisheries Bulletin* 82:337-363.

Synder, D.J. and M.S. Peterson. 1999. Life history of a peripheral population of bluespotted sunfish *Enneacanthus gloriosus* (Holbrook) with comments on geographic variation. *American Midland Naturalist* 141:345-357.

Torres-Castro, L., A. Santos-Martínez, and A. Acero P. 1999. Reproducción de *Bairdiella ronchus* (Pisces:Sciaenidae) en la Ciénaga Grande de Santa Marta, Caribe Colombiano. *Revue d'Hydrobiologie Tropicale* 47:553-560

Trent, L. and P. Pristas. 1977. Selectivity of gill nets on estuarine and coastal fishes from St. Andrew Bay, Florida. *Fisheries Bulletin* 75:185-198.

VanderKooy, S.J. and R.G. Muller. 2004. Management of spotted seatrout and fishery participants in the U.S. Pages 227-245. in: S.A. Bortone (ed.). *Biology of the Spotted Seatrout*. CRC Press, Boca Raton, Florida USA.

Waggy, G.L. 2004. Life history of silver perch, *Bairdiella chrysoura*, from the north-central Gulf of Mexico. Masters Thesis. The University of Southern Mississippi, Hattiesburg, Mississippi USA. 75 pp.

Welsh, W.W. and C.M. Breder, Jr. 1923. Contributions to life histories of Sciaenidae of the eastern United States coast. *Bull. U.S. Bur. Fish.* 39:141-201.

White, M.L. and M.E. Chittenden. 1977. Age determination, reproduction, and population dynamics of the Atlantic croaker, *Micropogonias undulatus*. *Fisheries Bulletin* 75:109-123.

Wilson, C.A and D.L. Nieland. 1994. Reproductive biology of red drum, *Sciaenops ocellatus*, from the neritic waters of the northern Gulf of Mexico. *Fisheries Bulletin* 92:841-850.

Winemiller, K.O. and K.A. Rose. 1992. Patterns of life-history diversification in North American fishes: implications for population regulation. *Canadian Journal of Fisheries and Aquatic Sciences* 49:2196-2217.

BLANK PAGE

New Paradigms for Yellowfin Tuna Movements and Distributions – Implications for the Gulf and Caribbean Region

RANDY E. EDWARDS[1] and KENNETH J. SULAK[2]
[1] *College of Marine Science*
University of South Florida
600 4th St. South
St. Petersburg, Florida 33701 USA
[2]*U.S. Geological Survey*
Center for Aquatic Resources Studies,
Florida Caribbean Science Center
Gainesville, Florida 32653 USA

ABSTRACT

Yellowfin tuna, *Thunnus albacares*, (YFT) is an important species in recreational and commercial fisheries in the Gulf of Mexico (GOM) and Caribbean region. However, very little scientific information about YFT in the region exists in general and in particular about its movements and migrations, except information from limited tag/recapture studies that indicates that juveniles move great distances and mix with the large Eastern Atlantic populations. Until recently, YFT was probably viewed by most fisheries scientists as a highly migratory species that is caught by fishermen at various places along the species' large-scale, oceanic migratory routes. Recently, however, independent acoustic tagging and telemetry studies of YFT in three different locations and environments have shown a previously unknown, different pattern. YFT have been shown to exhibit continued long-term residence around seamounts in the Gulf of California, fish aggregating devices (FADs) in Hawaii, and deepwater petroleum structures in the Gulf of Mexico. The recent findings of protracted association of YFT with objects and features suggest that fisheries scientists and managers should view YFT in a new and different light. Many large petroleum structures have been deployed in deep waters of the outer continental shelf of the northern GOM, numerous FADs have been installed around Caribbean islands, and numerous seamount-like bathymetric features exist in the Gulf and Caribbean. Resident or seasonally resident aggregations of YFT may occur at these locations, perhaps including some Caribbean islands.

KEY WORDS: Yellowfin tuna, *Thunnus albacares*, distribution

Los Paradigmas Nuevos para Movimientos de Atún de Yellowfin y Distribuciones – las Implicaciones para el Golfo y la Región Caribe

El atún de aleta amarilla (YFT), *Thunnus albacares*, es una especie importante en pesquerías recreativas y comerciales en el Golfo de México (GOM) y en el Caribe. Sin embargo, hay muy poco información científica acerca de YFT en la region, especialmente acerca de sus movimientos y migraciones, menos información de estudios limitados que indica que juveniles mueven gran distancias y se mezclan con las poblaciones atlánticas orientales. YFT fue visto, probablemente por la mayoría de científicos, como una especie migratoria capturada por pescadores en sus rutas migratorias. Recientemente, estudios acústicos de YFT en tres ubicaciones diferentes han mostrado una pauta previamente desconocida y diferente. YFT ha exhibido residencia continuada alrededor de promontorios marinos en el Golfo de California, alrededor de agregadores de peces (FADs) en Hawaii, y alrededor de plataformas de petróleo en aguas profundas en el Golfo de México. Estos resultados recientes describiendo la asociación de YFT con objetos sugieren que científicos deben considerar YFT en una manera diferente. Muchas plataformas de petróleo se han construado en el GOM, numerosas FADs se han instalado alrededor de islas caribes, y numerosos promontorios marinos existen en el Golfo y el Caribe. Agregaciones de YFT pueden ocurrir en estas ubicaciones, quizás inclusive algunas islas caribes.

PALABRAS CLAVES: Atún de aleta amarilla, *Thunnus albacares*, (YFT)

INTRODUCTION

The offshore oil and gas industry in the northern Gulf of Mexico (GOM) has rapidly expanded over the last decade into deeper and deeper waters of the continental shelf (Richardson et al. 2004) by developing new technology, including various types of permanent floating structures that presently drill and produce petroleum from structures in depths as deep as 1,646 m [Minerals Management Service (http://www.gomr.mms.gov/homepg/ offshore/deepwatr/dpstruct.html)]. Carney (1997) recognized early in this expansion that there was a potential for these new deepwater (depth > 305 m = 1,000 ft) petroleum structures (DPSs) to affect open-ocean fish species by acting as fish aggregating devices (FADs). Edwards and Sulak (2002) assessed this potential by examining the scientific literature on FADs and by obtaining expert opinions of FADs researchers. Furthermore, sport fishermen were already catching large numbers of open-ocean fish from around these new deepwater oil rigs (Sloan 2001). Therefore, Edwards and Sulak (2003) concluded that DPSs had a high likelihood of generally having substantial FADs effects on highly migratory fish species, particularly on tuna species, and thus that direct study of the effects of DPSs on tunas was needed.

Yellowfin tuna, *Thunnus albacares*, is recreationally and commercially important in the Gulf of Mexico and Caribbean Sea and undoubtedly is the species that is most strongly attracted to FADs. This attraction is so strong that presently most of the world catch of yellowfin tuna (YFT) is taken around drifting or anchored objects that serve as FADs (Fonteneau et al. 2000). This aggregating effect is so great that Marsac et al. (2000) suggested that drifting FADs may act as an "ecological trap" and negatively impact fisheries.

Twenty-six permanent DPSs presently are in place on the outer continental shelf of the northern GOM. Anchored FADs recently have been deployed in the French Antilles (Taquet 1998, Laurans et al. 2000) and off Cuba (Martin 1999). A network of FADs has been deployed around the Hawaiian Islands for over two decades and primarily benefits sport and artisanal fishermen (Holland et al. 2000).

Holland et al. (1990) provided some of the earliest information about the relationships between yellowfin tuna and FADs by using acoustic telemetry to track yellowfin tuna movements around Hawaiian FADs. They observed a diurnal pattern, with YFT remaining very near the FAD (on-FAD) during daylight hours, but making excursions of up to about 9.2 km away from the FAD (off-FAD) at night, and returning to the FAD early the next morning. They also found that YFT could navigate between FADs and to and from island drop-off features over distances separated by at least 18.5 km. Similarly, Marsac et al. (1996) acoustically tracked YFT around FADs deployed around Reunion Island in the Indian Ocean and suggested that YFT aggregate around FADs for a limited time until they migrate out of the area. Holland et al. (1999) evaluated the aggregation effects of a natural seamount off Hawaii using conventional tagging and estimated that the half-life residence time of YFT was about 15 days and suggested that seamounts act as orientation points for larger- scale migrations, rather than feeding stations. Sibert et al. (2000) considered YFT populations around this seamount to be "labile", although it must be pointed out that the YFT tagged in this study were relatively small, with the large majority being less than 60 cm FL (Itano and Holland 2000). However, in all these studies the developing concept or paradigm was that migrating YFT are attracted to FADs around which they temporarily aggregate before continuing their long, oceanic migrations.

For example, Kleiber and Hamilton (1994) modeled skipjack tuna movements in terms of diffusivity and concluded that four or five FADs in an area approximately 50 x 50 km could reduce propensity for skipjack tuna to leave that area by 50%. Hence the view was that FADs retarded normal migrational movements of tunas.

However, Klimley and Holloway (1999) studied movements of acoustically tagged YFT around Hawaiian FADs using automatic, continuously-recording hydrophone and receiver systems ("listening stations") attached to FADs moorings and found that YFT acoustically tagged at Hawaiian FADs returned repeatedly to FADs, sometimes with long intervals between visits, often synchronously with other tagged individuals, and often with temporal precision.

Klimley and Holloway (1999) viewed their findings as indicating that tuna had migratory pathways, within which "way points", such as FADs, are visited with temporal regularity. In other words, all of these earlier studies emphasized the migratory perspective of YFT presence, with FADs and some natural features acting as points of temporary residence within a larger migratory pathway.

In this light, we conducted a study of YFT around GOM DPSs, with the goal of examining their temporal and spatial relationships to these large structures. We planned to test the hypothesis that YFT would exhibit relationships similar to those described by Holland et al. (1990) and Josse et al. (2000) around anchored FADs — on-FAD during daylight, off-FAD movement and return during night and early morning. An alternative hypothesis was that YFT would exhibit the on-FAD during night and off-FAD during daylight pattern of YFT around drifting FADs (Hall et al. 1992, Marsac et al. 1996, Menard et al. 2000). Another major objective of the study was to determine if YFT presence near DPSs was ephemeral (hours to few days) or protracted (many days). A final objective was to determine if acoustic-tagged YFT presence, site fidelity, and movements between DPSs could be monitored in the future by continuously operating hydrophone/receiver systems such as used by Klimley et al. (1998) and Klimley and Holloway (1999) placed on or near the DPSs.

METHODS

Study Site

The primary study site was a deepwater oil rig (water depth = 1,006 m), Shell Oil Company's *Brutus*, located at 27.796 N, 90.648W in the northern Gulf of Mexico about 120 km west of the Mississippi River Delta, approximately 140 km due south of the easternmost tip of Isles Derenieres bordering western Terrebonne Bay, LA (Figure 1). This large tension-leg platform consists of a hull comprised of four 20-m diameter x 50-m tall cylindrical columns connected by 61-meter subsurface pontoons, anchored with 12, 81-cm dia. steel tendons connected to pilings driven 93 m into the bottom. Five levels of deck modules and supporting structures together weighing over 2,000 t are supported on the approximately 101 m x 101 m TLP hull. The DPS closest to *Brutus* is Chevron Oil Company's *Genesis*, a spar rig (single cylindrical hull, 37 m dia x 215 m tall, ~ 200 m subsurface, anchored with 14 13.3 cm chain/cable units) is 13 km E of Brutus in 789 m depth. The next closest structure is Shell *Bullwinkle*, a fixed-leg platform 27 km WNW of *Brutus* in 412 m depth. Current flow during the study was usually toward NNW and was roughly estimated (from vessel drift rate determined by GPS) to be 0.9-2.8 km/hr) and resulted in obviously visible turbulence downstream of the structures.

Tagging and Tracking

Yellowfin tuna were caught 50 - 300 m from the structure (*Brutus*) by angling using typical rod-and-reel gear with 23 - 36 kg-test (50 - 80 lb-test) line and circle hooks baited with live or dead natural baits. Fish were tagged from a small (4 m) inflatable boat tethered next to the research vessel (*R.V. Acadiana*, Louisiana Universities Marine Consortium, Cocodrie, LA). The fish were either brought alongside the inflatable, and restrained by holding the leader close to the hook while the fish was simultaneously held by the caudle peduncle, and tagged while in the water; or were brought aboard the inflatable, and placed on a seawater-soaked foam pad before tagging and releasing. Coded acoustic transmitter tags, Sonotronics CHP-87-L, 18 mm dia X 90 mm long, 35-72 kHz) or coded depth-indicating tags (Sonotronics DT-97-L, 18 mm dia X 86 mm long) tags (two tags) were attached by 7cm nylon monofilament (23 kg-test) tethers to nylon dart heads (Floy BFIM-96 billfish (BF) tags on stainless steel applicator mandrils) which were inserted about 1 cm below the dorsal fin at about a 45 deg angle from vertical (dorsal) and about the same angle posteriorly to a depth of about 5 cm). Some transmitter tags were applied, after bringing the fish into the inflatable boat, using a loop of monofilament line (23 kg-test) encircling the fish between the two dorsal fins (Figure 2). The loop was made snug around the fish by sliding a bronze leader sleeve down the loop, crimping the sleeve, and trimming the excess meter. The loop included a bimetallic (bronze and steel) link that would corrode and allow the loop and transmitter to fall away in a few weeks or months. Most circle hooks (all imbedded in the corner of the jaw) left in place by cutting the monofilament close to the hook. Hooks in the first three fish were cut below the hook eye using a small bolt cutter, but the practice was discontinued after seas became too rough to allow it to be done quickly. Because most fish were tagged and released without removing them from the water, weights were estimated by mental comparison with size of other YFT that had been caught, boated (but not tagged due to damage or poor condition) and weighed during the study.

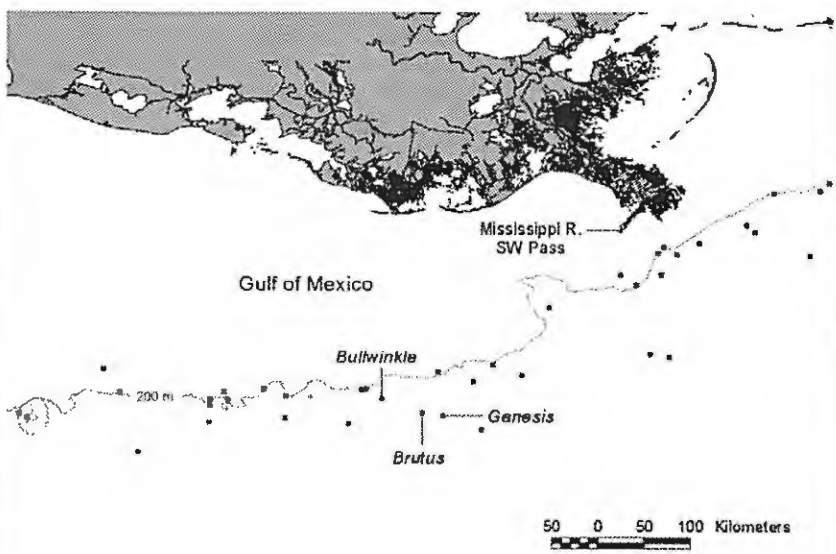


Figure 1. Study site

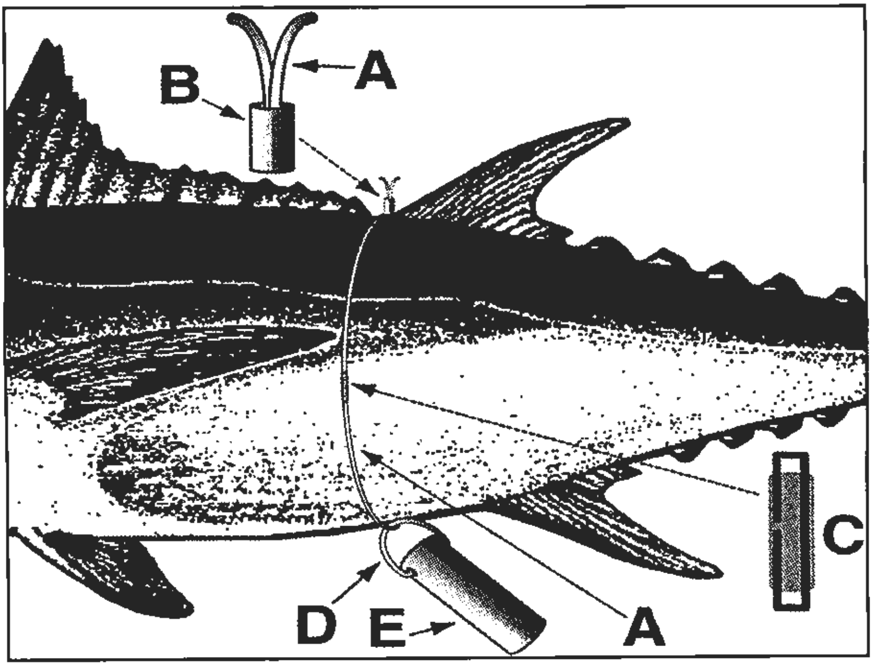


Figure 2. Acoustic transmitter harness. Labeled components are: A—monofilament loop, B—bronze leader sleeve, C—bimetallic (black = steel wire, gray – bronze leader sleeve) corrodible link, D—monofilament loop to transmitter, E—Acoustic transmitter.

Tracking gear consisted of a pair of parabolic (15-deg nominal cone angle) hydrophones (Sonotronics Model DH-4) mounted pointing forward on either side of the vessel, slightly aft of amidships on aluminum masts extending about 1 m below the water surface and secured by fore and aft lines attached to the mast near its lower end. Cables from each hydrophone were connected to separate receivers (Sonotronics Model USR-96), and the output of each receiver was connected to the respective side (relative to the boat/hydrophones) of stereo headphone jacks, providing a stereophonic output. The position of the fish relative to the boat was audibly detectable from amplitude difference in stereo headsets (Edwards 1998).

Fish were not tracked immediately after release or continuously at any time because of several unexpected technical problems (see discussion). Instead, the area (~1 km radius) around the structure was periodically searched several times a day, and sonic-tagged fish presence was detected and identified by code and/or transmitter frequency.

The work was done during the period (late summer) of peak YFT abundance and catches around northern GOM DPSs. It was separated into two legs (due to weather conditions and sea-keeping capability of the research vessel): 24-30 August, and 5-10 September, 2003.

RESULTS

Eleven yellowfin tuna, estimated weights 9-43 kg (20-95 lb), were tagged; nine during Leg 1, and two during Leg 2 (Table 1). Seven fish tagged during Leg 1 were each relocated during 3 - 18 time intervals extending 2 - 14 days after release (Figure 3). Fish 03-1 was not relocated beyond initial detections 40 minutes after release. No signals were detected during searches at *Genesis* on 25 and 28 August.

Table 1. Date, time, estimated weight, transmitter frequency and attachment method for yellowfin tuna tagged with sonic tags.

Fish	Tagged/Released		Weight	Frequency	Attachment
	Date	Time	(kg)	(kHz)	
03-1	08/24/03	20:45	23	37	Dart
03-2	08/25/03	19:50	20	35	Dart
03-3	08/25/03	20:25	18	37	Dart
03-4	08/25/03	22:24	32	35	Dart
03-5	08/26/03	01:10	9	38	Dart
03-6	08/26/03	20:40	27	38	Dart
03-7	08/27/03	20:34	19	72	Harness
03-8	08/27/03	21:34	27	38	Dart
03-9	08/27/03	22:00	11	72	Harness
03-10	09/07/03	13:20	43	35	Dart
03-11	09/08/03	15:40	32	38	Harness

During Leg 2, three of the seven fish relocated during Leg 1 were again relocated at *Brutus*. Only two fish were tagged during Leg-2 because of scarcity of YFT. Fish 03-10 was not relocated during searching shortly after release or during almost two days of searching around *Brutus*, but it was relocated when *Genesis* (13 km E) was searched on the second day after release. Fish 03-11 was relocated at *Brutus* after not being detected for 20 hours after release. No signals were detected around Bullwinkle (27 km WNW) when it was searched on 7 September.

Fish 03-10 and 03-11 were tagged with depth indicating tags. However, due to extremely rough seas on 9 September when they were relocated, they each telemetered only one repeatable depth, 31 m and 96 m, respectively.

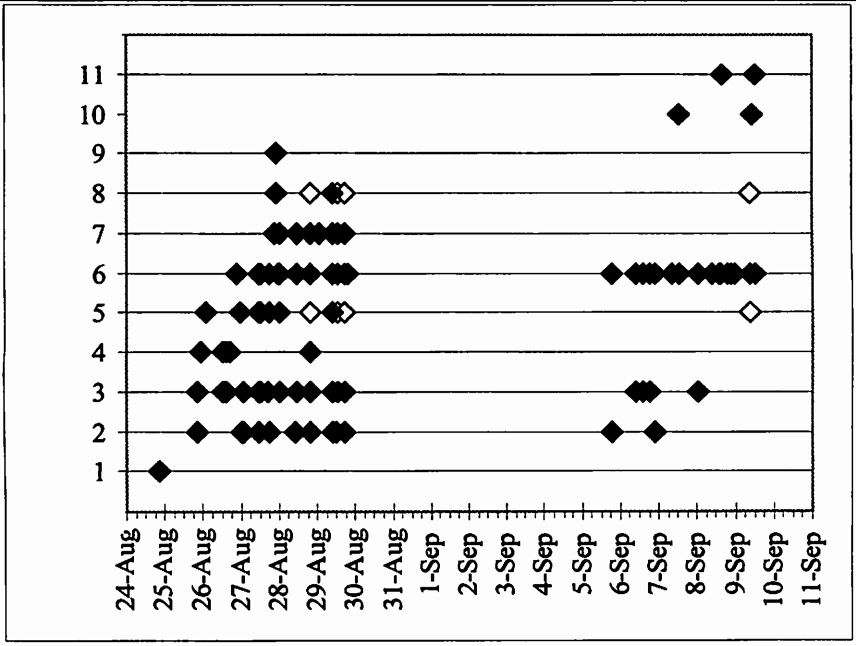


Figure 3. Relocations of acoustic-tagged yellowfin tuna 03-1 – 03-11. First diamond represents release, subsequent diamonds indicate relocations. Open diamonds indicate relocations based on signal frequency (38 kHz) alone but without code discrimination (indicating presence of either 03-5 or 03-8).

DISCUSSION

The relocations, as well as numerous sightings of schools of YFT feeding around *Brutus* at night, did not support the hypothesis that YFT around DPSs conformed to the daytime on-FAD, nighttime off-FAD pattern (Holland et al. 1990, Josse et al. 2000) for anchored FADs, nor did it conform to opposite pattern (day-off, night-on) drifting FAD pattern (Hall et al. 1992, Menard et al. 2000). Recent continuous monitoring around unlighted Hawaiian FADs has also found YFT present at all times of the day (Kim Holland, Personal communication). Acoustic-tagged YFT were relocated near *Brutus* during day and night hours, and diurnal patterns were not evident. It is likely that most fish remained in the immediate area of the structure throughout the day and night, periodically moving short distances away and out of range of acoustic detection. However, longer and more-distant movements also may have occurred during instances in which fish were undetected for long intervals.

The fact that these deepwater platforms are well lighted by numerous bright electric lights almost surely contributes to this 24 hour residence pattern. Schools of YFT were observed to feed intensively at the surface at night in the lighted area near the structure. They appeared to be feeding on flying fish that were abundant and were either attracted by the light or were vulnerable to predation because of the artificial lighting conditions. Interestingly, the fact that YFT are able to feed intensively at night in the lighted area around the structure may even result in trophic subsidy for YFT, perhaps to the degree that the DPSs not only attract YFT, but also enhance their production.

Individual Fish Relocation and Residence Patterns

The first fish (03-1) was never relocated after release. It may have moved out of the area, perhaps because it was released farther from the structure, due to our inexperience and inability to tag it before the boat had drifted away from the rig. It also may have died or shed its transmitter, again possibly due to our lack of previous experience in tagging YFT from a small inflatable boat at night.

Rarely were fish absent for an entire day between their first and last relocations. Fish 03-3 was relocated during every search between its first and last relocation. Fish 03-4 was unusual in that it was relocated a little more than half a day after release, but then was absent until more than two days later, suggesting that it had moved away from the rig during that period.

Fish 03-5 and 03-08 may or may not have been absent during some searches between their first and last relocations. This was due to the fact that both of these fish, plus Fish 03-06 were tagged with 38 kHz transmitters. Fish 03-06 was relocated, and identified from its code sequence, consistently until the end of Leg 1. On numerous occasions a second or second and third transmitter were detected simultaneously on 38 kHz indicating that 03-5 and or 03-08 were present. However, their codes could not be identified due to interference and overlapping pulses from presence of 03-06. On one occasion, 09:41on 29 August, we concluded that the all three transmitters were present, based on the number and frequency of pulses on 38 kHz. Overall, however, the information on presence of 03-5 and 03-6 is ambiguous.

Fish seeming to be absent during searches may have been in the immediate area but out of range and not detectable. Signals were detected but were not able to be identified by code on several occasions when transmissions appeared to be coming from near schools of YFT that were seen to be feeding at the surface and apparently rapidly moving (as indicated by surface feeding activity). Thus, tagged YFT may have been moving rapidly in and out of detection range while schooling with other YFT.

Continuous tracking (Edwards 1998, Edwards et al. 2003) was found to be infeasible. The tracking vessel, when the engines were engaged, produced a noise level (presumably from propellers or shafts) that almost totally obliterated the signal from the transmitter tags. We had never experienced this kind of high noise level while working from a variety of vessel types and sizes in the past. Additionally, the tuna were often very deep, while at other times came to or close to the surface, and geometrically, a 15° parabolic-reflector hydrophone is unable to directly receive surface and deep (>50 m) signals unless the vessel further than 200 m from the fish. At that distance, the noise from the vessel and sea surface often overwhelmed the tag signal. Furthermore, there were problems due to confusing signals reflected from the DPS hull, acoustic shadows of the hull, noise from rough seas and rain, pitch and roll of the vessel in large seas, and interference (on some frequencies) from powerful acoustic Doppler current profilers on the rigs.

CONCLUSIONS

New Information

The finding of relatively long (weeks or more) residence time for YFT around DPSs was at first surprising in view of what was expected from previous studies such as Holland et al. (1990). However, our work was done without the benefit of having seen the results reported by Klimley et al. (2003) that were published almost simultaneously with the start of our field work. Klimley et al. (2003) monitored YFT presence around a shallow seamount (monitored depths less than 18 m to over 66 m) in the Gulf of California using automatic listening stations and found that six of 23 tagged YFT remained for intermediate periods ranging from two to six weeks, while five others remained and were detected regularly for periods of six to 18 months, sometimes even after extended absences of many weeks or several months.

Most recently, Ohta and Kakuma (In press) used similar techniques and found that YFT had median continuous (no day-scale absence) residence times and intermittent residence (staying within 40 km) times of 7.9 and 17.0 days around giant (16 m diameter, maximum subsurface dimension) FADS (nirai) off Okinawa. YFT were resident up to 48 days. Although presence at a FAD was typically continuous with no daily absence until they departed the area, often being recaptured by fishermen at another FAD; one YFT remained at a FAD for 32 days and was absent for 33 days before returning for two more days (Ohta and Kakuma In press). Similar results were found by Dagorn et al. (2003) who used similar methods to monitor a network of FADs around Oahu, Hawaii and found mixed results, with a large fraction of the YFT resident around FADs for only a short period (few days) while others remained within the FADs network for weeks (up to five months) (Kim Holland Personal communication).

In this light, our finding that several YFT remained around a DPS for at least 13 days is not as surprising as it was first thought. Since we were unable to monitor the DPS continuously with automatic listening stations, as was done by Klimley et al. (2003) and Ohta and Kakuma (In press), we cannot say whether YFT residence at DPSs is more like that found the former (months to over a year) or the latter (days to weeks).

Many of the tuna tagged by Ohta and Kakuma (In press) and Dagorn et al. (2003) were small. The mean size of the fish tagged by Ohta and Kakuma (in press) was only 67 cm FL, and all of the fish tagged by Dagorn et al. (2003) were less than 70 cm FL and weigh less than 7 kg (Uchiyama and Kazama, 2003). However the fish tagged by Klimley et al, 2003 were all larger than 70 cm FL with 52% larger than 15 kg and 22% over 50 kg. Only one of the fish tagged in our study was less than 10 kg (9.0 kg) and all except two were larger than 15 kg. YFT begin to become sexually mature at around 70 cm TL (Itano, 2000), and their food habits shift from planktonic to nektonic organisms. Therefore, it is likely that smaller YFT have very different relationships to objects and that their movement and migrations are not the same as those of larger, mature individuals.

Additionally, the presence of other nearby structures, such as FADs shelf drop-offs, seamounts and other bathymetric features probably influences movement patterns. Physical (currents, water temperature, etc.) and biotic (prey and predators) factors also probably affect movements and migrations. Thus differences are to be expected between YFT studied in different locations and conditions.

Despite this complexity, a new, or at least modified, concept or paradigm about YFT residency at FADs and other objects is emerging. Clearly from Klimley et al (2003) it is now known that not all YFT are open-ocean nomads that only linger at features like sea mounts and FADs. Instead, some remain for long periods – periods long enough for the resident populations to be perhaps viewed as meta-populations. In any event, these new findings should be considered in assessment, monitoring, or management of YFT.

Speculation

An important related question is whether some YFT migrate from deeper water to aggregate around DPSs and natural bathymetric features and become resident metapopulations, or whether there is a more-continuous and substantial exchange between open-Gulf and aggregated populations. Other important questions include whether larger, open-ocean metapopulations exist and have regular exchange with local metapopulations. What is important, in terms of fishery management and understanding YFT, is the degree to which these two scenarios occur.

A substantial longline fishery in the GOM takes place mostly in deep waters farther offshore (González-Ania et al. 2001). It is well known among commercial longline fishermen and has now been documented (González-Ania et al. 2001) that catch per unit effort is lowest during winter with a minimum in March. However, recreational catches are very high at certain inner shelf bathymetric features, such as Sackett Bank, a diaper or salt dome formation, about 30 km offshore of the SW Pass mouth of the Mississippi River. Although not scientifically studied, knowledgeable sport fishermen attribute this seasonal inshore abundance of YFT at Sackett Bank (locally called Midnight Lump) to high abundance of prey species that are driven into deeper, warmer waters as coastal waters become very cold in winter. Whether YFT migration to winter feeding habitats associated with mid-shelf features, accounts for the low longline CPUE in winter is unknown but possible. Alternatively, YFT abundance at Sackett Bank during winter may reflect an inshore movement of a local YFT population that aggregates around DPSs in the summer.

In view of the new information from our study and other recent studies, it is becoming increasingly evident that movements and distributions of yellowfin tuna are different and more complex than previously thought. Yellowfin tuna are not exclusively nomadic wanderers of the pelagic realm. Instead, man-made objects like FADs and petroleum platforms, as well as natural structures like seamounts, banks and islands, probably substantially affect their movements, distributions, and possibly their population structure in the Gulf of Mexico and Caribbean Sea. Further study of these effects, relationships, and patterns is needed in order to scientifically understand yellowfin tuna and to effectively manage fisheries for this important species.

ACKNOWLEDGEMENTS

This work was funded by the U.S. Geological Survey's (USGS) Outer Continental Shelf Studies Program as a grant to the University of South Florida College of Marine Science through the USGS-USF Cooperative Program, and responds to information and research needs of the U.S. Department of Interior Minerals Management Service (MMS). The support of Gary Brewer (USGS) and Tom Ahlfeld and Greg Boland (MMS) is gratefully acknowledged. Kim Holland generously provided information on ongoing YFT research projects. Gary L. Hill, Bianca Klein, David LaPlante, Steve Berkeley, and Keith Taniguchi served as volunteer research crew. Captain Joe Marlbrough's (LUMCON *R.V. Acadiana*) enthusiasm and help is appreciated. Jana Miller contributed graphics.

LITERATURE CITED

Carney, R.S. 1997. Workshop on environmental issues surrounding deepwater oil and gas development: Final report. OCS study MMS 98-0022. U.S. Dept. of Interior, Minerals Management service, Gulf of Mexico OCS Region, New Orleans, Louisiana USA. 163 pp.

Dagorn L., K. Holland, and D. Itano. 2003. Behavior of large pelagic fish in a network of fish aggregating devices (FADS) as determined by coded acoustic transmitters and automated listening stations. ICES Symposium on Fish Behavior in Exploited Ecosystems. Bergen Norway, 23-26 June 2003 (Abstract and online presentation)

Edwards, R.E. 1998. Survival and movement patterns of released tarpon (*Megalops atlanticus*). *Gulf of Mexico Science* **16**:1-7.

Edwards, R.E. and K.J. Sulak. 2002. The potential of deepwater petroleum structures to function as fish aggregating devices (FADs) – scientific information summary and bibliography. U.S. Department of the Interior, Geological Survey, Biological Sciences Report 2002-0005 and Minerals Management Services, Gulf of Mexico OCS Region, New Orleans, Louisiana USA. OCS Study MMS 2002-32. 261 pp.

Edwards, R.E. and K.J. Sulak. 2003. The potential of deepwater petroleum structures to affect Gulf of Mexico fisheries by acting as fish aggregating devices (FADs). Pages 55-72 in: M. McKay and J. Nides (eds.). *Proceedings: Twenty-First Annual Gulf of Mexico Information Transfer Meeting.* January 2002. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, La. OCS Study MMS 2003-005. 748 pp.

Edwards, R.E., K.J. Sulak, M.T. Randall, and C.B. Grimes. 2003. Suwannee River (FL) Gulf sturgeon (*Acipenser oxyrinchus desotoi*) movements and nearshore Gulf of Mexico habitat determined by acoustic telemetry. *Gulf Mexico Science* 21:59-70.

Fonteneau, A., P. Pallares, and R. Pianet. 2000. A worldwide review of purse seine fisheries on FADs. Pages 15-35 in: J.Y. Le Gall, P. Cayre, and M.

Taquet (eds.). *Pêche Thonière et Dispositifs de Concentration de Poissons. Actes Colloque IFREMER*, 28. (Tuna fishing and fish aggregation devices). IFREMER, Brest Cedex, France.

González-Ania, L.V., C.A. Brown, and E. Cortés. 2001. Standardized catch rates for yellowfin tuna (*Thunnus albacares*) in the 1992-1999 Gulf of Mexico longline fishery based upon observer programs from Mexico and the United States. *Col. Vol. Sci. Pap. ICCAT* **52**:222-237.

Hall, M. 1992. The association of tunas with floating objects and dolphins in the eastern Pacific Ocean. VI. Some hypotheses on the mechanisms governing the association of tunas with floating objects and dolphins. In: M. Hall (ed.). *The Association of Tunas with Floating Objects and Dolphins in the Eastern Pacific Ocean*. Inter-American Tropical Tuna Commission, La Jolla, California USA.

Holland, K.N., R.W. Brill, and R.K.C. Chang. 1990. Horizontal and vertical movements of yellowfin and bigeye tuna associated with fish aggregating devices. *Fisheries Bulletin* **88**:493–507.

Holland, K.N., P. Kleiber, and S.M. Kajiura. 1999. Different residence times of yellowfin tuna, *Thunnus albacares*, and bigeye tuna, *T. obesus*, found in mixed aggregations over a seamount. *Fisheries Bulletin* **97**:392-395.

Holland, K.N., A. Jaffe, and W. Cortez. 2000. The Fish Aggregating Device (FAD) system of Hawaii. Pages 55-62 in: J.Y. Le Gall, P. Cayre, and M. Taquet (eds.). *Pêche Thonière et Dispositifs de Concentration de Poissons. Actes Colloque IFREMER*, 28. (Tuna fishing and fish aggregation devices). IFREMER, Brest Cedex.

Itano, D.G. 2000. The reproductively biology of yellowfin tuna (*Thunnus albacares*) in Hawaiian waters and the Western Tropical Pacific Ocean: Project Summary. *SOEST 00-01, JIMAR Contribution 00-328*.

Itano, D.G. and K.N Holland. 2000. Tags and FADs: Movement and vulnerability of bigeye (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) in relations to FADs and natural aggregation points. *Aquatic Living Resources* **13**:213-223.

Josse, E., L. Dagorn, and A. Bertrand. 2000. Typology and behaviour of tuna aggregations around fish aggregating devices from acoustic surveys in French Polynesia. *Aquatic Living Resources* **13**:183-192.

Kleiber, P., and J. Hampton. 1994. Modeling effects of FADs and islands on movement of skipjack tuna (*Katsuwonus pelamis*): Estimating parameters from tagging data. *Canadian Journal of Fisheries and Aquatic Science* **51**:2642-2653.

Klimley, A.P., F. Voegeli, S.C. Beavers, and B.J. Le Boef. 1998. Automated listening stations for tagged marine fishes. *Marine Technology Society Journal* **32**:94-101.

Klimley, A. P., and C. Holloway. 1999. Homing synchronicity and schooling fidelity by yellowfin tuna. *Marine Biology* **133**:307–317.

Klimley, P.A., S.J. Jorgensen, A. Muhilia-Melo, and S.C. Beavers. 2003. The occurrence of yellowfin tuna (*Thunnus albacares*) at Espiritu Santo Seamount in the Gulf of California. *Fisheries Bulletin* **101**:684-692.

Laurans, M., M. Taquet, L. Reynal, and A. Lagin. 2000. Comparisons of large pelagic fish catches in Martinique, with or without FADs. Pages 421-434 in: J.-Y. Le Gall, P. Cayre, and M. Taquet (eds.). *Pêche Thonière et Dispositifs de Concentration de Poissons. Actes Colloque IFREMER*, 28. (Tuna fishing and fish aggregation devices). IFREMER, Brest Cedex, France.

Marsac, F., P. Cayre, and F. Conand. 1996. Analysis of small-scale movements of yellowfin tuna around fish-aggregating devices (FADS) using sonic tags. *IPTP Collected Volumes* 9:151-159

Marsac, F., A. Fonteneau, and F. Menard. 2000. Drifting FADs used in tuna fisheries: an ecological trap? Pages 537-552 in: J.-Y. Le Gall, P. Cayre, and M. Taquet (eds.). *Pêche Thonière et Dispositifs de Concentration de Poissons. Actes Colloque IFREMER*, 28. (Tuna fishing and fish aggregation devices). IFREMER, Brest Cedex.

Martin, C.C. 1999. Results of the use of FADs in the pole and line skipjack (*Katsuwonus pelamis*) fishery in the North-West coast of Cuba. Pages 38-39 in J.-Y. Le Gall, P. Cayre, and M. Taquet (eds.). *Tuna Fishing and Fish Aggregating Devices* (collection of abstracts). IFREMER, Plouzane, France.

Menard, F., B. Stequert, A. Rubin, and E. Marchal. 2000. Food consumption of tuna in the Equatorial Atlantic ocean: FAD-associated versus unassociated schools. *Aquatic Living Resources* 13: 233-240.

Ohta, I. And S. Kakuma. [2004]. Periodic behavior and residence time of yellowfin and bigeye tuna associated with fish aggregating devices around Okinawa Islands, as identified with automated listening stations. *Marine Biology* (In press).

Richardson, G.E., L. S. French, R. D. Baud, R. H. Peterson, C. D. Roark, T. M. Montgomery, E. G. Kazanis, G. M. Conner, and M. P. Gravois. 2004. Deepwater Gulf of Mexico 2004: America's Expanding Frontier. OCS Report

MMS 2004-021. U.S. Department of the Interior, Minerals Management Service, New Orleans Gulf of Mexico OCS Region. 150 p.

Sibert, J., K. Holland, and D. Itano. 2000. Exchange rates of yellowfin and bigeye tunas and fishery interaction between Cross seamount and near-shore FADs in Hawaii. *Aquatic Living Resources* 13:223-323.

Sloan, R. 2001. Tuna boom off Texas. *Saltwater Sportsman Magazine* June 2001:79-113.

Taquet, M. 1998. The fish aggregating device (FAD): An alternative to the great fishing pressure on reef resources in Martinique. *Proceedings of the Gulf and Caribbean Fisheries Institute* 50:249-261.

Uchiyama J.H. and T.K. Kazama. 2003. Updated weight-on-length relationships for pelagic fishes caught in the Central North Pacific Ocean and bottomfishes from the northwestern Hawaiian Islands. Pacific Islands Fisheries Science Center Administrative Report H-03-01.

Comparison of Dolphinfish (*Coryphaena hippurus*) Commercial and Recreational Fisheries in Puerto Rico during 2000-2003

GRISEL RODRÍGUEZ-FERRER, YAMITZA RODRÍGUEZ-FERRER, DANIEL MATOS-CARABALLO, and CRAIG LILYESTROM
Puerto Rico Department of Natural and Environmental Resources
Fisheries Research Laboratory
P.O. Box 3665
Mayagüez Puerto Rico 00681-3665

ABSTRACT

All the factors affecting a fishery resource should be analyzed to determine its status. For example in fisheries, the resource is used by a variety of fishermen all with different interests. There are people with economic interest (commercial fishermen and charter/head boats), those that do it recreationally (family trips), and those that do it as a sport (fishing tournaments). The Department of Natural and Environmental Resources of the Commonwealth of Puerto Rico has several statistics programs that collect data on the fisheries. Since 1971, the Commercial Fisheries Statistics Program (CFSP) collects and analyzes data reported by commercial fishermen. Another program is the Marine Recreational Statistics Program (MRSP) that since 1999 collects data on recreational fisheries. This program is divided on recreational fisheries and fishing tournaments.

The CFSP and the MRSP collects data the dolphinfish (*Coryphaena hippurus*). This species has a commercial value and is an important gamefish. This migratory species is reported for all over the Caribbean, where it is one of the most prized species. It is fished throughout its migration route, and therefore, the fishing pressure is high.

The economic impact of this fishery is quite high; for example the commercial fishery of dolphinfish generates an average of $207,639.56 wholesale annually. Fishing tournaments generate an average of $33,247.50 on tournament's fees (17 tournaments with fee reported). Even though it is illegal for recreational fishers to sell their catch, most of them sell the majority of their dolphinfish catch to finance fishing expenses.

In Puerto Rico's fishery, dolphinfish is one of the most targeted. Data collected includes landings reported and biostatistics (length and weight) for the period of 2000 - 2003. This data was used to determine the current trends and status of this fishery.

Total weight reported for all the activities showed a decreasing tendency of fish landed through the four years of this analysis. There is a difference on the size of the fish reported; for example, commercial fishermen tend to report smaller fish both males and females.

Even though the highest fishing pressure received by the dolphinfish is from commercial fishermen, still the impact the recreational anglers make is considerable. This type of analysis is fundamental for the proper management of the species.

KEY WORDS: Fishery, dolphinfish, Puerto Rico

Comparación de la Pesquería Comercial y Recreativa del Dorado (*Coryphaena hippurus*) en Puerto Rico durante los Años 2000-2003

Para determinar el estatus de un recurso pesquero todos los factores que lo afectan deben ser analizados. Por ejemplo, en pesquería el recurso es usado por una variedad de pescadores cada uno distintos intereses. Hay personas con intereses económicos (pescadores comerciales/ charters), algunos pescan de manera recreativa y otros lo hacen en competencias (torneos de pesca). El Departamento de Recursos Naturales y Ambientales del Estado Libre Asociado de Puerto Rico cuenta con varios programas de estadísticas pesqueras que colectan datos de pesquería. Desde 1971, el Programa de Estadísticas de Pesca Comercial (PEPC) colecta y analiza datos de la pesca reportada por pescadores comerciales. Otro programa es el Programa de Estadísticas de Pesca Recreativa (PEPR) que desde 1999 colecta datos de la pesca recreativa. Este programa cuenta con dos componentes pesca recreativa y torneos de pesca.

El PECP y el PEPR colectan datos de pesquería del dorado (*Coryphaena hippurus*). Esta especie tiene un valor económico y es importante en la pesca recreativa. Se encuentra reportado para todo el Caribe, donde es uno de los especímenes más codiciados. En su migración por aguas caribeñas es capturado por toda el área, por lo tanto la presión al recurso es bastante alta.

El impacto económico de esta pesquería en Puerto Rico es alto. Por ejemplo la industria pesquera reporta un promedio de $207,639.56 al por mayor anual sólo en la pesca de dorado. Los torneos de pesca generan un promedio de $33,247.50 anuales en cuotas de inscripción (17 de 42 torneos visitados).

El dorado es una de las especies más pescada en la industria pesquera de Puerto Rico. Datos colectados incluyen peces abordados y su bioestadística (largo y peso) para el período de 2000-2003. Estos datos tanto de pesca comercial como de pesca recreativa se utilizaron para determinar patrones existentes y el estatus de esta pesquería.

El peso total reportado para todas las actividades muestra una tendencia de disminución a través de los años. Hay una diferencia marcada en el tamaño reportado por los diferentes pescadores; los pescadores comerciales tienden a reportar pescados más pequeños tanto hembras como machos y los recreativos tiende a pescar más peces grandes.

A pesar de que la mayor presión de pesca la reciben por parte de los pescadores comerciales, el impacto que causan los pescadores recreativos en la población del dorado es marcado. Este tipo de análisis es fundamental para el manejo apropiado de la especie.

PALABRAS CLAVES: Pesquería, dorado, Puerto Rico

INTRODUCTION

The dolphinfish (*Coryphaena hippurus,* Linneaus 1758) is a highly migratory pelagic species distributed throughout the tropical and subtropical waters of the world. It has been reported in the Atlantic, Pacific, and Indian Oceans. This species usually forms schools and feeds on almost all forms of fish and zooplankton; it also feeds on crustaceans and squid (Eschmeyer et al. 1983). Sexual maturity is reached in 4 - 5 months (3 months for captive fish) (Randall 1995). This species spawns in the open sea and probably approximate to the coast when water temperatures rise (Collete 1995).

The dolphinfish color is striking with golden hues on the sides, metallic blues, and greens on the back and sides, with white and yellow on the under parts. Small specimens have pronounced vertical bars on the sides of the body. Mature males have a prominent bony crest in front of the head. Maximum length reported has been 210 cm TL (male/unsexed Collete 1999) and the maximum weight 40.0 kg (Allen and Steene 1988). One of the characteristics of the species is its high reproduction rate; it has been reported that the population doubling time is less than fifteen (15) months (Allen and Steene 1988).

Due to its gregarious behavior, its high growth rate, and its high reproductive success, it is a very important species for the fisheries industries. The dolphinfish has a prominent commercial value worldwide. This species is one of the principal target species for commercial as well as recreational fishers worldwide. In Puerto Rico, it is the number one targeted species for recreational and the nineth reported for commercial fishers.

The two main hypotheses state that two different migratory stocks visit the coastal waters of Puerto Rico; therefore, there are two-dolphinfish seasons. For the northern stock, that comes from the Atlantic, the season starts in October and ends in March. The southern stock that ranges in the Caribbean is close to Puerto Rican waters from March to June (Oxenford and Hunte 1984). These stocks are highly exploited by commercial and recreational fishers.

Data analyzed came from three sources the Commercial Fisheries Statistics Program (CFSP), the Marine Recreational Statistics Program (MRST), and the Fishing Tournaments Statistics Program (FTSP), all under the auspices of DNER.

In the present paper, we compare and analyze landings and biostatistical data for commercial and recreational fisheries to describe tendencies in this fishery resource.

METHODS

Commercial Landings Data

Commercial fishery landing data were collected from voluntary fishers, fish buyers, and fishing associations from around Puerto Rico. Four port samplers and the principal investigator visited the 42 coastal municipalities including the islands of Vieques and Culebra, and the 88 identified fishing centers (Matos-Caraballo 2003). The data collection occurred from January 2000 - December 2003. Data were collected using a landing trip ticket system (Matos-Caraballo 2004) on a biweekly or monthly basis. Special boxes were placed in most fishing centers to enable port samplers to collect trip tickets from fishers.

Catch per unit of effort (CPUE) was evaluated in two ways: 1) for landings data by calculation of total pounds per trip, and 2) making a sub sample by month, using only those landings trip tickets that clearly indicated a single trip (Matos-Caraballo 2004).

Commercial Biostatistical Data

Port samplers collected biostatistical data from finfish three days per week. Each individual was identified by species to determine catch composition. Finfishes were measured in fork length (FL) both in millimeters (mm), and weighed in grams. For the purpose of this analysis the weight recorded was converted to kilograms. Data were recorded on the field and copied in the biostatistical data sheets using the format shown in (Matos-Caraballo 2004). Biostatistical CPUE data was handled as follows: catch is total capture expressed in pounds.

Recreational

The Marine Recreational Fisheries Program is divided on three main projects, the Recreational Anglers Program, the Telephone Surveys, and the Fishing Tournaments Program. The main objective of these is to generate statistically valid estimates of catch and fishing effort of marine anglers in Puerto Rico. The Recreational Anglers program collects data on charters, rental boats, sport fishers, and shore modes. A standardized form developed by MRFSS and adapted for Puerto Rico was used (Marine Recreational Fisheries Statistics Program Final Report 2003). Telephone household interviews were carried out in counties within 25 miles of ocean coastline. The information asked in these interviews is mainly regarding the fishing trips itself and not the biological characteristic of the species (i.e. measurements, weight etc); therefore this part is not discussed in this paper.

Samplers that intercept fishers at the docks or boat ramps collected the biostatistical data. Recreational fishing data included catch, species identification, length, weight, effort, location, bait, and fishing gear), and basic socioeconomic data (Marine Recreational Fisheries Statistics Program Final Report 2003).

For the fishing tournament program, the project staff attended each tournament and collected the landings and/or releases data as well as total effort information from records (logbooks) and also collected biometrical data. These include information on sex (whenever possible), length, weight, and species identification. The information was annotated to determine size and weight frequencies by species. These data was used to determine Catch per Unit effort (CPUE) for takes and for fishing activity. All measurements were taken in a straight line from the fish lower jaw (LJ) to the fork length (FL) (Rodríguez-Ferrer and Rodríguez Ferrer 2004).

RESULTS

Commercial

Data from the landings trip ticket system collected by the port samplers were combined to analyze this fishing mode. Of the 1,163 active commercial fishermen 842 reported dolphinfish as one of the landed species (Matos-Caraballo et al 2002). A steady decrease on the fish reported from 1990-2003 is noted (Figure 1). For this analyzes we will emphasize the 2000-2003 reported data. For the four from the four years combined, a total of 188,306 kg (Table 1) and an average mean weight of 5.72 kg were reported as landed by commercial fishers (Figure 2). The south and west coasts are the ones with the most total weight reported (Figure 3). The price per pound ranged from $1.96-$2.07 with an average income of $207,639.56 wholesale a year for this fishery (Table 2).

Table 1. Landings reported (kg) for the three fishing activities in Puerto Rico during 2000 - 2003 .

Fishing Activity	2000	2001	2002	2003	Total reported
Commercial	63,555.45	50,488.64	45737.27	29,476.36	189,258
*Recreational	1,214.19	937.65	782.65	1,376.89	4,311.38
Fishing Tournaments	7,322.01	9,049.65	9,553.16	6,336.2	32,261.02
Totals kg reported	72,091.65	60,475.94	56,073.08	37,189.45	225,830.4

*Only fish measured by the port samplers

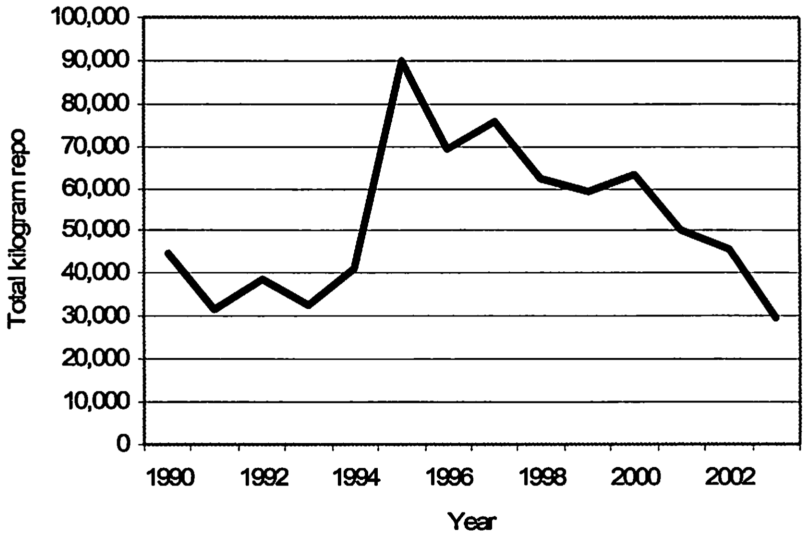


Figure 1. Commercial landings of dolphinfish (*Coryphaena hippurus*) for 1990-2003 reported in kilograms.

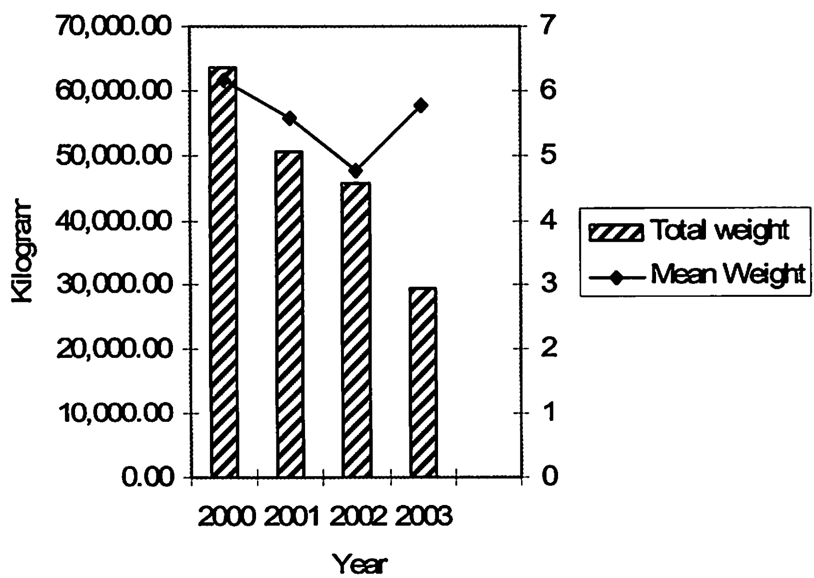


Figure 2. Total weight reported by commercial landings (kg).

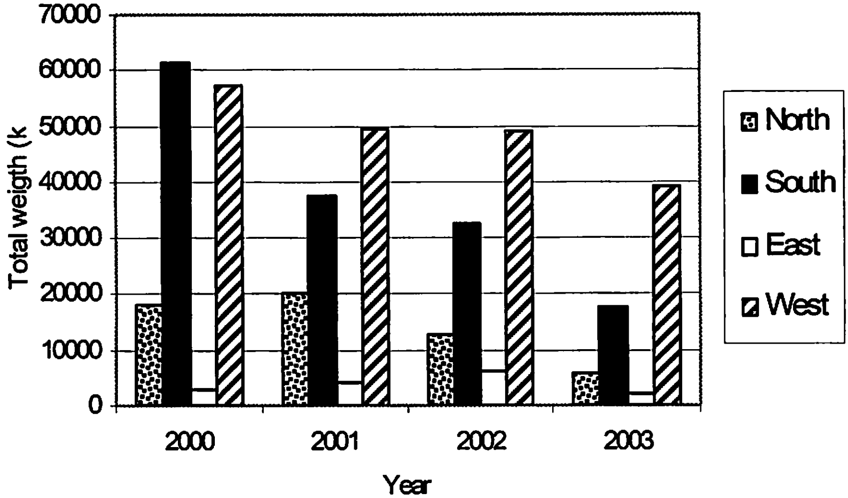


Figure 3. Landings reported (kg) in Puerto Rico by coast during 2000-2003.

Table 2. Total income reported in commercial landings (wholesale) on dolphinfish (*Coryphanea hippurus*) fishery in Puerto Rico 2000-2003.

Year	Average price/ pound	Pounds	Total
2000	2.04	139,822	$285,236.88
2001	1.89	111,075	$209,931.75
2002	2.07	100,622	$208,287.54
2003	1.96	64,848	$127,102.56
		Average	$207,639.56

Most fish measured between 414 -1100 mm (Figure 4) for the four years. When we compared the size difference between the fishing zones (i.e. north, south, east, west) there is quite a significant difference between several of the zones. Both the south and west coast reported significantly larger fishes than the north coast (Kolmogorov-Smirnov Dmax= 0.58) for the south coast (Kolmogorov-Smirnov D Max 0.62) for the west coast. Between the north and east coast, the north coast has significantly larger individuals (Kolmogorov-Smirnov D max= 0.93). There was not significant difference between the east and west and between east and south. The difference between fish sizes of the south versus the west coast is slightly significant (Kolmogorov-Smirnov D max= 0.13).

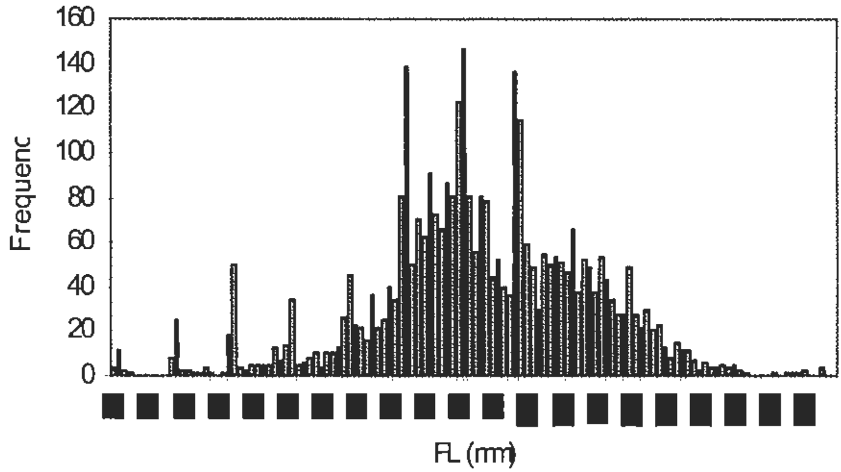


Figure 4. Size frequency distribution commercial fisheries 2000 - 2003.

Recreational Tournaments

A total of 155 fishing tournaments were visited on the period 2000 - 2003 of which 35 or 22.5% of tournaments the target species were dolphinfish. Regarding participation 3,695 fishers took part in this activity (18,468 fishers for all tournaments, n = 155 tournaments between 2000 - 2003, n = 4,617 fishermen S.D. = 606.26) Table 3. The tournament fee ranges $33,247.50 in 20 of 35 tournaments visited. The average fee per boat is $280.00 and the average income the marina gets from the tournament fee only is about $7,054.50.

A total of 32,261.02 kg of dolphinfish were boarded during fishing tournaments for all three years (Table 1). The mean weight of dolphinfish for tournaments was 7.60 kg (Figure 5). Most fish measured between 800 - 1149 mm (n = 3909 fish measured) (Figure 6). These fishes where mostly mature individuals as previous research has determined the size for sexual maturity as 820 mm for males and 900 for females (Pérez et al. 1992). The differences in sizes between the zones is as follows. Contrary to our expectations there was not a significant difference between the north and south coast (Kolmogorov-Smirnov.0,5 D max = 0.01). Between north, east, and north, west coast there was not a significant difference between sizes reported (ie. Kolmogorov-Smirnov Dmax = 0.01 for north versus east, and Dmax = 0.02 for north versus west). Contrary to commercial data, there is a marked differences between the west and east coast having the west coast the largest individuals (Kolmogorov-Smirnov D0.05 = 0.08, Dmax = 0.86). The south coast reported larger dolphinfishes than the east or west coasts (Kolmogorov-Smirnov Dmax = 0.62 for the south versus east coasts and Dmax = 0.11 for the south versus west coasts).

Table 3. Total number and participation in dolphinfish tournaments in Puerto Rico during 2000-2003.

	North		South		East		West	
Year	Number of Tournaments	# Of fishers	Number of Tournaments	# Of fishers	Number of Tournaments	# Of fishers	Number of Tournaments	# Of fishers
2000	NR	236	NR	NR	NR	NR	NR	NR
2001	4	381	4	430	2	192	2	215
2002	2	172	4	424	1	215	2	220
2003	4	444	4	486	1	100	1	72

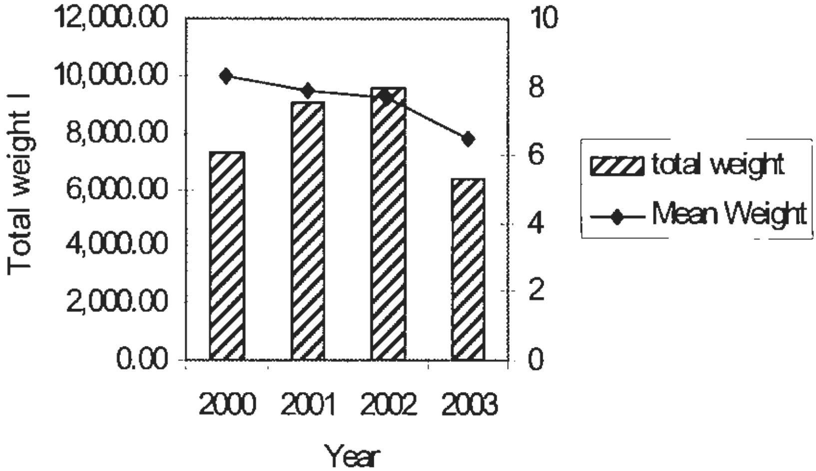


Figure 5. Total Weight (kg) reported by tournament landings 2000-2003

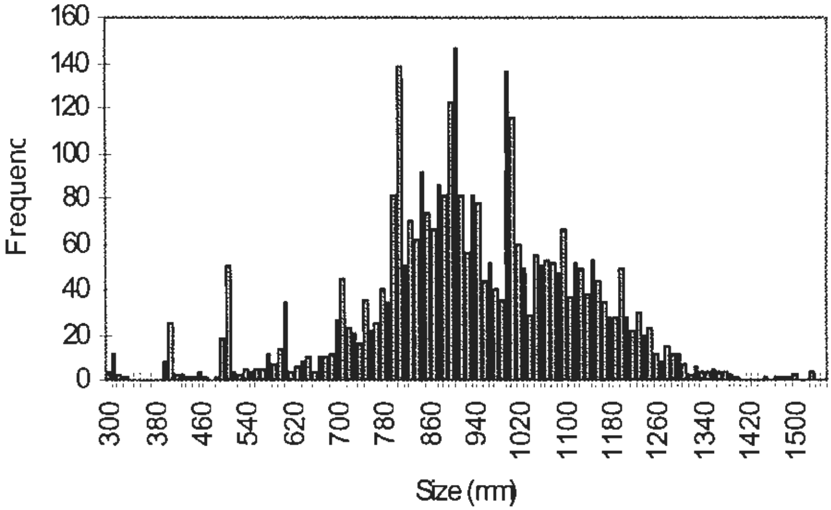


Figure 6. Size frequency distribution for Puerto Rico's fishing tournaments 2000 - 2003

Regarding the sex composition of the fish boarded, females still dominated as the most sex boarded for all years (Figure 7). Contrary to the commercial fishers data the south coast is the one with the most weight reported for fishing tournaments (Figure 8).

Non Tournaments

Only the biostatistical data collected by the data samplers was used on this analysis. Port samplers on fish caught recreationally for the four years measured a total of 4, 311.38 kg of dolphinfish (Table 1). The mean weight for this mode was 5.78 kg (Figure 9).

Relatively mature individuals were reported as being caught by recreational fishers (i.e. 700 - 1100 mm) by port samplers (Figure 10).

There was a significant difference on the length between the north and south coast (Dmax = 0.31) (Figure 11). For the rest of the zones there was no significant difference between the lengths of the dolphinfish reported.

Samplers did not determine the sex of the individuals therefore no analysis on the fishing preferences regarding sex and sexual maturity was not done for this activity.

Comparison Between Fisheries

Due to the nature of sampling the data set for the fishing tournament (n = 3452) is larger than both the commercial fishers (n = 792) data and the non-tournament recreational data (n = 804).

Commercial versus Tournaments

When we compared the reported commercial landings with the tournaments landings, there is significant difference on the size of the fish landed (Kolmogorov-Smirnov Dmax = 1). Where the tournament fishers had the largest fishes.

In tournaments, participants outnumbered the commercial fishermen that reported dolphinfish as a target species. Regarding fishing tournaments the south coast is the zone with the most participation (Table 3), the most fishing tournaments celebrated with dolphinfish as a target species specifically and is the zone with the highest number in total weight reported (Figure 8). For commercial fishermen in 2000, the south coast was the zone with the highest total weight; during the following years it shifted to the west coast (Figure 9).
Commercial versus recreational non-tournaments

Recreational fishers tend to report larger fishes when we compared to commercial fishers (Kolmogorov-Smirnov Dmax = 1, average length for recreational fishers 887.12mm vs. 877.10 mm for non tournament fishers).

Recreational Non-tournaments versus Tournaments

There is a high tendency for the tournament fishers to land larger individuals (Kolmogorov-Smirnov, Dmax = 3.29).

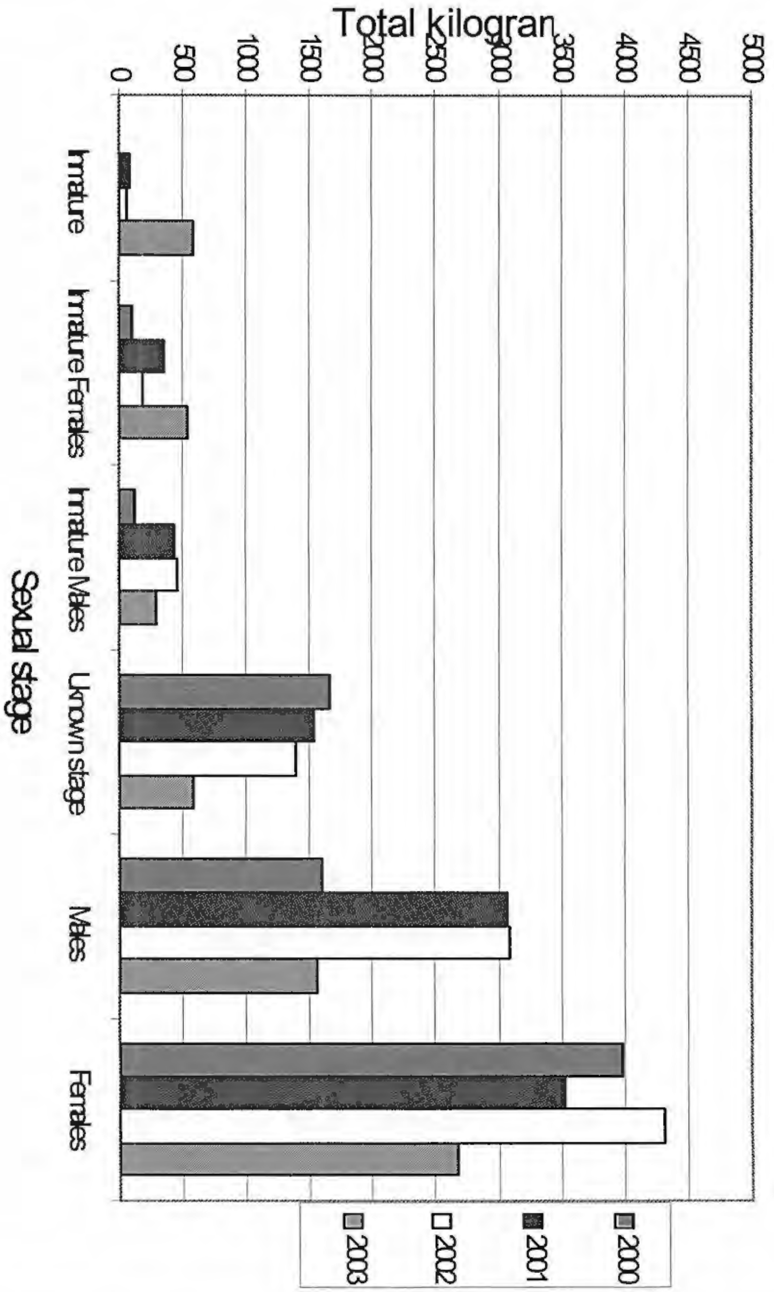


Figure 7. Reported dolphinfish by sex in fishing tournaments 2000-2003

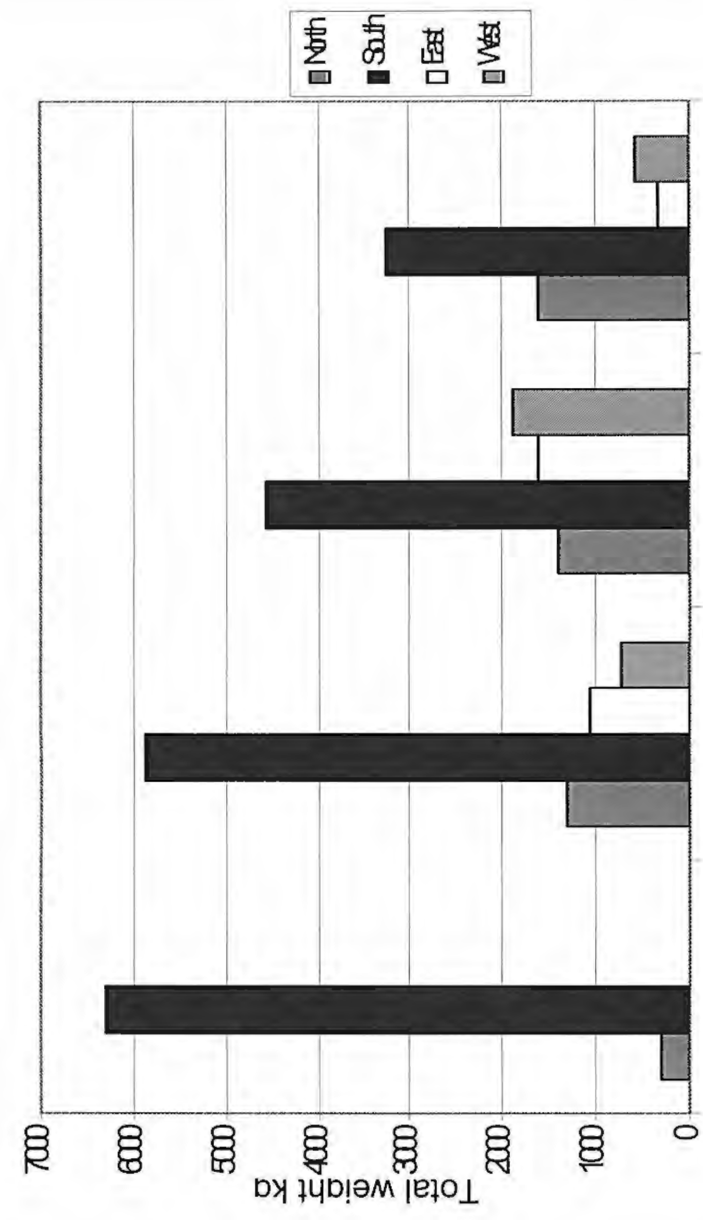


Figure 8. Total weight by coast fishing tournaments in Puerto Rico 2000 - 2003

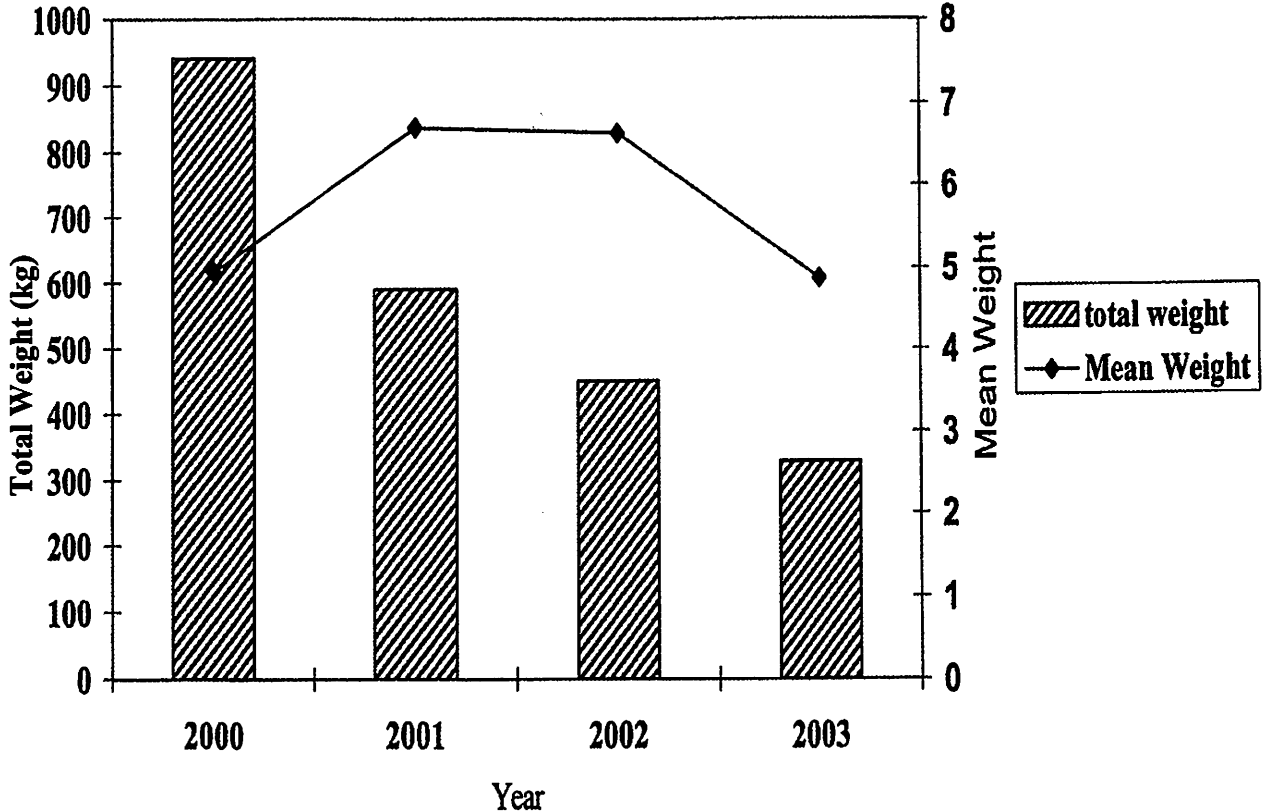


Figure 9. Total weight (kg) reported by port sampler's interviews

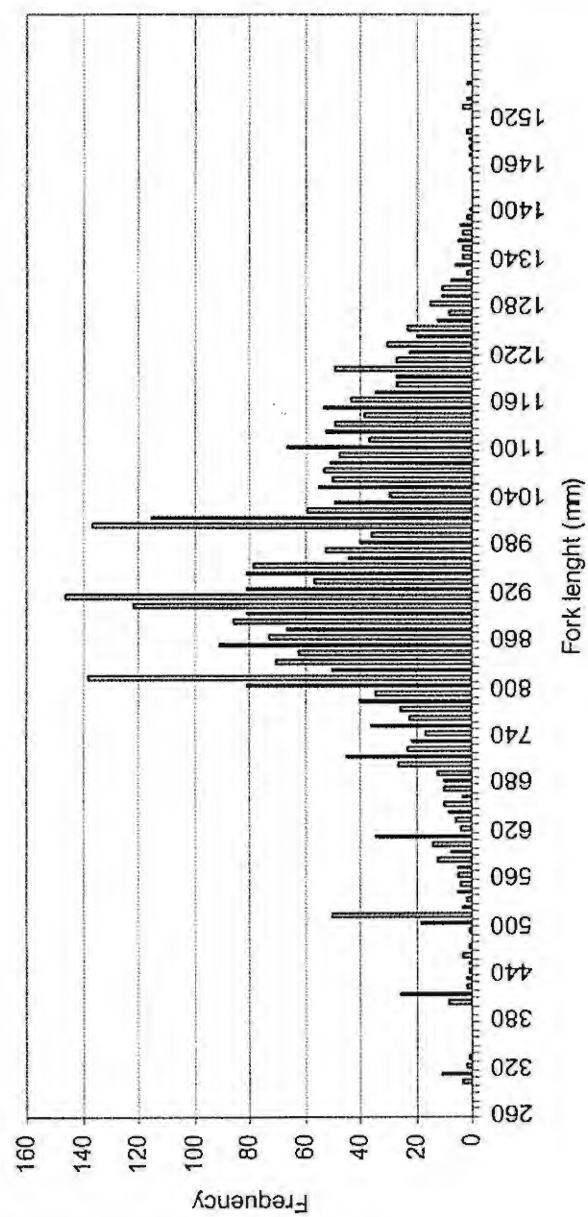


Figure 10. Size frequency distribution for recreational fisheries (2000 - 2003)

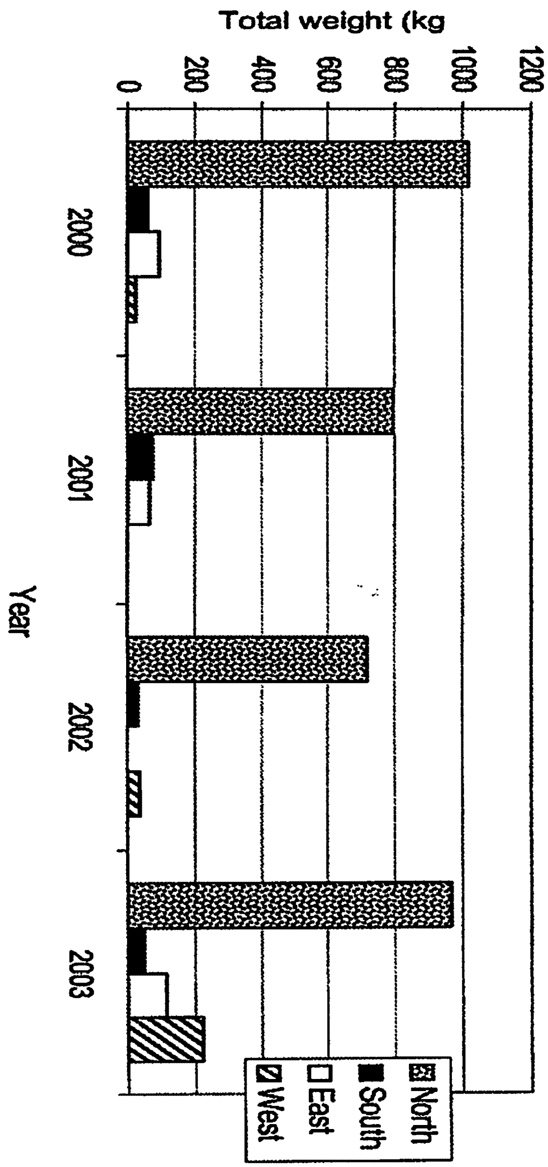


Figure 11. Total weight (kg) by coast non-tournaments (2000 - 2003)

DISCUSSION

Even though the commercial fishery reports the highest total weight landed of dolphinfish, its recreational fishing is an important activity and is clearly affecting this species also.

The peak in captures reported by commercial fishermen, recreational fishers, and the tournaments celebrated coincide with the dolphinfish migration pattern (Oxenford and Hunte 1984).

The differences on fishing zone (i.e. the commercial fishers report mainly form the west coast and the recreational from the south coast) could be due to the nature of the commercial fishery report system, because fishermen report the fishing center where they landed and not the fishing area. This is something that will be corrected with the new ticketing system developed by the Department of Natural and Environmental Resources Department.

When the reported fork length for 2000 - 2003 is compared with previous studies, the specimens are relatively smaller than in earlier years (i.e. 381 - 1479 mm Pérez et. al. 1992 vs. 414 - 1149 mm). This could reflect fishery exploitation due to the fact that even though is not a marked difference a trend is noted and this trend could increase in the near future.

Dolphins are caught in the Island year round and throughout the area. With the seasonal peaks and aggregations areas, there are zones where the specimens are more abundant. It is a popular believe that the south coast has the largest specimens and the highest total weight. With this analysis we established that the total weight and the dolphin size is larger in the south coast. When we compared sizes between fishing activities, recreational fishers reported larger individuals than the commercial fishers. Before the fish reach maturity they are already economically valuable (Fishery Management Plan for the dolphin and wahoo fishery of the Atlantic 2003); therefore, commercial fishers will target all sizes available to increase profits. On the other hand, recreational fishers are targeting larger individuals principally in tournaments because they will guarantee a prize. It is worth mentioning, that in tournaments where total fishing weight is used to determine the winner, fishermen tends to bring as many individuals as possible ignoring the sizes.

Dolphinfish landings have increased in recent years in the Atlantic (Fishery Management Plan for the dolphin and wahoo fishery of the Atlantic 2003). It was established by genetic studies that dolphin from the Gulf of Mexico, US Atlantic, including Puerto Rico, the Virgin Islands, Mid Atlantic and New England is a single stock (Wingroove R in: Fishery Management Plan for the dolphin and wahoo fishery of the Atlantic 2003). If this is the case, special attention should be place on this species that is being fished all over its migratory route. Even though Prager (2000) suggested that the species may be able to withstand a relatively high rate of exploitation. Mahon and Oxeford (1999) warn that there is a high risk of stock depletion, given that the fishery may remain feasible at low stock levels because of high tendency of the species to aggregate.

In Puerto Rico there is competition between recreational and commercial fishers for the resource. This can lead to a localized depletion of stocks and a "shift in the historical levels of catch between commercial and recreational fishers"; as it happened in the Atlantic and Gulf of Mexico (Fishery Management Plan for the dolphin and wahoo fishery of the Atlantic 2003).

In 2005 a new fishing regulation (DNER 6768) was established in Puerto Rico. For the first time, a bag limit will be established for recreational fishers, five dolphins per fishermen per fishing day. Consequently, the dynamics of the recreational fisheries, especially the tournaments will have to change. It is imperative that data on the specimens continues to be recorded to determine the impact of this regulation in both the species and on the fishermen.

ACKNOWLEDGEMENTS

We would like to thank the Fisheries Research Laboratory personnel for all the support they provide to this project. Especially Mr. Miguel Figuerola for his assistance in the literature research for this paper. Mrs. Noemí Peña for her help with the editing process and with the commercial fisheries data. Mrs. Milagros Cartagena for her aid with the commercial fisheries data, Mr. Wilfredo Torres for his help with the statistics and Ms. Verónica Seda for her aid with the presentation. In addition, we would like to thank NOAA-DNER-Task force Rangers for their presence in the tournaments.

This work could not be made without the help and collaboration of all recreational and commercial fishers and tournament organizers from Puerto Rico.

LITERATURE CITED

Allen G.R. and R.C. Steene. 1988. *Fishes of Christmas Island Indian Ocean.* Christmas Island Natural History Association, Christmas Island, Indian Ocean, 6796 Australia. 197 pp.

Collete B.B. 1995. Coryphaenidae: Dorados. Pages 1036-1038 in: W. Fischer, F. Krupp, W. Sneider, C.Sommer and V. Niem (eds.). *Guía FAO para la Identificación de las Especies para los Fines de Pesca.* Pacífico Oriental

Collete B.B. 1999. Coryphaenidae: Dolphinfishes. Pages 2656-2658 in: K.E. Carpenter and V.H. Niems (eds.). *FAO Species Identification Guide for Fisheries Purposes. The Living Marine Resources of the Western Central Pacific Volume 4. Bony fishes part 2 (Muglilidae to Carangidae).* FAO, Rome, Italy.

Eschmeyer W.N., E.S. Herald, and H. Hamman. 1983. *A field guide to Pacific Coast Fishes of Nortn America.* Houghton Miffin Company, Boston, Massassuchetts USA. 336 pp.

South Atlantic Fishery Management Council (SAFMC). 2003. Fishery management plan for the dolphinfish and wahoo of the Atlantic. Charleston, South Carolina USA. 386 pp.

Mahon R. and H.A. Oxenford. 1999. Precautionary assessment and management of dolphinfish in the Caribbean. *Sci. Mar.* 63(3-4):429-438

Matos-Caraballo D., N. Peña-Alvarado, and M. Cartagena-Haddock. 2003. Comprehensive census of marine fishery of Puerto Rico 2002. *Proceedings of the Gulf and Caribbean Fisheries Institute Meeting.* 56:97-110.

Matos-Caraballo, D. 2004. Puerto Rico/NMFS Cooperative Fisheries Statistics Program. Final Report to National Marine Fisheries Service NOAA. 229 pp.

Marine Recreational Fisheries Statistics Program. 2003. Final Report Project F-42 Department of Natural and Environmental Resources 150 pp.

Palko B.J., Beardsley G.L., and W. Richards. 1982. Synopsis of the biological data on dolphin-fishes *Coryphaena hippurus* Linneaus and Coryphaena equisetus Linneaus. FAO Fish. Synopsis 130, NOAA Technical Report NMFS 443 pp.

Pérez, R.N., A.M . Román, and G.R. Rivera. 1992. Investigation pf the reproductive dynamics and preliminary evaluation of landings data of the dolphinfish *Coryphaena hippurus,* Linneaus. Final Report for Dingell-Johnson Project F-26-1. PR Department of Natural and Environmental Resources, Fisheries Research Laboratory, Mayaguez, Puerto Rico. 95 pp.

Prager, M.H. 2000. *Exploratory Assessment of Dolphinfish Coryphaena hippurus, Based on U.S. landings from Atlantic Ocean and Gulf of Mexico* NMFS, Washington, D.C. USA. 18 pp.

Randall, J.E. 1995. *Coastal fishes of Oman.* University of Hawaii Press, Honolulu, Hawaii USA. 439 pp.

Rodríguez-Ferrer, G. and Y. Rodríguez-Ferrer. 2004. Puerto Rico fishing Tournaments. Final Report Project F-42.3 Department of Natural and Environmental Resources, San Juan, Puerto Rico. 40 pp.

BLANK PAGE

Bioaccumulation of Mercury in Pelagic Fishes in NW Gulf of Mexico and its Relationship with Length, Location, Collection Year, and Trophic level

YAN CAI, JAY R. ROOKER, and GARY GILL
Department of Marine Biology
Texas A& M University
5007 Ave U
Galveston, Texas 77551 USA

ABSTRACT

Total mercury (Hg) concentrations were determined in the tissues of 11 species of pelagic fishes, with a special emphasis on apex predators (large vertebrates). Highest mercury concentrations were observed in blue marlin (*Makaira nigricans*), Carcharhinid sharks (genus *Carcharhinus*)and little tunny (*Euthynnus alletteratus*), ranging from 1.0 to 10.6 ppm. Moderate to low concentration (< 1.0 ppm) were observed in greater amberjack (*Seriola dumerili*), blackfin tuna (*Thunnus atlanticus*), cobia (*Rachycentron canadum*), king mackerel (*Scomberomorus cavalla*), little tunny (*Euthynnus alletteratus*), wahoo (*Acanthocybium solandri*), yellowfin tuna (*Thunnus albacares*) and dolphinfish (*Coryphaena hippurus*). For the majority of species examined, contaminant loads of mercury did not vary significantly between two consecutive years (2002 and 2003) and between two adjacent locations (Texas and Louisiana). The relationship between Hg concentration and fish size was also explored in certain species. Several species showed a positive relationship between mercury level and body size. Natural dietary tracer, stable isotopes of nitrogen also showed that Hg levels in fish tissues were positively associated with trophic position. Our findings in this study not only added to the information on mercury contamination in pelagic fish, but also furthered our understanding on mercury accumulation in these fish.

KEY WORDS: Mercury concentration, pelagic fish, size, location, trophic position, Gulf of Mexico

Bioaccumulation de Mercurio en Peces Pelágicos del NO Golfo de México

Fueron determinadas las concentraciones de Metil Mercurio (MMHg) en los tejidos de 10 especies de peces pelágicos, con especial énfasis en predadores del ápice de la cadena trofica (grandes vertebrados). Altas concentraciones de Mercurio fueron observadas en billfish y en tiburones (e.s. blue marlin, maco shark), fluctuando de 1.0 a 19.6 ppm. Moderadas a bajas concentraciones (<1.0 ppm) fueron observadas en greater amberjack, blackfin tuna, cobia, king mackerel, little tunny, wahoo, yellowfin tuna y dolphinfish. Las cargas contaminantes de mercurio variaron en función del año y la localización geográfica. Para la mayoria de las especies examinadas, fueron observadas significativamente altas concentraciones de MMHg en LA comparadas con TX. También, la mayoria de las especies examinadas, mostraron un incremento en la concentración de MMHg en 2003 comparado con 2002. Las relaciones entre la concentración de MMHg

Y el tamaño del pez fueron exploradas en ciertas especies. Algunas especies mostraron una relación positiva entre su nivel de MMHg y el tamaño del cuerpo, lo cual indica que la concentración de MMHg es también función del tamaño del cuerpo. Los trazadores naturales de dieta (isótopos estables, acidos grasos) encontrados en tejidos de consumidores, fueron conectados a concentraciones de MMHg, para posteriormente explorar procesos responsables de los elevados niveles en algunos consumidores. El análisis del isótopo estable de nitrógeno, indicó que los niveles de MMHg fueron positivamente asociados con la posición trófica del consumidor. Además, los perfiles de ácidos grasos (proxy para historia dietaria), fueron similares entre consumidores con elevado MMHg, sugiriendo que la acumulación de MMHg es directamente conectada con historia de la alimentación.

PALABRAS CLAVES: Metil Mercurio, bioaccumulation, peces pelágicos, Golfo de Mexico

INTRODUCTION

There are three forms of mercury in the natural environment (elemental, inorganic and organic) among which methylmercury, the organic form, is the most toxic (Fitzgerald 1991). Elemental mercury (Hg^0) is released into the environment by natural sources like volcano eruptions or by industrial production like gold mining. The Hg^0 vapor may be oxidized into divalent mercury (Hg^{2+}), which may be subjected to methylation by sediment microbiota. Methylmercury is then bioaccumulated in aquatic food webs (Malm et al. 1990). Methylmercury is a neurotoxin that can cause nervous system disorders, and fetuses and infants are more susceptible to brain damage from methylmercury since it inhibits cell division and migration (Clarkson 1987). The effects of localized methylmercury contamination in natural waters have been tragically demonstrated by mass poisonings at Minamata and Niigata, Japan. Because methylmercury comprises more than 80% of the total Hg in fish, often total mercury is measured to represent the methylmercury level in fish (Andersen and Depledge 1997). Fish are also the primary dietary source of methylmercury in humans (Clarkson 1992). Currently, fish consumption advisories for mercury exist in 44 states (U.S. EPA 2001, FDA 2001). Marine fish of greatest concern include sharks, swordfish, king mackerel, and tilefish, all of which are recreationally caught in waters of the Gulf of Mexico. A survey of mercury levels in finfish collected from the Gulf of Mexico was recently compiled by Ache et al. (2000), who found that 15 of the 26 species surveyed exceeded EPA (U.S. Environmental Protection Agency) consumption advisory level of 0.3 ppm mercury (U.S. EPA 2002).

We studied 11 species of pelagic fish that are commonly caught in the recreational fishery of northwestern Gulf of Mexico: blackfin tuna (*Thunnus* *atlanticus*), blue marlin (*Makaira nigricans*), cobia (*Rachycentron canadum*), dolphinfish (*Coryphaena hippurus*), greater amberjack (*Seriola dumerili*), king mackerel (*Scomberomorus cavalla*), little tunny (*Euthynnus alletteratus*), Carcharhinid sharks (genus *Carcharhinus*), swordfish(*Xiphias gladius*), wahoo (*Acanthocybium solandri*), and yellowfin tuna (*Thunnus albacares*). Because methylmercury in fishes is primarily transferred up the food chain, we examined nitrogen stable isotope as tracer of nutritional history since consumer tissues reflect the isotopic composition of prey in a predictable manner (Peterson and Fry 1987). Nitrogen stable isotope ratios ($d^{15}N$) in the muscle tissue of marine consumers are typically enriched by approximately 3 to 4 ‰ per trophic step and have been used to delineate the trophic positions of consumers (Owens 1987, Wada et al. 1991).

The objectives of this study were:

i) Measure mercury concentration in the tissue of pelagic fishes from the NW Gulf of Mexico,
ii) Examine spatial variation (Louisiana versus Texas) and annual (2002 versus 2003) variation in concentration of mercury in the tissue of pelagic fishes,
iii) Examine the relationship between fish size to mercury in pelagic fishes, and
iv) Examine the relationship between trophic position (based on analysis of stable nitrogen isotopes) and mercury in pelagic fishes.

METHODS

We sampled fish at ports in two states: Galveston and Freeport, Texas and Venice, Louisiana. In addition, we collected samples with hook-and-line to complement port sampling efforts. To assess annual variation, samples were collected in two years (2002, 2003). Muscle tissue (~20 g) was removed from the dorsal region behind the head, and samples were transported on ice and subsequently frozen. We collected 389 samples from 11 species.

We measured total Hg in fish tissue with a Milestone DMA-80 Direct Mercury Analyzer (Cizdziel et al. 2002). Fish muscle samples were cut into small pieces (about 0.01 - 0.27 g), and each sample was split into two fractions; one was introduced into the machine while the other was dried to determine the water concentration of the tissue. We evaluated water concentration to determine whether dehydration of samples during storage affected measurements of mercury in the wet fraction. We observed no significant dehydration effects; therefore, only wet weight mercury concentrations were reported.

The analytical procedure was calibrated and checked with standard reference materials (Dogfish muscle, Dogfish Liver, Oyster tissue, Lobster hepatopancreas) from the National Research Council of Canada. Sample order was randomized within species. We conducted three replicate measurements on every tenth sample. If inter-replicate variability exceeded 10%, the previous 10 samples were re-analyzed.

From each species, five muscle tissue samples were randomly chosen for stable isotope analysis. Isotope ratios ($^{15}N/^{14}N$) and total nitrogen content were determined using a Finnigan MAT DeltaPlus continuous-flow stable isotope mass spectrometer attached to a Carlo Erba elemental analyzer at the University of Texas at Austin Marine Science Institute. We report isotope ratios in parts per thousand (‰) relative to atmospheric nitrogen, and used delta notation:

$$\delta\,^{15}N = (R_{sample}/\,R_{standard} - 1) \times 10^3$$

where $R = {}^{15}N/^{14}N$. A secondary standard reference material (chitin of marine origin, Sigma Aldrich Co., USA, No. C-8908) was used to verify the accuracy of isotopic measurements (Herzka and Holt 2000).

We tested for differences in mercury concentration between years and between states with t-test. For each species, we modeled the relationship between mercury and total length with an exponential equation using regression. We also used an exponential function to model the relationship between mercury concentration and trophic position (as indicated by nitrogen stable isotope values).

RESULTS

In blue marlin, we detected exceptionally high mercury concentrations (mean = 10.59 ppm wet wt, Table 1) that were 10 times the FDA (2001) consumption advisory level (1.0 ppm wet wt). Among the 11 species of pelagic fish surveyed, four had a higher mean mercury concentration than the FDA criterion value, and nine species exceeded the EPA's consumption advisory level (0.3 ppm wet wt, U.S.EPA 2002). Lowest mean mercury levels were found in yellowfin tuna and dolphinfish: 0.18 and 0.07 ppm wet wt, respectively.

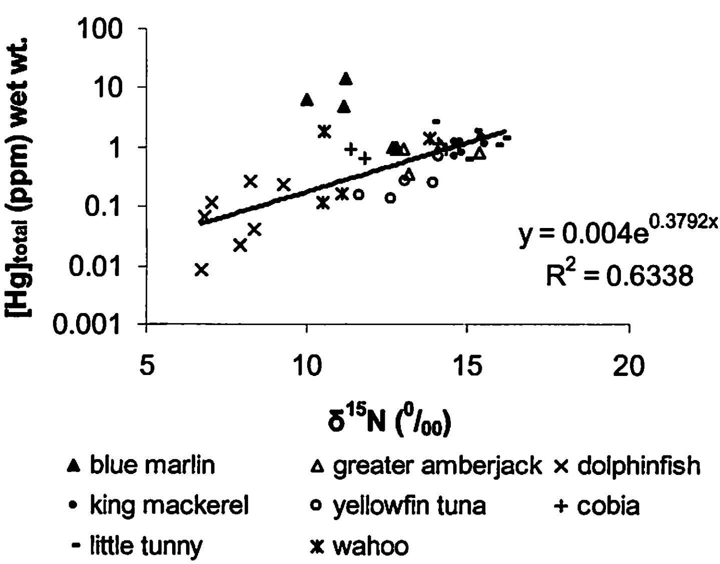
We explored associations between total mercury concentrations and size, and five species showed a statistically significant positive exponential relationship between total mercury concentration and size (Table 2). Blackfin tuna and wahoo had the highest mercury increase rates with size with slope values of 0.081 and 0.046, respectively (Table 2). Due to small sample sizes for blue marlin and swordfish, we did not model mercury versus total length relationships. Greater amberjack (df = 33, t-statistic = 3.05, $p < 0.01$) and yellowfin tuna (df = 58, t-statistic = -6.48, $p < 0.001$) were the only species that showed statistically significant differences in mercury concentration between years, and no species showed significant differences between states (TX vs. LA). Note that we did not examine annual and spatial differences in blue marlin and swordfish due to small sample sizes.

Nitrogen stable isotope values ($\delta^{15}N$) for 8 species that we examined ranged from 6.7 to 16.2 $^0/_{00}$ (Figure 1). Based upon $\delta^{15}N$ values, little tunny had the highest trophic position ($\delta^{15}N$ = 13.9 to 16.2 $^0/_{00}$), king mackerel had the second highest ($\delta^{15}N$ = 12.9-15.5 $^0/_{00}$), and dolphinfish were the lowest ($\delta^{15}N$ = 6.7 to 9.3 $^0/_{00}$). Though they had the highest mercury concentration (mean = 8.37 ppm wet wt), trophic position of blue marlin was intermediate ($\delta^{15}N$ = 10.0 - 11.2 $^0/_{00}$). Excluding blue marlin, there was a significant positive relationship between total mercury and trophic position (expressed as $\delta^{15}N$): $y = 0.004e^{0.3792x}$, where x = $\delta^{15}N$ and y=mercury concentration (R^2 =

Table 1. Total mercury in the muscle tissue of 12 pelagic fish from NW Gulf of Mexico

Species	N	$[Hg]_{total}$ ppm wet wt.	
		mean	SD
blue marlin**	9	10.59	±5.03
Carcharhinid sharks **	9	1.42	±0.45
little tunny**	9	1.08	±0.72
king mackerel*	39	0.96	±0.27
cobia*	17	0.89	±0.52
wahoo*	52	0.76	±0.87
blackfin tuna*	48	0.66	±0.31
greater amberjack*	44	0.6	±0.23
swordfish*	2	0.46	±0.24
yellowfin tuna	103	0.18	±0.15
dolphinfish	57	0.07	±0.09

N = Number of individuals.
** > FDA 2001 human consumption advisory level (1.0 µg/g wet wt.).
* > EPA 2002 human consumption advisory level (0.3 µg/g wet wt.).



0.63).

Figure 1. The relationship between total mercury concentration and trophic position for pelagic marine fishes. An exponential equation was fitted to data from eight species. Blue marlin were not used in the regression.

DISCUSSION

Methylmercury can accumulate from one trophic level to the next with highest concentrations in long-lived top predators (Andersen and Dephledge 1997). Most of the pelagic fishes in this study were apex predators and elevated mercury levels detected in these fish were in accordance with the results of many other mercury studies (Walker 1976, Freeman et al. 1978, Lyle 1984). Among all the other top predator fishes, blue marlin showed an exceptionally high mercury level (10.59 ± 5.03 ppm). This was 10-fold higher than king mackerel (0.96 ± 0.27ppm), 18-fold higher than greater amberjack (0.60 ± 0.23ppm), and 59-fold higher than yellowfin tuna (0.18 ± 0.15ppm). Yet, the trophic position of blue marlin was intermediate. The reason that blue marlin stood out from all the other species in this study could be due to their long life span and large size. For example, the maximum age and weight ever recorded for king mackerel is 14 years, 40 kg (Collette and Nauen 1983), while blue marlin can live 28 years and grow to 906 kg (Kailola et al. 1993). The long life span may allow blue marlin to accumulate high levels of mercury. In addition, our blue marlin samples were from sport fishing contests, which targeted the biggest individuals in the population. The other species that we examined were smaller and more comparable in size. Mercury levels in swordfish (n = 2, body weight ~ 200 lbs each) were not as high as reported by FDA and EPA, and more data from the Gulf of Mexico are needed to better quantify this pattern. For the other species, we measured mercury concentrations that were similar compared to those recently reported by FDA (2004) and EPA (2004).

Most of the species in the present study exhibited a significant positive relationship between total mercury concentration and size, which is a common observation in fish (e.g. Huckabee 1979, Monteiro and Lopes 1990, Wiener and Spry 1996). For yellowfin tuna, dolphinfish, and king mackerel the slopes of the relationship were nearly identical (0.025, 0.024, and 0.023, respectively, Table 2). The increasing concentration with size results from the very slow rate of elimination of methylmercury relative to the rapid rate of uptake (Huckabee et al. 1979, Trudel and Rasmussen 1997).

The environmental chemistry of mercury is complex, and subtle changes in chemical, physical, biological, and hydrologic conditions can cause substantial shifts in its physical form and valence state over time scales ranging from hourly to seasonal (Amyot et al. 1994, Krabbenhoft et.1998, Lalonde et al. 2002). The entry of methylmercury into the base of the food web and its subsequent trophic transfer in the lowest levels are still poorly understood (James et al. 2003). Reliance on data from total-mercury determinations from trophic levels below fish (including water, seston, plants, and invertebrates) can produce misleading assessments of food-web contamination and erroneous estimates of potential methylmercury transfer to fish and higher trophic levels (Francesconi and Lenanton 1992, Riisgårdand 1986, Watras and Bloom 1992). In addition, many of the pelagic fishes like tuna, little tunny, blue marlin are known to be highly migratory species that migrate to distances far beyond the coast line of Texas and Louisiana (FAO 1994). These processes probably contributed to the lack of differences observed between years and locations.

Table 2. Mercury concentration in muscle tissue (y, mg/g wet weight) of apex predator species in the Gulf of Mexico as a function of total length (x, cm). Significant exponential functions were fitted by regression, and the r-square value (R^2) and size range (minimum and maximum) is listed by species.

Species	Regression Equation	R^2	Min.	Max.
blackfin tuna*	$y = 0.0015e^{0.081x}$	0.74	22.2	81.9
yellowfin tuna*	$y = 0.0094e^{0.025x}$	0.64	54	158.8
dolphinfish*	$y = 0.0065e^{0.024x}$	0.55	38	135.5
king mackerel*	$y = 0.13e^{0.023x}$	0.47	63.5	104.1
wahoo*	$y = 0.0008e^{0.046x}$	0.36	102.9	175.3
greater amberjack*	$y = 0.19e^{0.014x}$	0.15	68.6	111.8
Carcharhinid sharks	Not significant	nd	61	81.3
cobia	Not significant	nd	78.7	147.3
little tunny	Not significant	nd	53.3	68.6

* P-value < 0.05
nd: Not detected

Across species there was a positive exponential relationship between mercury concentration and trophic position. Currently, we are processing more samples to determine whether this pattern holds within as well as across species. The positive effect of trophic position on mercury concentration was also found in many other studies (Walker 1976, Freeman et al. 1978, Lyle 1984, Cabana and Rasmussen 1994, Greenfield et al. 2001). Blue marlin had an intermediate trophic level, and a higher-than-predicted mercury concentration. More samples of blue marlin from a broader size range are needed to better understand why this species did not follow the same trend as the other species that we examined.

LITERATURE CITED

Ache, B.W., J.D. Boyle, and C.E. Morse. 2000. survey of the occurrence of mercury in the fisheries resources of the Gulf of Mexico. Prepared by Battelle for the U.S. EPA Gulf of Mexico Program, Stennis Space Center, Mississippi USA.

Amyot, M., G. Mierle, D.R.S. Lean, and D. McOueen. 1994. Sunlight-induced formation of dissolved gaseous mercury in lake waters. *Environmental Science and Technology* 28:2366-2371.

Andersen, J.L. and M.H. Depledge. 1997. A survey of total mercury and Methylmercury in edible fish and invertebrates from Azorean waters. *Marine Environmental Research* 44(3):331-350.

Cabana, G. and J.B. Rasmussen. 1994. Modeling food chain structure and contaminant bioaccumulation using stable nitrogen isotopes. *Nature* 372: 255-257.

Cizdziel, J.A., T. A., Hinners, and E.M. Heithmar. 2002. Determination of total mercury in fish tissues using combustion atomic absorption spectrometry with gold amalgamation. *Water, Air, and Soil Pollution* 135:355-370.

Clarkson, T.W. 1987. Metal toxicity in the central nervous system. *Environmental Health Perspectives* 75:59-64.

Clarkson, T.W. 1992. Mercury major issues in environment health. *Environmental Health Perspectives* 100:31-38.

Collette, B.B. and C.E. Nauen, 1983. *FAO species catalogue. Vol. 2. Scombrids of the world. An Annotated and Illustrated Catalogue of Tunas, Mackerels, Bonitos and Related Species Known to Date.* FAO Fisheries Synopsis 2(125):137 pp.

FAO Fisheries Department. 1994. World review of highly migratory species and straddling stocks. *FAO Fisheries Technical Papers No.337*. Rome, Italy. 70 pp.

FDA. 2001. Consumer Advisory – An Important Message For Pregnant Women and Women of Childbearing Age Who May Become Pregnant About the Risks of Mercury in Fish. (see: http://www.cfsan.fda.gov/~dms/admehg.html).

FDA. 2004. Mercury in Fish: FDA Monitoring Program (1990- 2003). (see: http://www.cfsan.fda.gov/~frf/seamehg2.html).

Fitzgerald W.F. and T.W. Clarkson. 1991. Mercury and Monomethylmercury: Present and Future Concerns. *Environmental Health Perspectives* 96:159-166.

Francesconi, K.A. and R.C. Lenanton. 1992. Mercury contamination in a semi-enclosed marine embayment: organic and inorganic mercury content of biota, and factors influencing mercury levels in fish, *Marine Environmental Research* 33:189-212.

Freeman, H.C., G. Shum, and J.F. Uthe. 1978. The selenium content in swordfish (*Xiphias gladius*) in relation to total mercury content. *Journal of Environmental Science and Health* A13:235-240.

Herzka, S.Z. and G.J. Holt. 2000. Changes in isotope composition of red drum (*Sciaenops ocellatus*) larvae in response to dietary shifts: potential applications to settlement studies. *Canadian Journal of Fisheries and Aquatic Sciences* 57:137-142.

Huckabee, J.W., J.W. Elwood, and S.G. Hildebrand. 1979. Accumulation of mercury in freshwater biota. Pages 277-302 in: J.O. Nriagu (ed.). *Biogeochemistry of Mercury in the Environment*, Elsevier/North-Holland Biomedical Press, New York, New York USA.

Kailola, P.J., M.J. Williams, P.C. Stewart, R.E. Reichelt, A. McNee, and C. Grieve. 1993. *Australian Fisheries Resources*. Bureau of Resource Sciences, Canberra, Australia. 422 pp.

Krabbenhoft, D P., J.P. Hurley, M.L. Olson, and L.B. Cleckner. 1998. Diel variability of mercury phase and species distributions in the Florida Everglades, *Biogeochemistry* 40:311-325.

Lalonde, J.D., A.J. Poulain, and M. Amyot. 2002. The role of mercury redox reactions in snow on snow-to-air mercury transfer, *Environmental Science and Technology* 36:174 –178.

Lyle, J.M. 1984. Mercury concentrations in four Carcharhinid and three Hammerhead sharks from coastal waters of the Northern Territory. *Australian Journal of Marine and Freshwater Research* 35:441-451.

Malm, O., M.B. Castro., W.R. Bastos., F.J.P. Branches., J.R.D. Guimaraes., C.E. Zuffo., W.C. Pfeffer. 1995a. An assessment of Hg pollution in different goldmining areas, Amazon Brail. *The Science of the Total Environment* 175L:127-140.

Monteiro, L.R., and H.D. Lopes. 1990. Mercury content of swordfish, *Xiphias gladius*, in relation to length, weight, age, and sex. *Marine Pollution Bulletin* 21:293-236.

Owen, N.J.P. 1987. Natural variation in ^{15}N in the marine environment. *Advances in Marine Biology* 24:389-451.

Peterson, B.J. and B. Fry. 1987. Stable isotopes in ecosystem studies. *Annual Review of Ecology and Systematics* 18:293-320.

Riisgård, H.U. and P. Famme. 1986. Accumulation of inorganic and organic mercury in shrimp, *Crangoncrangon*. *Marine Pollution Bulletin* 17:255-257.

Trudel, M. and J.B. Rasmussen. 1997. Modeling the elimination of mercury by fish. *Environmental Science and Technology* 31:1716-1722.

Wada, E., H. Mizutani, and M. Minagawa. 1991. The use of stable isotopes for food web analysis. *Crit. Tech. Food Sci. Nutr.* 30:361-371.

Walker, T.I. 1976. Effects of species, sex, length and locality on the mercury content of school shark *Galeorhinus australis* (Macleay) and gummy shark *Mustelus antarcticus* (Guenther) from South-eastern Australian waters. *Australian Journal of Marine and Freshwater Research* 27:603-616.

Watras, C. J. and N.S. Bloom. 1992. Mercury and methylmercury in individual zooplankton: Implications for bioaccumulation. *Limnology and Oceanography* 37:1313-1318

Wiener, J.G., D.P. Krabbenhoft, G.H. Heinz, and A.M. Scheuhammer. 2003. Ecotoxicology of Mercury Page 424 in: D.J. Hoffman, B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr. (eds.). *Handbook of Ecotoxicology*. D.C. Lewis publishers, Boca Raton, London, New York, and Washington, D.C. USA.

Wiener, J.G. and D.J. Spry. 1996. Toxicological significance of mercury in freshwater fish. Pages 297-339 in: W. Beyer, G.H. Heinz, and A.W. Redmon-Norwood (eds.). *Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations*. Lewis Publishers, Boca Raton, Florida USA.

U.S. Environmental Protection Agency 2001. Fact Sheet-National Advice on Mercury in Fish Caught by Family and Friends: For Women Who Are Pregnant or May Become Pregnant, Nursing Mothers, and Young Children. EPA Document EPA-823-F-01-004. http://www.epa.gov/waterscience/fishadvice/factsheet.html.

U.S. Environmental Protection Agency. 2002. National Recommended Water Quality Criteria 2002. U.S.EPA Document EPA-822-R-02-047.

U.S. Environmental Protection Agency. 2004. EPA and FDA Advice For: Women Who Might Become Pregnant, Woman Who are Pregnant, Nursing Mothers, Young Children 2004. U.S. EPA Document EPA-823-R-04-005.

Portrait of the Fishery of Mutton Snapper, *Lutjanus analis*, in Puerto Rico during 1988-2001

DANIEL MATOS-CARABALLO, MILAGROS CARTAGENA-HADDOCK, and NOEMÍ PEÑA-ALVARADO
Puerto Rico Department of Natural and Environmental Resources
Fisheries Research Laboratory
P.O. Box 3665
Mayagüez, Puerto Rico 00681-3665

ABSTRACT

The Puerto Rico Department of Natural and Environmental Resources (DNER) is responsible to conserve and manage all the Island's natural resources, including the fishery resources. The DNER's Commercial Fisheries Statistics Program (CFSP) collects and analyzes the dependent fisheries data. The CFSP has been collecting data since 1971. During the 1980s, it was observed that Puerto Rico's commercial fishery resources had shown symptoms of overfishing (e.g. decrease in landings pounds, changes in catch composition, decrease in the size of some important species).

Snappers (Lutjanidae) are the most important fish family in Puerto Rico's fishery market, in pounds landed and prices. Many snappers are red in color, which is preferred by local customers. Mutton snapper (*Lutjanus analis*) has a red color and is often sold as deepwater snapper (silk snapper *Lutjanus vivanus*). The mutton snapper is found in the western Atlantic Ocean from Massachusetts to Brazil, but is most common in the tropical waters of the Caribbean Sea. Mutton snapper spawning aggregations exhibit site fidelity and are related to the full moon phase of the month of February. In Puerto Rico, commercial fishers reported that mutton snapper aggregation occurs in many places around the island near the full moon of April, May and June. That characteristic in the life history of the mutton snapper makes this species particularly vulnerable to human exploitation, resulting in the decline of this population. The primary methods for catching mutton snapper in Puerto Rico are bottom lines, fish traps, SCUBA divers, and beach seines.

The objective of this study is to describe the fishery of mutton snapper thru the data collected by the CFSP (landings and biostatistics data) during 1988 - 2001. Length frequency distributions (LFD) of this species by years, fish traps, beach seine, bottom line and SCUBA divers will be analyzed.

KEY WORDS: Fisheries statistics, mutton snapper, Puerto Rico

Un Retrato de la Pesquería del Pargo, *Lutjanus analis*, en Puerto Rico durante 1988-2001

El Departamento de Recursos Naturales y Ambientales de Puerto Rico (DRNA) es el responsable de conservar y administrar todos los recursos

naturales de la Isla, incluyendo los recursos pesqueros. El Programa de Estadísticas Pesqueras Comerciales del DRNA se encarga de recolectar y analizar los datos dependientes de la pesca comercial. El PEP ha estado recolectando datos desde 1971. Estos datos muestran que durante la década de 1980, la pesca comercial en Puerto Rico mostraba indicios de sobre pesca (Ej. disminución en las libras desembarcadas, cambios en la composición de la captura, disminución en el tamaño de especies importantes).

Los pargos (Lutjanidae) son la familia más importante en el mercado pesquero de Puerto Rico, en libras desembarcadas y precios. Muchos pargos son de color rojo, que es el preferido por los consumidores locales. La sama (*Lutjanus analis*) es de color rojo y a menudo es vendida como pargo de aguas profundas (chillo, *Lutjanus vivanus*). La sama se encuentra en el Océano Atlántico Occidental desde Massachussets hasta Brasil, pero es más común en las aguas tropicales del Mar Caribe. Las agregaciones de apareo de la sama exhiben fidelidad de ocurrir en los mismos lugares y están relacionadas con la fase de la luna llena en el mes de febrero. En Puerto Rico, los pescadores comerciales han reportado que las agregaciones de la sama ocurren en muchos lugares alrededor de la Isla al acercarse la luna llena de abril, mayo y junio. Esta característica en la historia de vida de la sama hace que esta especie sea particularmente vulnerable a la explotación por el ser humano, resultando en la disminución de esta población. Los métodos principales para capturar la sama en Puerto Rico son líneas, nasas y buceo.

El objetivo de este estudio es describir la pesquería de la sama utilizando los datos recolectados por el PEP (desembarcos y datos bioestadísticos) durante 1988-2001. Se analizó la distribución de frecuencia de tallas de esta especie por año y método de captura (nasas, chinchorro de arrastre, línea y buceo).

PALABRAS CLAVES: Estadísticas pesqueras, Puerto Rico, sama

INTRODUCTION

The Puerto Rico Department of Natural and Environmental Resources (DNER) is responsible to conserve and manage all the Island's natural resources, including the fishery resources. The DNER's Commercial Fisheries Statistics Program (CFSP) collects and analyzes the dependent fisheries data. The CFSP has been collecting data since 1971. Matos-Caraballo (2005, 2004) mentioned that during the 1980s, it was observed that the Puerto Rico's commercial fishery resources had shown over fishing symptoms (e.g. decrease in landings pounds, changes in catch composition, decrease in the size of some important species). Species considered in the market as trash during the 1970s, today are considered a second class market species (Matos-Caraballo 2005, 2004).

Snappers (Lutjanidae) are the most important fish family in the Puerto Rico's fishery market, in pounds landed and prices (Suárez-Caabro 1979, Matos-Caraballo 2005, 2004). Many snappers are red color that is preferred by local customers. Mutton snapper (*Lutjanus analis*) has a red color and is often sold as deep water snapper (silk snapper *Lutjanus vivanus*). The mutton snapper is found in the western Atlantic Ocean from Massachusetts to Brazil, but is most common in the tropical waters of the Caribbean Sea (Allen 1985). In Bermuda this species had been introduced (Randall 1996). Large adults are found in or near offshore reef and rock rubble habitats, and around coral reefs, while the juveniles live in inshore areas with mangroves and seagrass bottoms (Allen 1985). The mutton snapper has an average length of 500 mm, although has maximum length of 900 mm, reaching a maximum age of 14 years (Allen 1985). The mutton snapper form large, transient spawning aggregations. It has been reported that in the northeastern Caribbean, these spawning aggregations exhibits site fidelity and are related to the full moon phase of the month of February. However in other areas of the eastern and southeastern Caribbean the spawning aggregations have been reported during the summer (Allen 1985). In Puerto Rico, commercial fishers reported that mutton snapper aggregation occur in many places around the island near the full moon of April, May, and June. That characteristic in the life history of the mutton snapper makes this species particularly vulnerable to human exploitation (Mannoch 1987). Allen (1985) also mentioned that because of high fishing pressure on the mutton snapper spawning aggregation the population has been declining. The primary methods for catching mutton snapper in Puerto Rico are bottom lines, fish traps, SCUBA divers, and beach seines.

The objective of this study is to describe the fishery of mutton snapper through the data collected by the CFSP (landings and biostatistics data) during 1988 - 2001. Length frequency distributions (LFD) of this species by years, fish traps, beach seine, bottom line and SCUBA divers.

METHODS

This report will discuss the mutton snapper fishery using two types of dependent data collected by CFSP from 1988 to 2001. First, the landings data were collected by CFSP's port samplers. The commercial fishers and/or fish houses reported their catch in a trip ticket system.

The second type of data used in this study was biostatistics. This data were also collected by CFSP's port samplers. They visited the fishing centers and randomly selected commercial landings. Then they proceed to identify by species all the catch to obtain data about composition. Then port samplers measured fish's fork length (FL) in mm. If it is possible the whole catch was individually measured. CFSP's port samplers collect catch per unit effort data (CPUE) *in situ* when they do the biostatistics sampling. The total landings by trip and by gear, number of traps hauled and nets length in fathoms was recorded.

Port samplers delivered the landings and biostatistics data to CFSP and statistical clerks edited and entered in computers using Microsoft FoxPro and NMFS Trip Interview Program (TIP). The data were analyzed using length frequency distribution (LFD) of this species by years, fish traps, beach seine,bottom line and SCUBA divers. LFD for both species by years and by gears were analyzed. Kolmogorov-Smirnov Two Sample Test, $p \leq 0.05$ (Sokal and Rohlf 1981) was used to know if there is any significant difference among the comparisons.

RESULTS

Landings data show that a total of 807,363 pounds of mutton snappers were reported to the CFSP during 1988 - 2001 (Figure 1). During the late 1980s, a process was started to educate commercial fishers to report mutton snapper specifically; before this species was reported as only as snappers. However, it is known by the CFSP' personnel that a significant percentage of the pounds reported as first class were also mutton snapper. For this paper only, the mutton snapper data were used. Since 1988 - 1994, mutton snapper reported represented 1.4% of the total pounds reported of fish and shellfish. Since 1995 - 2001, mutton snapper reported represented a total of 2.4% of the total pounds reported of fish and shellfish. During 1988 - 2001, mutton snapper reported represented a 2.0% of fishes and shellfish. For this period the mutton snapper were in the first 15 categories of fish and shellfish landed reported.

Figure 2 shows the trend of landings reported by beach seine, fish trap, bottom line, and SCUBA divers during 1988 - 2001. Landings reported by the mentioned gears show that fish traps caught 28.3% of the 807,363 pounds of mutton snapper reported during 1988 - 2001. For the same time period, bottom lines caught 60.4%, beach seines caught 3.6%, and SCUBA divers caught 7.6% of the total landed pounds of mutton snapper reported. Figure 2 shows that reported landings increased for fish trap, bottom line and SCUBA divers for years 1995 - 2001. On the other hand, beach seine shows a decreased in landings reported during 1995 - 2001.

Biostatistics data indicate that from 1988 - 2001, a total of 2,308 individuals of mutton snappers were measured by CFSP's port samplers. Mutton snappers measured during 1988 - 1994, had a FL mean of 381mm (Figure 3) and during 1995 - 2001 was 396.5 mm (Figure 4). Kolmogorov-Smirnov Test shows a significant difference in the LFD among both periods of time (Dmax = 0.0602).

The mean FL for mutton snapper caught by fish traps during 1988 - 2001 was 324 mm (Figure 5). For the same time period, mutton snapper caught by bottom line had a mean FL of 464 mm (Figure 6). SCUBA divers for the same period had a FL mean of 480 mm (Figure 7), and beach seine had a FL mean of 282 mm (Figure 8). Kolmogorov-Smirnov Test shows a significant difference in the mutton snapper LFD among beach seine and fish trap (Dmax = 0.0822). Also, the same test indicated a significant difference among LFD of fish trap and bottom line methods (Dmax = 0.4502). Bottom lines LFD and SCUBA divers also showed a significant difference too (Dmax = 0.1580).

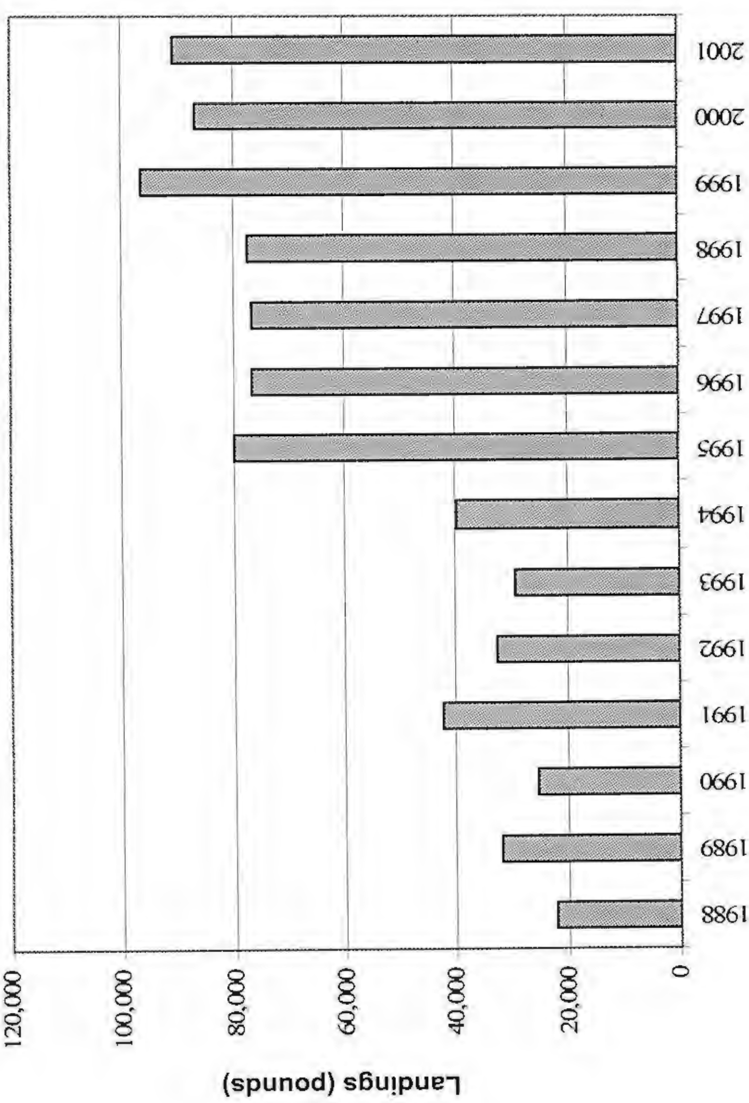


Figure 1. Landings reported of mutton snapper in Puerto Rico during 1988-2001.

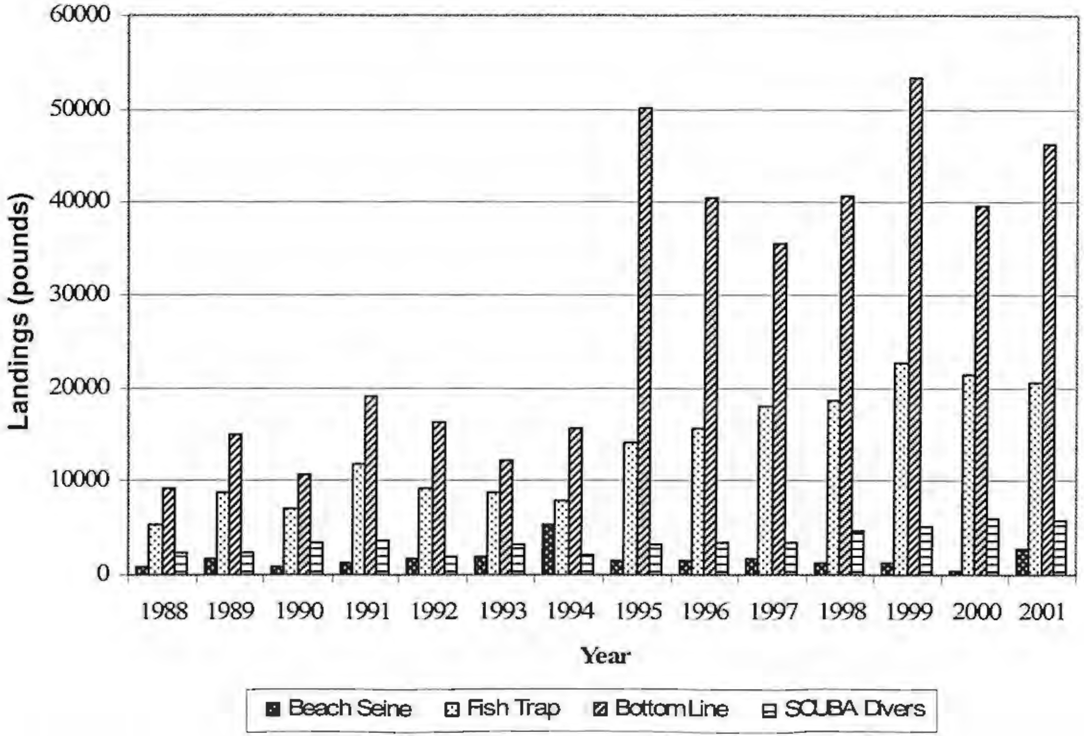


Figure 2. Landings reported of mutton snapper by beach seine, fish trap, bottom line and SCUBA divers in Puerto Rico during 1988 - 2001.

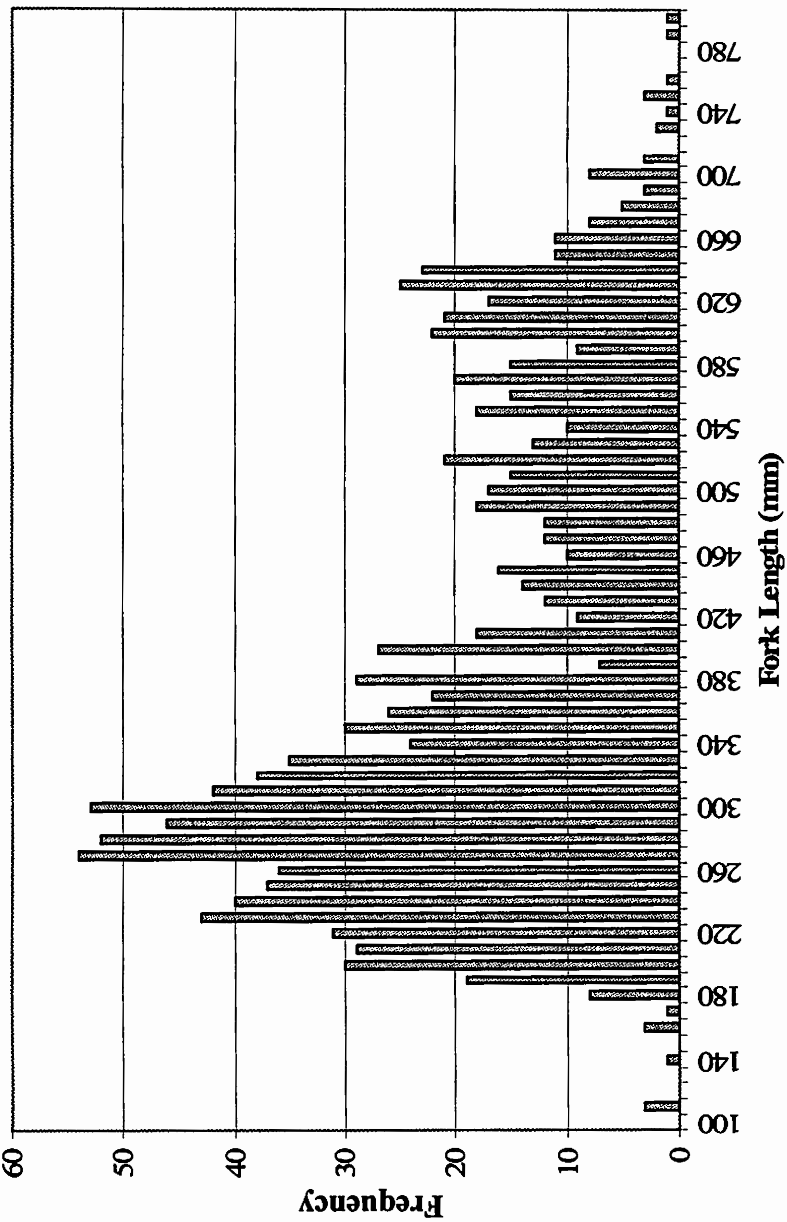


Figure 3. Length frequency distribution for mutton snapper caught by all gears in Puerto Rico during 1988 - 1994.

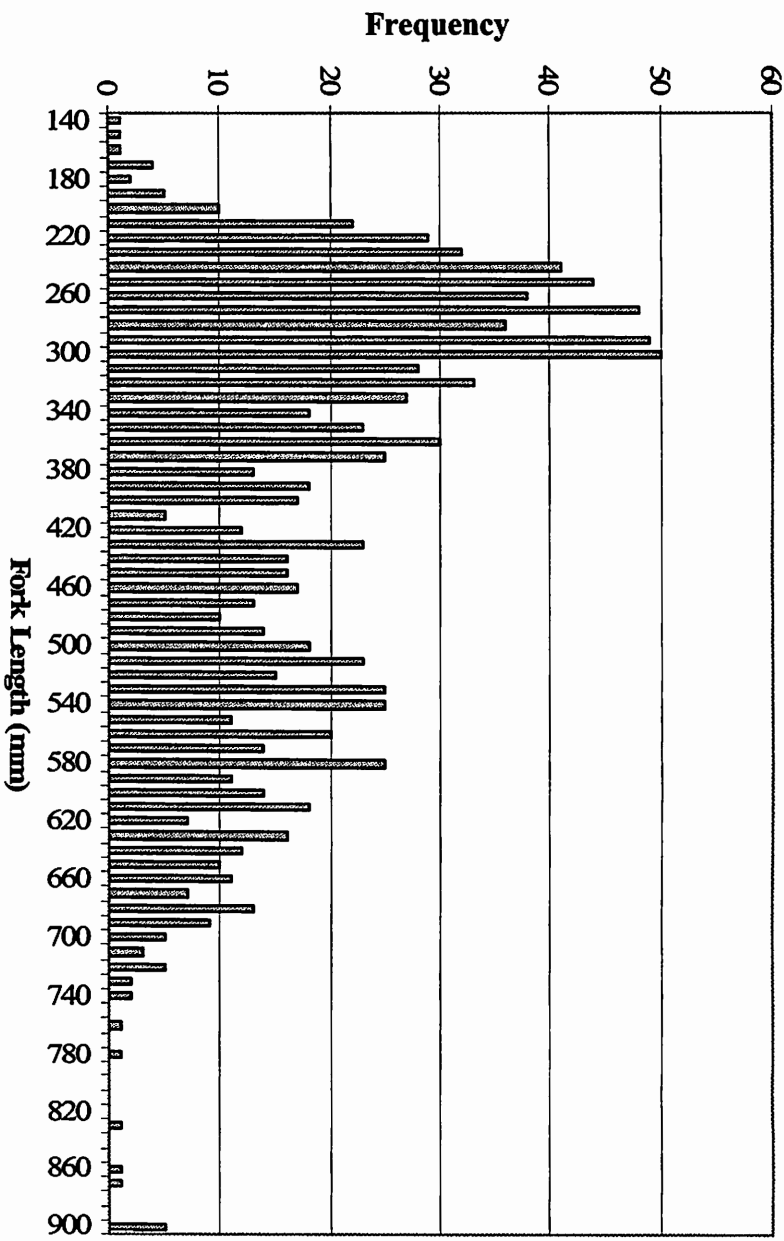


Figure 4. Length frequency distribution for mutton snapper caught by all gears in Puerto Rico during 1995 - 2001.

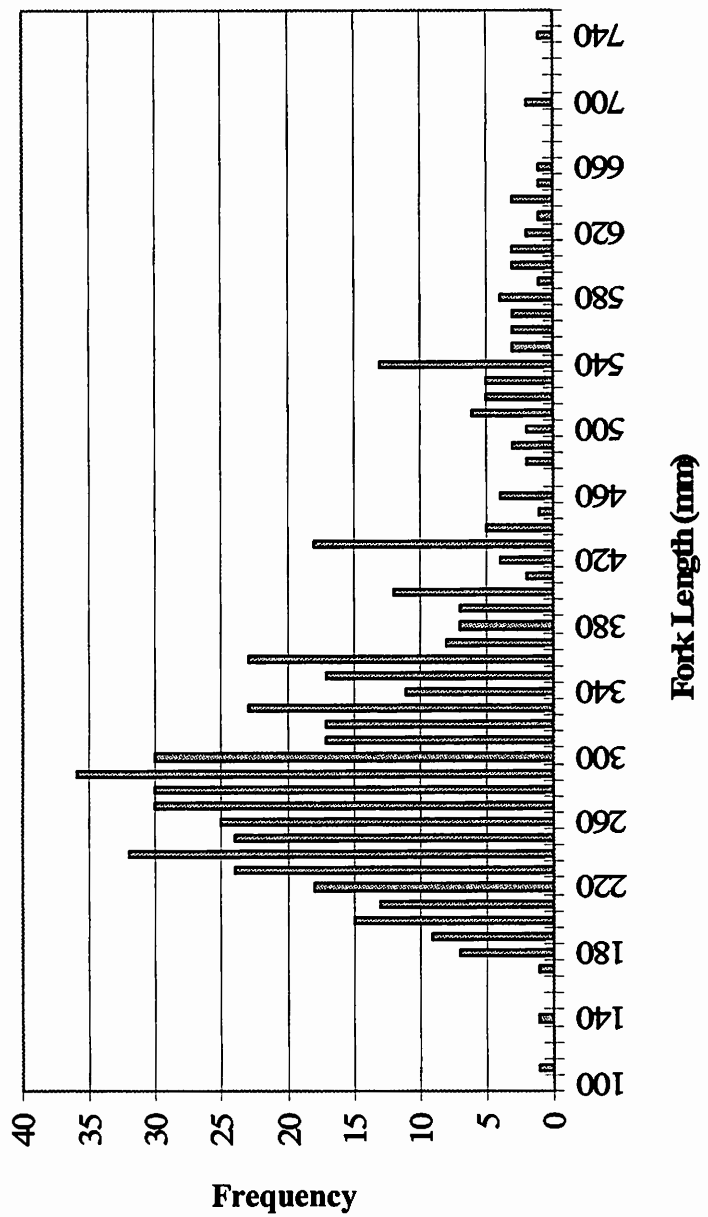


Figure 5. Length frequency distribution for mutton snapper caught by fish trap in Puerto Rico during 1988 - 2001.

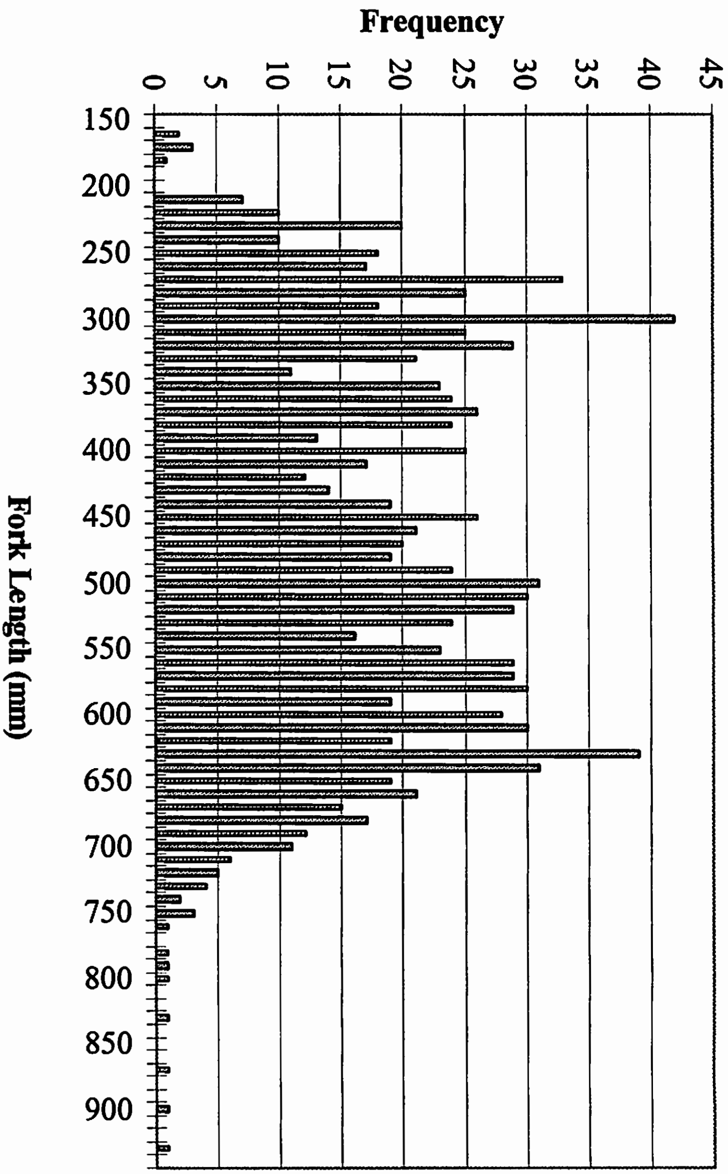


Figure 6. Length frequency distribution for mutton snapper caught by bottom line in Puerto Rico during 1988 - 2001.

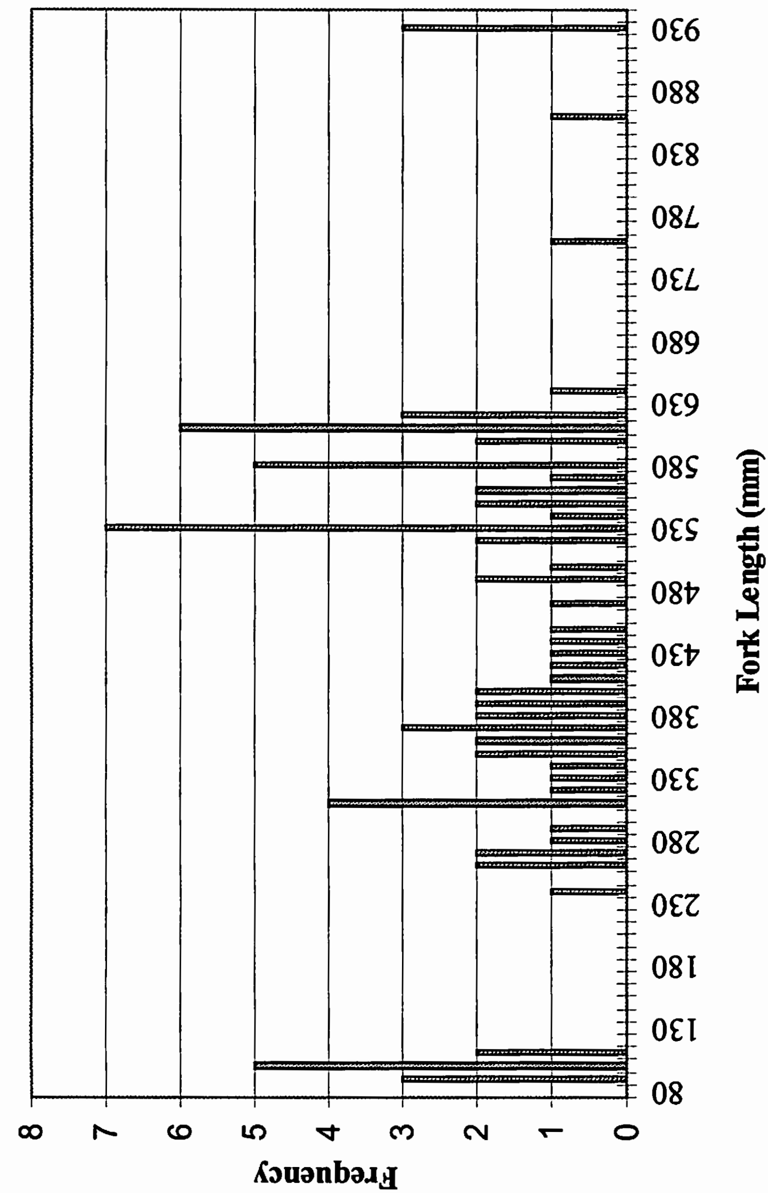


Figure 7. Length frequency distribution for mutton snapper caught by SCUBA divers in Puerto Rico during 1988 - 2001.

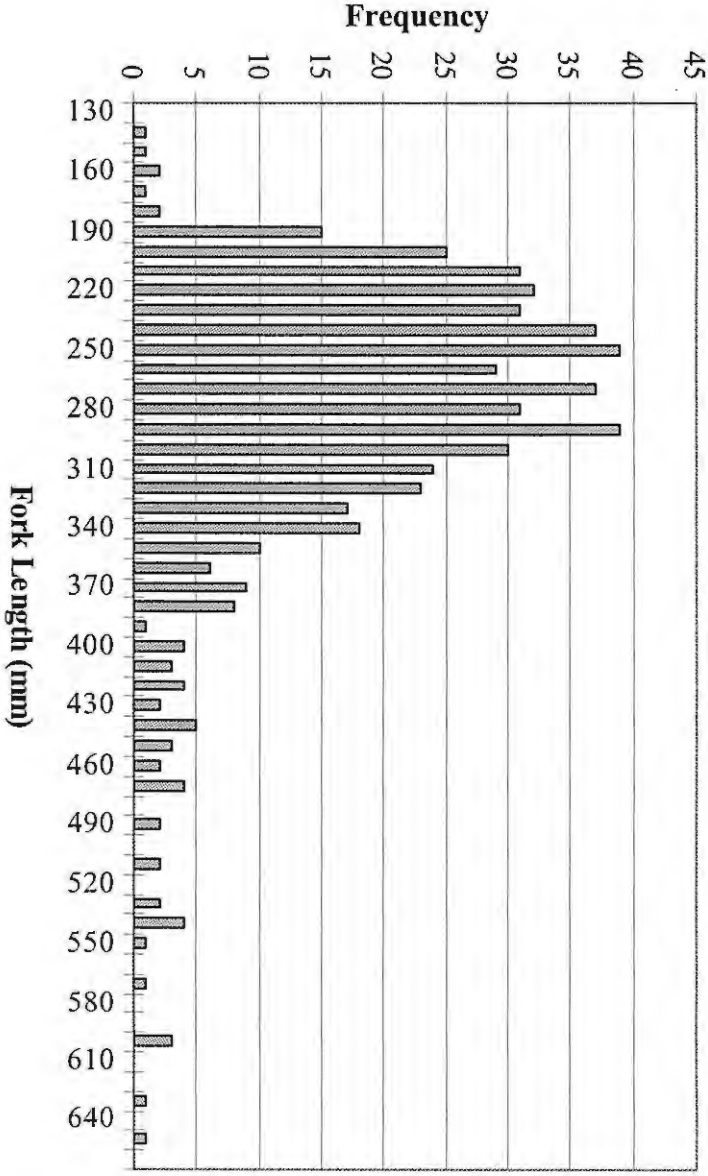


Figure 8. Length frequency distribution for mutton snapper caught by beach seine in Puerto Rico during 1988 - 2001.

A total of one-hundred biostatistics interviews were randomly selected to obtain mutton snapper CPUE estimates data analysis. All interviews include reports of mutton snapper and other reef fishes. However, the mutton snapper was significant in the number of individuals and weight in the landings interviews. CFSP data show that during 1988 - 1994, the fish traps had an average catch of 34 pounds/trip. During this period of time fishing trips had an average hauling of 24.5 fish traps and the average soak time of 4.3 days. It was estimated that every fish trap caught 0.32 pound/trap/day. On the other hand, for the period of 1995 - 2001, fish traps show a landings increase, obtaining an average of 69.6 pounds/trip. Fishing trips showed a decrease in the average number of fish traps hauled to 21.6, and the average soak time increased to 5.8 days. For this period, it was estimated that every fish trap caught 0.56 pounds/trap/day. During 1988 - 1994, bottom line fishing trips had an average of 49 pounds/trip. During this period, fishing trips had an average of 2.5 hooks, and the average fishing time was 9.9 hours. It was estimated that bottom lines caught 1.94 pounds/hook/hour. On the other hand, for the period of 1995 - 2001, bottom lines showed a landings increase, obtaining an average of 56 pounds/trip. During this period, reef fishes fishing trips had an average of 2.1 hooks/trip and the average fishing time was 9.4 hours. It was estimated that bottom lines caught 2.88 pounds/hook/hour. CFSP SCUBA divers data shows that during 1988 - 1994, had an average catch of 65 pounds/trip. During this period, fishing trips averaged 2.3 divers with an average fishing time of 5.0 hours. It was estimated that a SCUBA diving catch was 5.57 pounds/diver/hour. On the other hand, for the period of 1995 - 2001, SCUBA divers showed a landings decrease in pounds/trip obtaining 48 (17 less). During this period, reef fishes fishing trips had an average of 1.33 SCUBA divers/trip and the average fishing time was 4.2 hours. It was estimated that SCUBA divers catch 8.75 pounds/diver/hour. CFSP beach seine data shows that during 1988 - 1994, had an average catch of 304 pounds/trip. During this period, the length of beach seines averaged 220 fathoms, with an average fishing time of 4.6 hours. It was estimated that a beach seine caught, on average, 0.30 pounds/fathom/hour. On the other hand, for the period of 1995 - 2001, beach seine shows a landings decrease in the pounds/trip obtaining 166 (138 less). During this period of time reef fishes fishing trips had an average of 6.4 hours, and seines averaged 200 fathoms length. It was estimated that beach seines caught 0.13 pounds/fathom/hour.

DISCUSSION

Puerto Rico's commercial fishery of mutton snapper has shown that marketing and demand for this species continues to be one of the most important during the last 15 years. The data analyzed in this report show that a high fishing pressure occurred on mutton snapper during 1988 - 2001. The landings data show trends of increase in mutton snapper landings during 1995 - 2001. However, it is necessary to mention that before 1987 mutton snapper was reported in the snapper category. Also in 1995, more fishers participated in the CFSP, which probably explains the increasing landings reported during 1995 - 2001. Commercial fishers mentioned that the mutton snapper spawning aggregation has been exploited since the early 1980s. Commercial fishers who participated in the mutton snapper spawning aggregation fishery during the early 1980s mentioned to CFSP that the harvest of this activity had been decreased significantly. This situation is comparable with Florida and Cuba, where fishing pressure on spawning aggregations has caused a decrease in fishing harvest and the total collapse of some spawning aggregations (Mueller 1995). The CPUE data shows an increase in the fishing pressure on the mutton snapper for bottom lines, fish traps, and SCUBA divers. Beach seines have shown a decrease in the CPUE. Bottom lines are more efficient gears to catch mutton snappers (60.4%) than the fish traps (28.3%), SCUBA divers (7.6%), and beach seines (3.6%). It is important to comment that fish trap gear has shown a decrease in landings during 1989 - 1995; during this time a decrease in the use of fish traps was observed, as well as an increase in the use of bottom lines (Matos-Caraballo 2005).

This study shows that mutton snapper that were caught during 1995 - 2001 were, on average, larger than those caught during 1988 - 1995. The CPUE data shows that bottom lines caught the larger individuals. Both trends probably occur due to the fishing exploitation of the spawning aggregations, where the larger individuals were caught and sampled by the CFSP. Also, fish traps, beach seines, and SCUBA divers caught significantly smaller individuals because these gears were not used in the mutton snapper spawning aggregations areas. In addition, many commercial fishers have claimed that they fish these species only during the spawning aggregations. All these facts are symptoms that indicate that mutton snapper's population is overexploited.

Figuerola Fernández and Torres Ruíz (2001) determined that 50% of male mutton snappers reach sexual maturity (SM) at 330 mm FL. They also determined that 50% of female mutton snappers reach SM at 414mm FL. Although no sex was determined for the individuals measured in this study, 42% of them did not reach 330 mm (Figure 3 and 4). That means a very high percentage of the mutton snapper caught by commercial fishers in Puerto Rico did not reach maturity before they were caught. The LFD by gear shows that bottom line caught approximately 19% of individuals that did not reach SM. On the other hand, the SCUBA divers caught 26% of individuals before reaching SM, the fish traps caught 54% and beach seine caught 90%. Mutton snapper is heavily fished during their spawning aggregations, resulting in the removal of the larger individuals before they spawn. This activity resulted in a reduction of the population. Fish traps and beach seines mostly caught mutton snapper before reaching their sexual maturity.

The DNER fishing regulations will help to conserve the mutton snapper fishery resource creating a closed season during April 1st – May 31st of every year, when the first two spawning aggregations occur. The last spawning aggregation in June will be open for fishers. It is hoped that this regulation will forestall the collapse of the mutton snapper fishery in Puerto Rico. To support this regulation Muller (1995), Figuerola-Fernández and Torres-Ruíz (2001), mentioned that the exploitation of mutton snapper spawning aggregation resulted in the decrease of landings and the collapse of the fishery in some locations of Florida and Cuba. Also the DNER will prohibit the use of beach seines in Puerto Rico beginning in 2007. Beach seines are responsible for the fishing mortality of many juvenile mutton snapper and other species in Puerto Rico. CFSP's personnel observed and sampled beach seine catching juvenile yellowtail snapper, *Ocyurus chrysurus*, various species of groupers (Serranidae), king mackerel, *Somberomorus cavalla*, cero, *S. regalis*, and various species of jacks (Carangidae). During 1987 - 1992, most of the mentioned juvenile species were discarded at the beach. However, during 1998 - 2004, CFSP's personnel observed marketing for this juvenile species. This is another symptom of Puerto Rico's overexploited fishery resource. This study shows the urgent need of the mentioned fishing regulations to help to improve the mutton snapper population.

ACKNOWLEDGEMENT

We want to express our deep gratitude to all that made possible this research. To NOAA/NMFS Cooperative Fisheries Statistics Program and Puerto Rico's Department of Natural and Environmental Resources (DNER) that provided the funds. Also, thanks to the Caribbean Fisheries Management Counsil that provided the funds to participate in the 57th Gulf and Caribbean Fisheries Institute. To Puerto Rico's Commercial Fisheries Statistics port samplers Walter Irizarry, Jesús León, Héctor Y. López, and Luis A. Rivera, whom collected the data. To Albaliz Mercado and Lucía T. Vargas who edited and entered the data in computers. To Miguel Figuerola who helped in editing the paper. Finally, we want to acknowledge all the commercial fishers that participate in the Commercial Fisheries Statistics Program (CFSP).

LITERATURE CITED

Allen, G.R. 1985. FAO Species Catalog Vol. 6. Snappers of the World. An Annotated and Illustrated Calogue of Lutjanid species known to Date. *FAO Fisheries Synopsis* 6(125):208 pp.

Figuerola-Fernández, M. and W. Torres-Ruíz. [2001]. Aspectos de la Biología Reproductiva de la sama (*Lutjanus analis*) en Puerto Rico y Recomendaciones para su Manejo. Reporte Final al Departamento de Recursos Naturales y Ambientales. Unpubl. MS. 29 pp.

Manooch, C.S.,III. 1987. Age and Growth in Snappers and Groupers. Pages 329-373 in J.L. Polovonian and S. Ralston (eds.). *Tropical Snappers and Groupers; Biology and Fisheries Management.* West View Press. Boulder, Colorado USA.

Matos-Caraballo, D., M. Cartagena-Haddock, and N. Peña-Alvarado. 2005. Comprehensive census of the marine commercial fishery of Puerto Rico 2002. *Proceedings of the Gulf and Caribbean Fisheries Institute* 56:97-110.

Matos-Caraballo, D. 2005. Status of the fishery in Puerto Rico, 1990 - 1993. *Proceedings of the Gulf and Caribbean Fisheries Institute* 47:217-235.

Matos-Caraballo, D. 2004. Overview of Puerto Rico's small-scale fisheries statistics 1998 - 2001. *Proceedings of the Gulf and Caribbean Fisheries Institute* 55:103-118.

Muller, K.W. 1995. Size structure of mutton snapper, *Lutjanus analis,* associated with unexploited artificial patch reefs in the central Bahamas. *Fisheries Bulletin* 93 (3):573-576.

Randall, J.E. 1996. *Caribbean Reef Fishes. 3rd Edition.* T.F.H., Inc. Ltd., Hong Kong. 368 pp.

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

Suárez-Caabro, J. A. 1979. *El Mar de Puerto Rico. Una Introducción a las Pesquerías de la Isla.* Editorial Universitaria. Río Piedras, Puerto Rico. 257 pp.

Portrait of the Fishery of Red Hind, *Epinephelus guttatus*, in Puerto Rico during 1988-2001

DANIEL MATOS-CARABALLO, MILAGROS CARTAGENA-HADDOCK, and NOEMÍ PEÑA-ALVARADO
Puerto Rico Department of Natural and Environmental Resources
Fisheries Research Laboratory
P.O. Box 3665
Mayagüez, Puerto Rico 00681-3665

ABSTRACT

The Puerto Rico Department of Natural and Environmental Resources (DNER) is responsible for the conservation and management of all the Island's natural resources, including the fishery resources. The DNER's Commercial Fisheries Statistics Program (CFSP) collects and analyzes the dependent fisheries data. The CFSP has been collecting data since 1971. During the 1980s, it was observed that the Puerto Rico's commercial fishery resources had shown overfishing symptoms (e.g. decrease in landings pounds, change in catch composition, decrease in the size of some important species).

Groupers (Serranidae) are an important resource in Puerto Rico's commercial fishery. Grouper species share a number of life history characteristics believed to render them particularly vulnerable to human exploitation. Several groupers species in the Caribbean and Western Atlantic are known to aggregate for spawning at specific times and locations. The fishing activity of these resources during their aggregation periods make these groupers very vulnerable to being overexploited.

The red hind, *Epinephelus guttatus*, has become the most important species of grouper taken commercially in Puerto Rico. E. *guttatus* is a protogynous hermaphrodite and forms spawning aggregations. However, this species is also heavily fished during the spawning aggregation. During the last 12 years there are many studies reporting red hind as an overfished species. Since 1995, three spawning aggregation sites of the red hind in the west coast of Puerto Rico have been closed to all fishing activity. The Caribbean Fishery Management Council and the DNER work together to enforce this action.

The objective of this study is to describe the fishery of red hind through the data collected by the CFSP (landings and biostatistics data) during 1988 - 2001. Length frequency distributions (LFD) of this species by years, fish traps, SCUBA diving, and bottom lines were compared.

KEY WORDS: Biostatistics data, commercial fishery, red hind, Puerto Rico

Un Retrato de la Pesquería de *Epinephelus guttatus* en Puerto Rico durante 1988-2001

El Departamento de Recursos Naturales y Ambientales de Puerto Rico (DRNA) es el responsable de conservar y administrar todos los recursos

naturales de la Isla, incluyendo los recursos pesqueros. El Programa de Estadísticas Pesqueras (PEP) del DRNA se encarga de recolectar y analizar los datos dependientes de la pesca. El PEP ha estado recolectando datos desde 1971. Estos datos muestran que durante la década de 1980, la pesca comercial en Puerto Rico mostraba indicios de sobre pesca (Ej. disminución en las libras desembarcadas, cambios en la composición de la captura, disminución en el tamaño de especies importantes).

Los meros (Serranidae) son un recurso importante en la pesca comercial de Puerto Rico. Los meros comparten un número de características que los hacen vulnerables a la explotación por el ser humano. Varias especies de mero en el Caribe y el Atlántico Occidental se agregan para aparearse en un tiempo y un lugar específico. La pesca de estos recursos durante periodos de agregación hace muy vulnerables a ser sobre explotados.

La cabrilla, *Epinephelus guttatus*, se ha convertido en la especie de mero más importante capturada comercialmente en Puerto Rico. El mero cabrilla es hermafrodita protogíneo y forma agregaciones para aparearse. No obstante esta especie ha sido fuertemente pescada durante las agregaciones para aparearse. Durante los últimos 12 años muchos estudios reportan a *E. guttatus* como una especie sobre pescada. Desde 1995, tres lugares de agregación para aparearse de la cabrilla, en la costa oeste de Puerto Rico, han sido cerrados a toda actividad pesquera. El Consejo de Pesca del Caribe y el DRNA trabajan en conjunto para hacer cumplir esta acción.

El objetivo de este estudio es describir la pesquería de *E. guttatus* utilizando los datos recolectados por el PEP (desembarcos y datos bioestadísticos) durante 1988-2001. Se comparó la distribución de frecuencia de tallas de esta especie por año y arte de pesca (nasa, buceo y línea).

PALABRAS CLAVES: Datos de bioestadísticas, pesca comercial, mero cabrilla, Puerto Rico

INTRODUCTION

The Puerto Rico Department of Natural and Environmental Resources (DNER) is responsible to conserve and manage all the Island's natural resources, including the fishery resources. The DNER's Commercial Fisheries Statistics Program (CFSP) collects and analyzes the dependent fisheries data. The CFSP has been collecting data since 1971. Matos-Caraballo (in press a and b) mentioned that during the 1980s decade, it was observed that the Puerto Rico's commercial fishery resources had shown overfishing symptoms (e.g. decrease in landings pounds, change in catch composition, decrease in the size of some important species). Species considered in the market as trash during the 1970s, today have been considered a second class market species (Matos-Caraballo in press a and b).

Groupers (Serranidae) are an important resource in the Puerto Rico's commercial fishery. Grouper species share a number of life history characteristics believed to render them particularly vulnerable to human exploitation (Mannoch 1987). Sadovy (1994) mentioned that groupers are carnivores, have relatively long life span, large size of sexual maturation, slow growth, and appear to be relatively easy to catch, being susceptible to a wide range of sizes and types of fishing gear. Many species of groupers exhibit adult sex change. Several groupers species in the Caribbean and Western Atlantic are known to aggregate for spawning at specific times and locations. The fishing activity of these resources during their aggregation periods make these groupers very vulnerable to overexploitation. The Nassau grouper, *Epinephelus striatus,* was the main grouper species landed in Puerto Rico by commercial fishers from 1900 to the 1970s (Everman 1900, Suárez-Caabro 1970). This species was heavily fished during spawning aggregations resulting in a gradual decrease of landings. Since the mid-1980s, this species has been considered extinct for commercial fishery purposes (Sadovy 1996).

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 1999). Red hind is a protogynous hermaphrodite and forms spawning aggregations. However, this species is also heavily fished during the spawning aggregation. The result of this activity would cause the same fate as that of *E. striatus*. During the last 12 years there are many studies reporting red hind as an overfished species (Appeldorn et al. 1992, Sadovy and Figuerola 1992, Rosario 1996, Matos-Caraballo 2002). *Epinephelus guttatus* forms spawning aggregations around the full moon of December, January, and February. Since 1995, three spawning aggregation sites for *E. guttatus* along 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. Matos-Caraballo (2000), discussed how the mentioned regulation significantly improved the red hind population.

The objective of this study is to describe the fishery of red hind through the data collected by the CFSP (landings and biostatistics data) during 1988 - 2001. Length frequency distributions (LFD) of this species by years, fish traps, SCUBA diving, and bottom lines were compared.

METHODS

This report will discuss the red hind fishery using two types of dependent data collected by CFSP thru 1988-2001. First, the landings data were collected by CFSP's port samplers. The commercial fishers and/or fish houses reported their catch using a ticket. Unfortunately, some reports of this species had been reported as groupers or first class fishes.

The second type of data used in this study was biostatistics. That data were also collected by CFSP's port samplers. They visited the fishing centers and randomly selected commercial landings. Then they proceeded to identify by species all the catch to obtain data about composition. Then port samplers measured fishes' fork length (FL) in mm. If possible, the entire catch was individually measured and sex was also registered. CFSP's port samplers collected catch per unit effort data (CPUE) when they did the biostatistics sampling. The total landings by trip and by gear, number of traps hauled, and nets length in fathoms were recorded.

Port samplers delivered the landings and biostatistics data to CFSP and statistical clerks edited and entered in computers using Microsoft FoxPro and NMFS Trip Interview Program (TIP). The data were analyzed using length frequency distribution (LFD) of this species by years, fish traps, SCUBA diving, and bottom line. LFD for both species by years and by gears were analyzed. Kolmogorov-Smirnov Two Sample Test, $p \leq 0.05$ (Sokal and Rohlf, 1981) was used to know if there is any significant difference among the LFD's.

RESULTS

Landings data show that a total of 680,601 pounds of red hind were reported to the CFSP during 1988 - 2001 (Figure 1). During the late 1980s, a process was initiated to educate commercial fishers about reporting red hind landing. This fact explains the significant increase in reported landings during 1988 - 1991. Figure 1 includes the grouper category because many fishers reported red hind in the grouper category; besides red hind was the main grouper caught in Puerto Rico during the time period of this study. The number of pounds reported of red hind represented a 1.7% from the total catch reported during the mentioned period. However, it is known by the CFSP personnel that a significant percentage of the pounds reported as first class fish were also red hind. For this paper, only the red hind data were used. During 1988 - 1994, red hind reported represented 1.7% of the total pounds reported of fish and shellfish. During 1995 - 2001, red hind reported represented a total of 2.0% of the total pounds reported of fish and shellfish. During 1988 - 2001, red hind reported represented 1.9% of fishes. For this period the red hind was

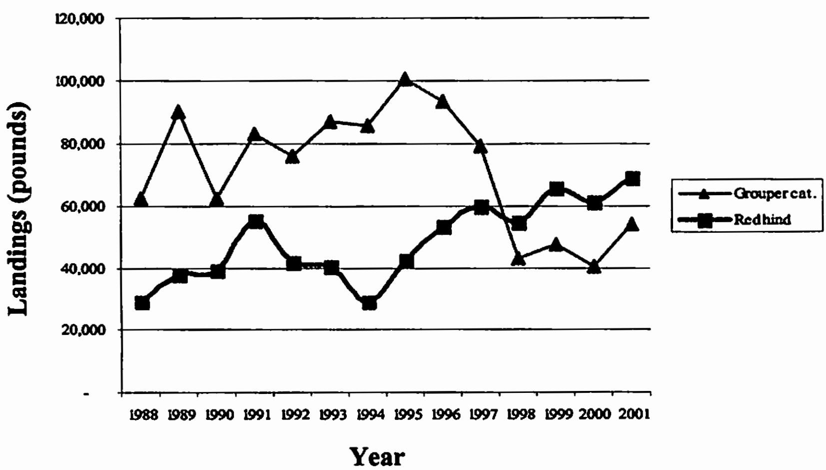


Figure 1. Landings reported of grouper category and red hind in Puerto Rico during 1988 - 2001.

Figure 2 shows the trend of landings reported by fish traps, bottom lines and SCUBA divers during 1988 - 2001. Landings reported by the mentioned gears show that fish traps caught 33% of the 680,601 pounds of red hind reported during 1988 - 2001. For the same period, bottom lines caught 47%, and SCUBA divers caught 14% of the total landed pounds of red hind reported. Figure 2 shows that fish trap landings decreased from those reported from 1995 - 2001. On the other hand, bottom line and SCUBA divers show an increase in landings reported during 1995 - 2001. Biostatistical data show that from 1988 - 2001, a total of 8,861 individuals of red hind were measured by CFSP's port samplers. Red hind measured during 1988 - 1994, had a FL mean of 306.5 mm (Figure 3) and during 1995 - 2001 was 318.5 mm (Figure 4). Kolmogorov-Smirnov Test shows a significant difference in the LFD among both periods of time (Dmax = 0.0981).

The mean FL for red hind caught by fish traps during 1988 - 2001 was 291 mm (Figure 5). For the same period red, hind caught by hook and line had a mean FL of 313 mm (Figure 6). Kolmogorov-Smirnov Test shows a significant difference in the red hind LFD among fish traps and hook and line during 1988 - 2001 (Dmax = 0.1321). The mean FL for red hind caught by SCUBA divers during 1988 - 2001 was 336 mm (Figure 7). Kolmogorov-Smirnov Test shows a significant difference in the red hind LFD among hook and line and SCUBA divers during 1988 - 2001 (Dmax = 0.1163).

A total of one-hundred biostatistics interviews were randomly selected to obtain red hind CPUE estimates for data analysis. All interviews include reports of red hind and other reef fishes. However, the red hind was significant in number of individuals and weight in the catch composition. CFSP data show that during 1988 - 1994, the fish traps had an average catch of 62.8 pounds/trip. During this period, fishing trips had an average of hauling 28.5 fish traps and the average soak time was 5.6 days. It was estimated that every fish trap caught 0.40 pounds/day. On the other hand, for the period of 1995 - 2001, fish traps show a landings increase, averaging 78.7 pounds/trip. During this period, fish traps fishing trips had an average of hauling 41.4 fish traps and the average soak time was 5.4 days. It was estimated that every fish trap caught 0.37 pound/days. Bottom lines CFSP data show that during 1988 - 1994, had an average catch of 44.2 pounds/trip. During this period of time fishing trips had an average of 6.5 hooks, and the average fishing time was 8.5 hours. It was estimated that bottom lines caught 0.80 pounds/hook/hour. On the other hand, for the period of 1995 - 2001, landings from bottom lines increased, obtaining an average of 64.8 pounds/trip. During this period, reef fishes fishing trips had an average of 7.0 hooks/trip and the average fishing time was 9.5 hours. It was estimated that bottom lines catch 0.97 pound/hook/hour. CFSP SCUBA divers data shows that during 1988 - 1994, had an average catch of 31.4 pounds/trip. During this period, fishing trips had an average of 1.8 divers with an average fishing time of 3.9 hours. It was estimated that a diver caught 8.1 pound/hour. On the other hand, for the period of 1995 - 2001, SCUBA divers shows a landings increase, obtaining an average of 44.7 pounds/trip. During this period, reef fishes fishing trips had an average of 1.37 SCUBA divers per trip, and the average fishing time was 3.5 hours. It was estimated that SCUBA divers caught 12.8 pounds/hour.

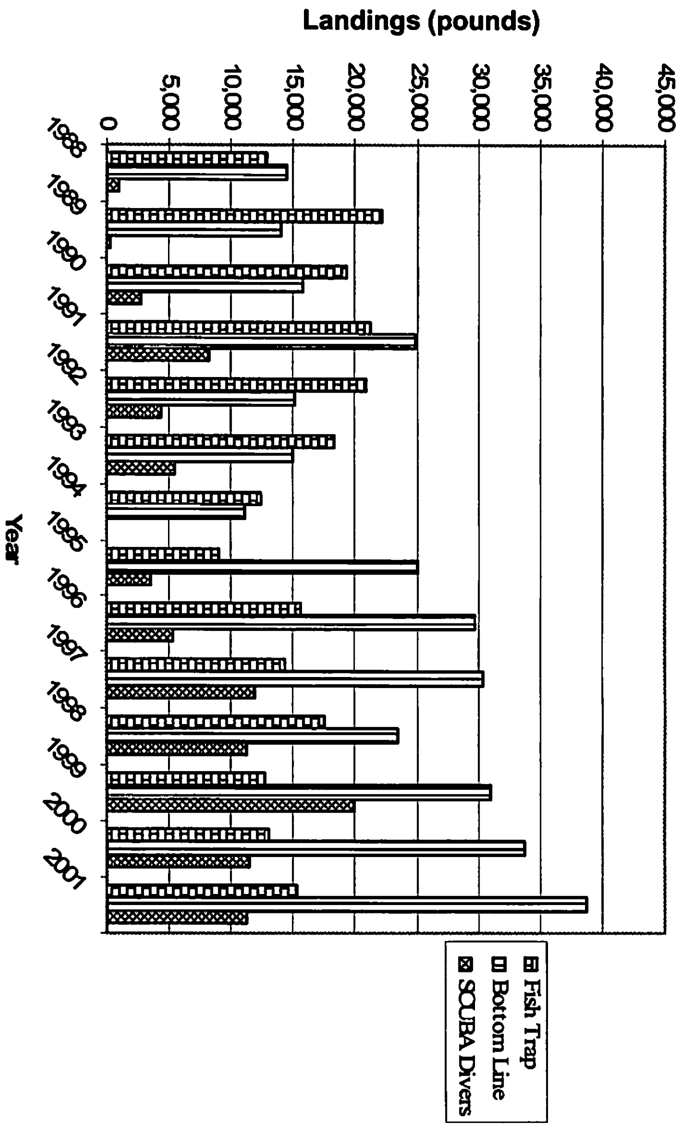


Figure 2. Landings reported of red hind by fish trap, bottom line and SCUBA divers in Puerto Rico during 1988 - 2001.

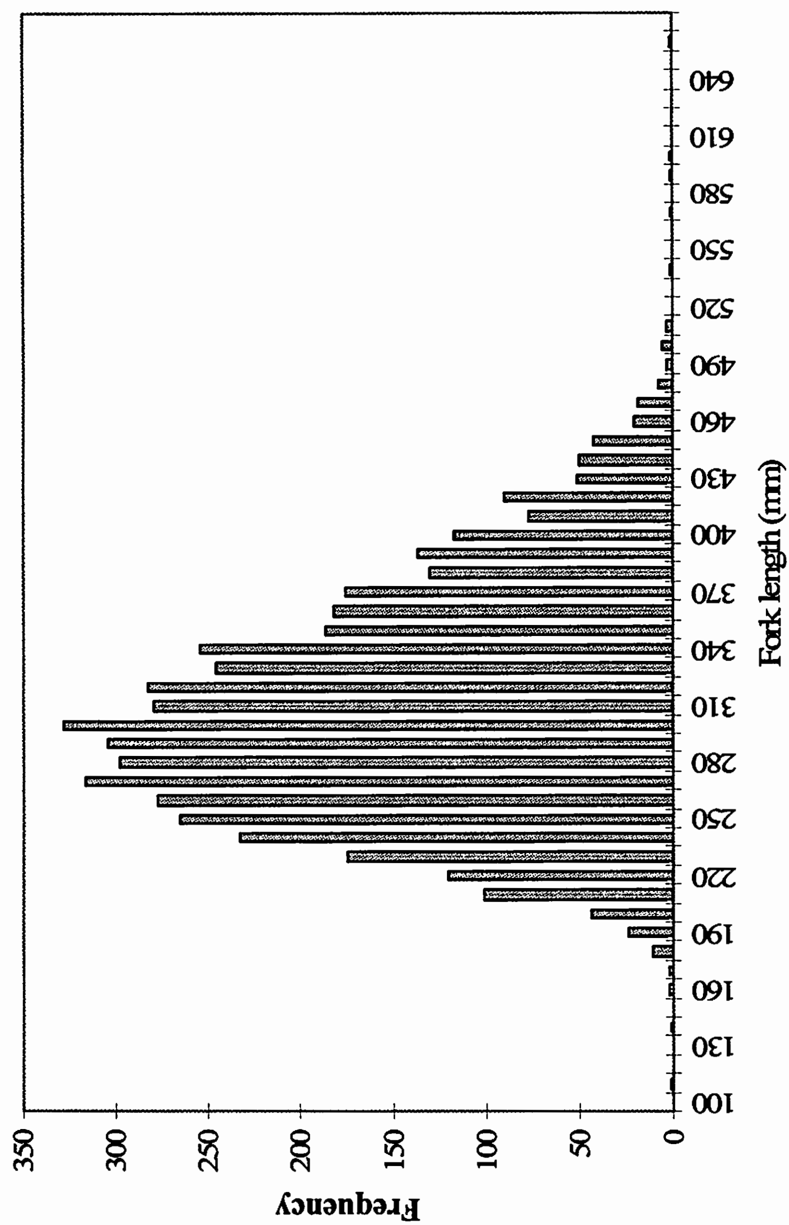


Figure 3. Length frequency distribution for red hind caught in Puerto Rico during 1988 - 1994.

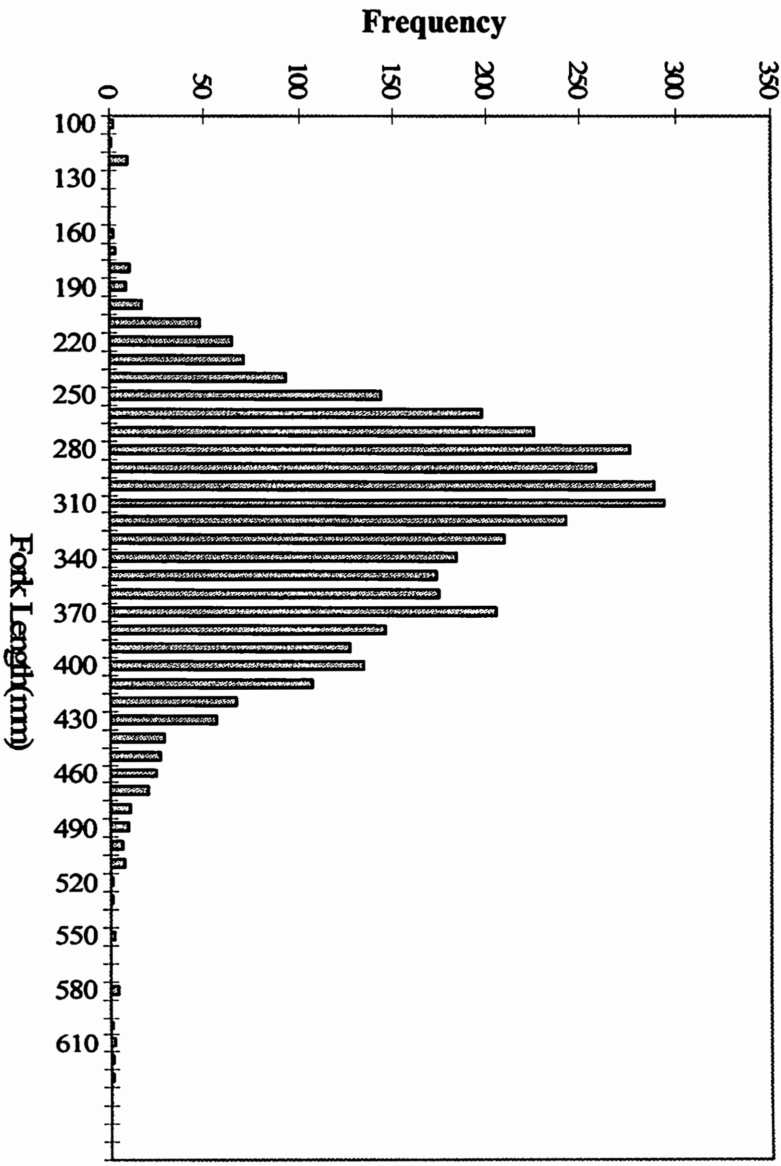


Figure 4. Length frequency distribution for red hind caught in Puerto Rico during 1995 - 2001.

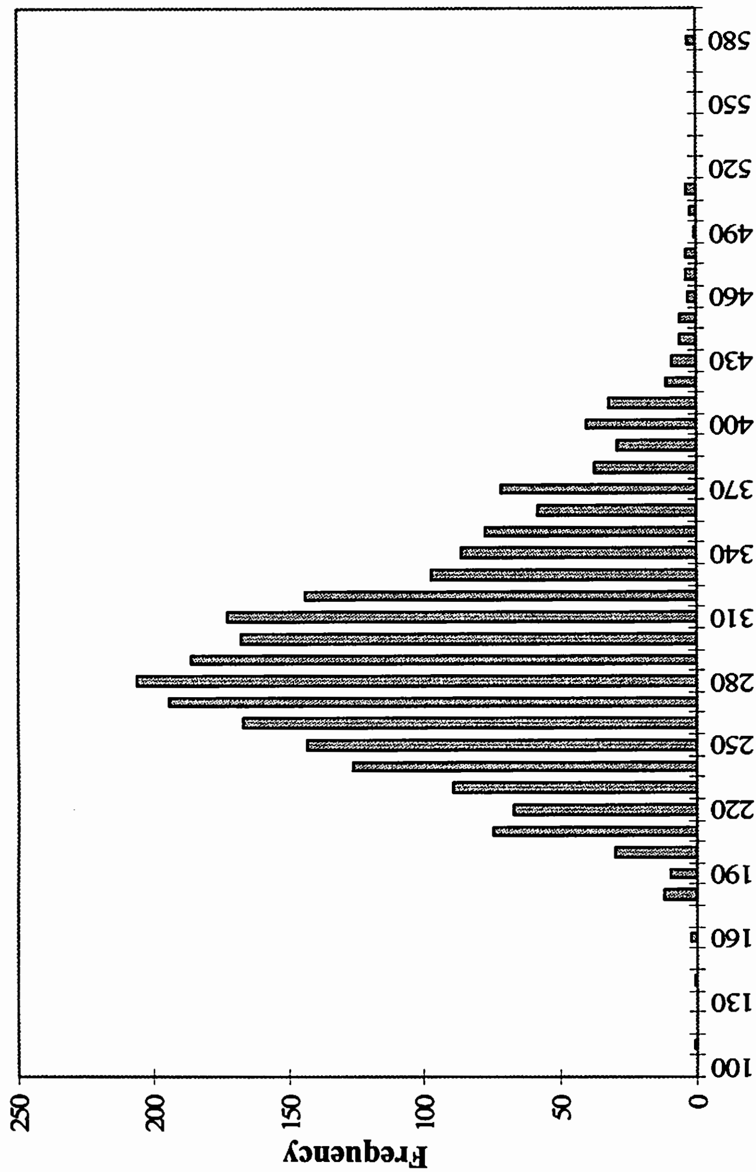


Figure 5. Length frequency distribution for red hind caught in Puerto Rico by fish trap during 1988 - 2001.

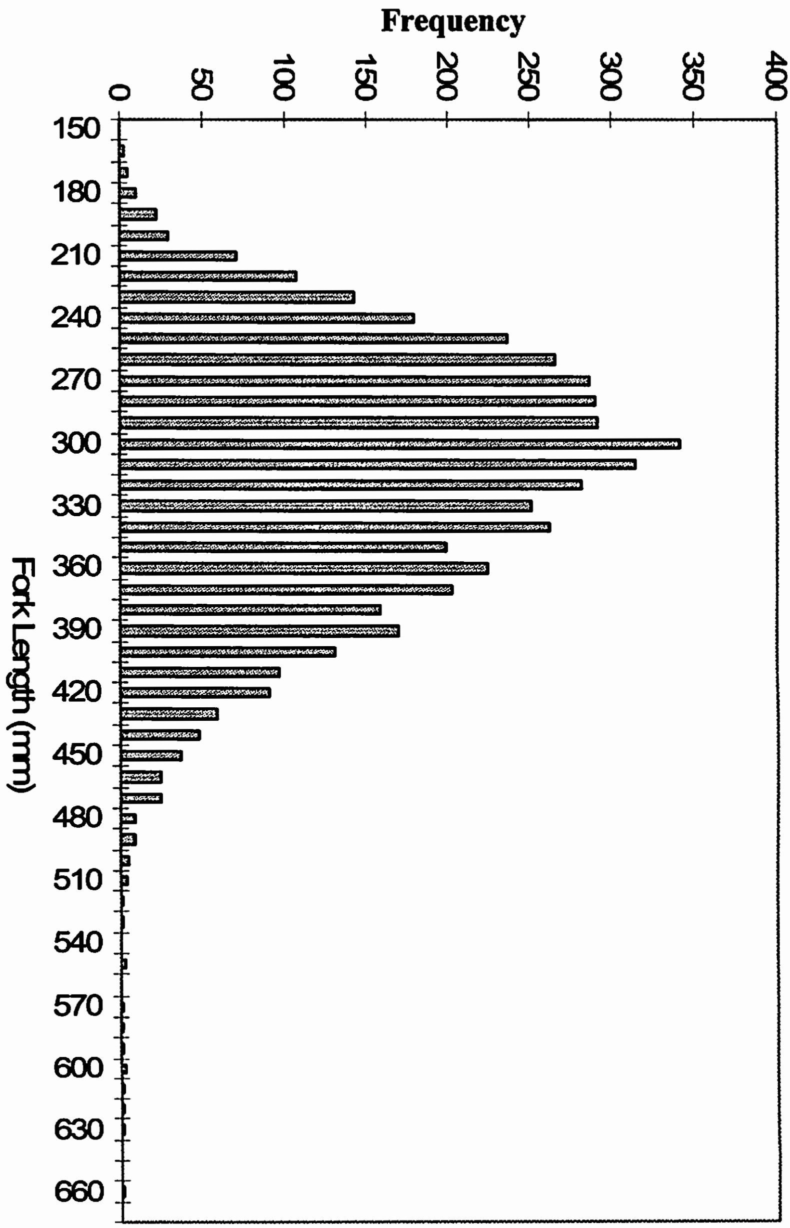


Figure 6. Length frequency distribution for red hind caught in Puerto Rico by bottom line during 1988 - 2001.

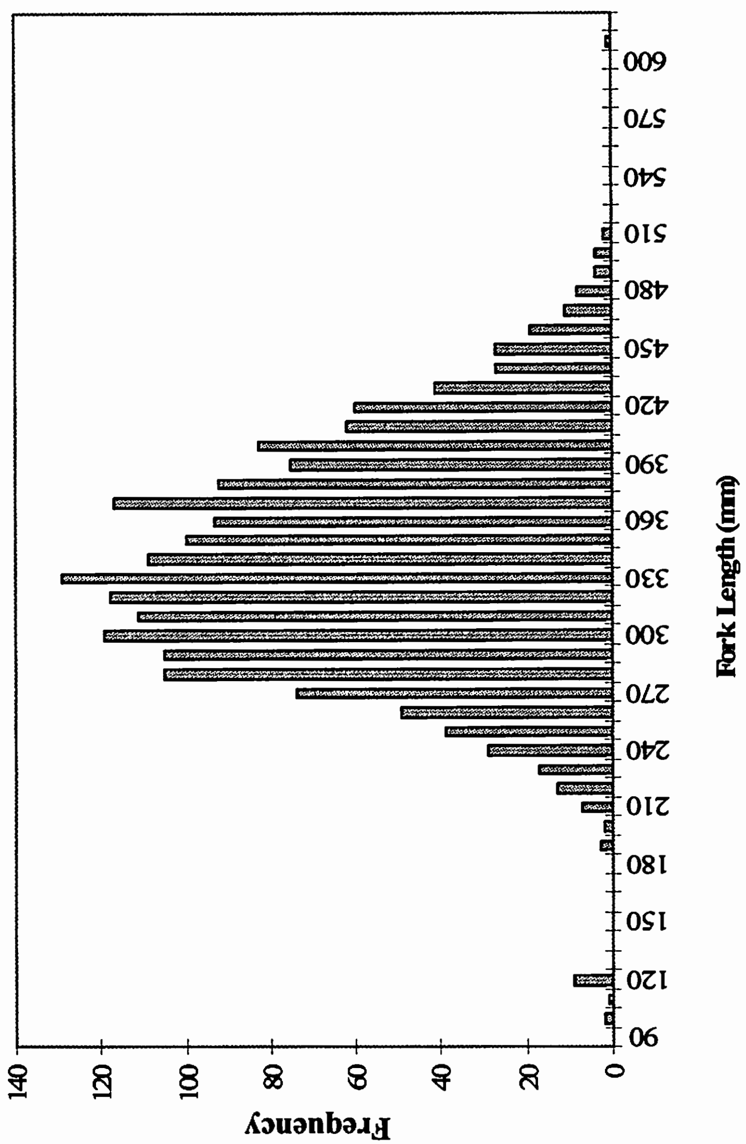


Figure 7. Length frequency distribution for red hind caught in Puerto Rico by SCUBA divers during 1988 - 2001.

DISCUSSION

Puerto Rico's commercial fishery of red hind has shown that marketing and demand for this species continues to be one of the most important during the last 15 years. The data analyzed in this report show that a high fishing pressure occurred on red hind during 1988 - 2001. The landings data show an increasing trend in landings for red hind during 1995-2001. However, before 1987, red hind was reported in the grouper category. It is assumed that during 1988 - 1989, most fishers probably still reported red hind in the grouper category. Beginning in 1995, three red hind spawning aggregation areas were closed in Puerto Rico's west coast. Matos-Caraballo (2002) mentioned that during 1995 - 1998, increased landings of red hind were reported, also larger individuals were caught compared to 1992 - 1994. The CPUE data also confirms the increase in the fishery pressure for red hind. Bottom lines are the most efficient gear for catching red hind (47%), followed by fish traps (33%) and SCUBA divers (14%). However, fish traps landings decreased during 1989 - 1995, and during this time a decrease in fish traps gear was also observed (Matos-Caraballo 2005). Also it is interesting to observe that the Puerto Rico's Fishery Census 2002 shows an increase in bottom line gears and SCUBA divers in Puerto Rico's commercial fishery (Matos-Caraballo 2005).

Matos-Caraballo (2002) mentioned that individuals of red hind were significantly larger in their LFD for 1988 than for 1992. In this study, the red hind caught were larger during 1995 - 2001 than 1988 - 1994. It is very probable that the closed areas to protect the spawning aggregations in the west coast help to improve the fishery resource (Matos 1999, 2002). The DNER fishing regulation established a closed season for red hind during December 1st to February 28th of every year. This closed season will help to improve the fishery population of red hind.

Sadovy and Figuerola (1992) reported that red hind has a minimum size of sexual maturation (MSSM) of 215 mm FL. The data analysis shows that only 2% of red hind were caught before reaching the MSSM during 1988 - 2001. Biostatistics data shows that 5% of red hind caught by fish traps were caught before they reached MSSM during 1988 - 2001. In contrast, the bottom lines caught only 2.6% of red hind before reaching the MSSM and 0.3% for SCUBA divers. This evidence suggests that the juvenile mortality for this species is very low. However, it is necessary to mention the need for bycatch data for these gears.

The landings data and biostatistics data presented in this study show that red hind can be considered as an overfished resource when it is compared with the 1970s data (Sadovy and Figuerola 1992). However, the data presented during 1988 - 2001, show that red hind populations have not changed significantly. Due to the fact that red hind it is a very important component of Puerto Rico's commercial fishery and also is a fragile species because it is a protogynous hermaphrodite species, the CFSP must continue monitoring this species.

The average number of fish traps increased from 28.5 in 1988 - 1994 to 41.4 in 1995 - 2001. Bottom lines also showd an increase in the number from 1988 - 1994 (6.5 hooks) to 1995 - 2001 (7.0 hooks). Also, an average one hour increase from the same two periods 8.5 hours to 9.5 hours. The CPUE increased from 1988 - 1994 to 1995 - 2001. Again, it is probable that the closed spawning aggregation on the west coast helped the red hind population to recover from fishing pressure.

ACKNOWLEDGEMENT

We want to express our deep gratitude to all that made possible this research. To NOAA/NMFS Cooperative Fisheries Statistics Program and Puerto Rico's Department of Natural and Environmental Resources (DNER) that provided the funds. Also, thanks to the Caribbean Fisheries Management Council that provided the funds to participate in the 57th Gulf and Caribbean Fisheries Institute. To Puerto Rico's Commercial Fisheries Statistics port samplers Walter Irizarry, Jesús León, Héctor Y. López, and Luis A. Rivera, whom collected the data. To Albaliz Mercado and Lucía T. Vargas who edited and entered the data in computers. To Miguel Figuerola who helped in reviewing the paper. Finally, we want to acknowledge all the commercial fishers that participate in the Fisheries Statistics Program (FSP).

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.

Everman, B.W. 1900. *Fishes and Fisheries of Puerto Rico.* United States Commission of Fish and Fisheries, Washington D.C. USA. 350 pp.

Figuerola, M., D. Matos-Caraballo, and W. Torres. 1998. Maturation and reproductive seasonality of four reef. fish species in Puerto Rico. *Proceedings of the Gulf and Caribbean Fisheries Institute* 55:938-968.

Manooch, C.S. III. 1987. Age and growth in snappers and groupers. Pages 329-373 in J.L. Polovina and S. Ralston (eds.). *Tropical Snappers and Groupers; Biology and Fisheries Management.* West View Press, Boulder, Colorado USA.

Matos-Caraballo, D. 1999. Status of the groupers in Puerto Rico 1970 - 1995. *Proceedings of the Gulf and Caribbean Fisheries Institute* 46: 299-308

Matos-Caraballo, D. 2002. Portrait of the commercial fishery of the red hind *Epinephelus guttatus* in Puerto Rico during 1992 - 1999. *Proceedings of the Gulf and Caribbean Fisheries Institute* 53:446-459.

Matos-Caraballo, D. 2004. Overview of Puerto Rico's small-scale fisheries statistics 1998 - 2001. *Proceedings of the Gulf and Caribbean Fisheries Institute Meeting* 55:103-118.

Matos-Caraballo, D. 2005. Status of the fishery in Puerto Rico, 1990 - 1993. *Proceedings of the Gulf and Caribbean Fisheries Institute* 47:217-235.

Matos-Caraballo, D., M. Cartagena-Haddock, and N. Peña-Alvarado. 2005. Comprehensive Census of the Marine Commercial Fishery of Puerto Rico 2002. *Proceedings of the Gulf and Caribbean Fisheries Institute* 56:97-110.

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. Grouper 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. 1996. The case of the disappearing grouper: *Epinephelus striatus*, the Nassau grouper in the Caribbean. *Proceedings of the Gulf and Caribbean Fisheries Institute* **45**:2-22.

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.

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

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.

Fecundidad Potencial Anual de *Epinephelus guttatus* en el Parque Nacional Archipiélago Los Roques, Venezuela

BARBARA ÁLVAREZ[1], JUAN M. POSADA[2],
y FRANCISCO PROVENZANO[1]
[1]*Instituto de Zoología Tropical, Universidad Central de Venezuela*
Apartado Postal 47058
Caracas, Venezuela 1041-A
[2]*Departamento de Biología de Organismos, Universidad Simón Bolívar*
Apartado Postal 89000
Caracas, Venezuela 1080-A

RESUMEN

Epinephelus guttatus representa un recurso ligeramente explotado en Los Roques. El presente estudio esta orientado a determinar su fecundidad potencial anual y frecuencia de desove. Se examinaron 819 ejemplares, capturados comercialmente entre enero (12) y febrero (20) de 2003. La talla de las hembras 645 hembras capturadas osciló entre 265 y 520 mm LT (385,3 ± 55,7 mm). Se observo que las hembras de enero fueron significativamente mayores a las de febrero ($H_{(1, N=645)}$= 119,62; p = 0,0000). Se emplearon 353 hembras, cuyo tamaño estaba por encima de la talla a la cual madura el 50% de las mismas (380 mm), a fin determinar los valores promedio diarios del Índice Gonadosomático, que alcanzaron los niveles máximos en los días cercanos a la luna llena de cada mes. Para esos días, se analizó la variación en la frecuencia de diámetro de los ovocitos en 97 ovarios, observándose un patrón de distribución unimodal, excepto en los días de luna llena, donde se registró la presencia simultanea de ovocitos hidratados y vitelogénicos. El desove, alrededor de la luna llena de enero y febrero, fue confirmado con el análisis histológico de 24 gónadas, que revelaron la presencia de folículos post–ovulatorios. La fecundidad potencial anual se determinó en 1.470.803 ± 176.356,81 ovocitos, encontrándose que los valores estimados en enero superan a los de febrero. Se concluye que la fecundidad es determinada, sospechándose que las hembras de mayor talla liberan la totalidad de sus huevos entre enero y febrero, mientras que las hembras más pequeñas podrían estar siendo relegadas a desovar en febrero. Por ello, se recomienda que para estudios de dinámica poblacional y establecimiento de modelos pesqueros se utilice el promedio de fecundidad de enero.

PALABRAS CLAVES: Fecundidad, *Epinephelus guttatus*, Los Roques, Venezuela

Annual Potential Fecundity of *Epinephelus guttatus* in the Los Roques Archipelago Nacional Park, Venezuela

Epinephelus guttatus represents a resource slightly exploited in Los Roques. The present study is oriented to determine its annual potential fecundity and frequency of spawning. A total of 819 specimens, commercially captured among January (12) and February (20) of 2003, were examined. The size of 645 females captured oscillated between 265 and 520 mm LT (385.3 ± 55.7 mm). It was observed that the females of January were significantly larger than those of February ($H_{(1, N=645)}$ = 119,62; p = 0,0000). A sample of 353 females, whose size was above the size to which 50% are reproductively mature (380 mm), were employed to determine the mean daily values of the Gonodosomatic Index, that reached the maximum levels in the days close to the full moon of each month. For those days, the variation in the frequency of diameter of the ovocitos in 97 ovaries was analyzed, being observed a unimodal distributional pattern, except in the days of full moon, where it was registered the simultaneous presence hydrated and vitellogenic oocytes. The spawning, around the full moon of January and February, was confirmed with the histological analysis of 24 gonads, that revealed the presence of post-ovulatory follicles. The annual potential fecundity was determined in 1.470.803 ± 176.356,81 oocytes, being found that the values estimated in January surpass to those of February. It is concluded that the fecundity of this species is determined, being suspected that the females of greater size release all their eggs between January and February, while the smallest females could be being relegated to spawn in February. It is recommended that population dynamics studies and the implementation of fishery models use the mean average fecundity estimates of January.

KEY WORDS: Fecundity, *Epinephelus guttatus*, Los Roques, Venezuela

INTRODUCCIÓN

La fecundidad es un término que generalmente se emplea para describir el número total de ovocitos presentes en un ovario maduro, muchas veces sin tomar en cuenta el estado de desarrollo de los mismos, así como el tipo de fecundidad de la especie (determinada o indeterminada). Hunter y Macewicz (1985) definen que la fecundidad será determinada cuando el número de ovocitos maduros (vitelogénicos) está fijado antes del inicio de la puesta anual, sin que ocurra un reclutamiento de estos a partir del lote de reserva de ovocitos inmaduros (previtelogénicos). En caso contrario, la fecundidad será indeterminada.

La evidencia tradicional de fecundidad determinada es la existencia de una separación marcada entre los ovocitos (o sus clases de diámetros) que maduran para una inminente temporada reproductiva y el reservorio de ovocitos inmaduros presentes en el ovario durante todo el año (Yamamoto 1956, Hunter y Macewicz 1985). Lo contrario será evidencia de fecundad indeterminada.

De esta manera, en especies con fecundidad indeterminada la fecundidad anual (número total de óvulos producidos por hembra, por año) sólo podrá ser estimada mediante la sumatoria de las fecundidades parciales, contabilizadas a lo largo de los consecutivos eventos de desove que se presentan y su fecundidad potencial anual (número de ovocitos vitelogénicos que maduran por año, sin tener en cuenta las pérdidas por atresia) no podrá ser estimada antes del comienzo de la época de desove. En contraste, en especies con fecundidad determinada la fecundidad anual es igual a la fecundidad potencial anual, y ésta se fija antes del comienzo de la época de desove, ya que no hay un aporte de nuevos ovocitos vitelogénicos una vez que ha comenzado el desove.

Estudios de fecundidad realizados en el mero tofía, *Epinephelus guttatus* (Linnaeus 1758), señalan que su fecundidad es determinada (Sadovy et al. 1994, Falfán 2003). Esta especie pertenece a la subfamilia Epinephelinae (Pisces, Serranidae) y se distribuye geográficamente desde el Golfo de México y el Mar Caribe, hasta Brasil. En Venezuela es una especie muy común, pero ha sido escasamente estudiada, salvo por el trabajo de Pérez-Villarroel (1982), quien confirmó la existencia de un breve período reproductivo, el cual se extiende entre los meses de enero a marzo.

El presente estudio es el primero en Venezuela dedicado a cuantificar la fecundidad de *E. guttatus* y permitirá incrementar los conocimientos de la biología reproductiva de la especie, ya que se evaluará el proceso de desove, en una base diaria, a lo largo de la temporada reproductiva.

MATERIALES Y MÉTODOS

El estudio fue realizado en el Parque Nacional Archipiélago Los Roques, el cual se ubica a 157 km al norte de la costa central de Venezuela. El trabajo de campo se desarrolló en un período de 40 días continuos, comprendidos entre el 12 de enero (inicio del cuarto creciente lunar) y el 20 de febrero del 2003 (inicio del cuarto menguante).

Las muestras de *E. guttatus* se obtuvieron a partir de las capturas comerciales, siendo procesados hasta un máximo de 30 ejemplares diarios. A cada uno de los ejemplares examinados se le estimó el peso total (PT), la longitud total (LT) y la longitud estándar (LE). Posteriormente se realizó una disección en la región ventral del pez para exponer las gónadas y determinar el sexo, procediéndose a extraer únicamente las de las hembras, las cuales fueron pesadas (PG). Se estableció microscópicamente el estadio de madurez sexual de cada ovario, utilizando para ello el criterio de cuatro categorías de Pérez-Villaroel (1982) y Sadovy et al. (1994): Inmaduro o en reposo, maduro, maduro activo y desovados.

Posteriormente se tomaron aleatoriamente un máximo de cinco ovarios diarios y sus lóbulos fueron separados. Uno de ellos fue fijado en formaldehído al 10% y fue preservado para su eventual análisis histológico. El otro lóbulo se fijó en formaldehído al 2% y se destinó para la cuantificación de diámetros de los ovocitos, así como para caracterizar la frecuencia de desove y magnitud de la fecundidad.

Se determinó la talla de madurez sexual de las hembras, registrando la LT del ejemplar más pequeño con ovarios maduros (a nivel macroscópico), así como determinando la talla a la cual madura el 50% de la población de hembras. Para ello se utilizó una regresión no lineal, ajustada a la función logística (Sokal y Rohlf, 1995):

$$Y = 100 / (1+e^{(-a(X-b))}$$

Donde Y es el porcentaje de hembras maduras en función de los intervalos de tallas, b corresponde a la talla a la cual el 50% de la población de hembras es madura y X es la LT (en mm).

El Índice Gonadosomático (IGS) fue calculado para determinar los cambios diarios de la actividad reproductiva y precisar el pico de desove para la especie. Para ello se utilizó la siguiente relación de Htun-Han (1978):

$$IGS = [PG / PT] * 100$$

Donde PT es el peso total de la hembra y PG el peso del ovario.

La distribución de frecuencia de diámetro de los ovocitos se estimó a partir de 97 lóbulos. En cada uno de ellos se midieron, con un micrómetro ocular, los diámetros de 150 ovocitos, los cuales fueron organizados en intervalos de 0,049 mm cada uno. Se realizó una prueba Chi-cuadrado (Sokal y Rohlf 1995) y un análisis de residuales estandarizados (Bulla 2003), a fin de determinar si la frecuencia de diámetros de los ovocitos variaba con el tiempo.

Toda esta información fue utilizada para establecer el intervalo de tiempo donde se sospecha se inicia y termina el proceso de desove. Se procedió entonces a examinar microscópicamente los lóbulos de las hembras capturadas en ese intervalo, a fin de detectar la presencia de ovocitos hidratados y/o folículos post-ovulatorios.

Para estimar la fecundidad potencial anual (FPA) se usó el método gravimétrico. Se pesaron los ovarios y se tomaron tres submuestras de peso conocido, entre 0,01 y 0,02 gr. Posteriormente se contaron los ovocitos contenidos en dichas submuestras y se extrapolaron al peso total de la gónada según la ecuación: FPA= (PG x n)/PM, donde PG es el peso del ovario en gramos, n es el número de ovocitos en cada submuestra y PM es el peso de la muestra (Hunter et al. 1992).

RESULTADOS

De los 819 ejemplares capturados, unas 645 resultaron hembras, cuyas tallas oscilaron entre 265 y 520 mm de LT (385,3 ± 55,7 mm). Las hembras capturadas en enero presentaron tallas significativamente superiores a las colectadas en febrero (Kruskal-Wallis: $H_{(1, N=645)} = 119{,}6251$; $p = 0{,}0000$). Este comportamiento también se observó en los machos (Kruskal-Wallis: $H_{(1, N=174)} = 44{,}03522$; $p = 0{,}0000$).

La Figura 1 presenta la distribución de frecuencias de los distintos estadios de desarrollo gonadal, en su base diaria. Allí se puede apreciar que el porcentaje de ovarios maduros activos aumenta en los días cercanos a la luna llena (tanto entre el 16 y 20 de enero, como entre el 17 y 20 de febrero), así como entre los días 20 y 29 de enero es mayor el porcentaje de ovarios desovados. Igualmente se apreció que el número de hembras inactivas o en reposo incrementó entre los días intermedios a las lunas llenas de enero y febrero.

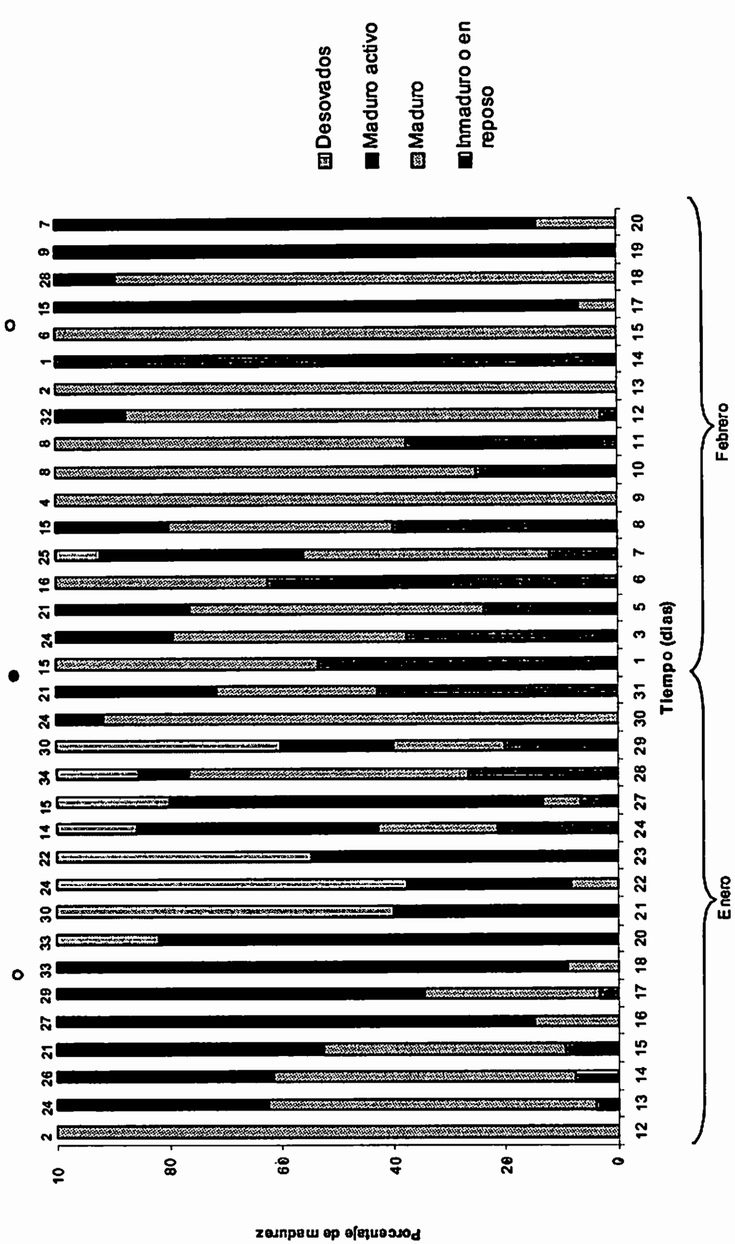


Figura 1. Distribución de frecuencia de aparición de los distintos estadios de madurez del ovario de *E. guttatus*, entre el 12 de enero y el 20 de febrero de 2003. Los círculos claros representan la luna llena y el oscuro a la luna nueva. Los números sobre las barras indican la cantidad de hembras capturadas en ese día.

La hembra de menor talla que presentó gónadas maduras midió 270 mm LT. Sin embargo, la talla a la cual madura el 50 % de la población de hembras se estimó en 380 mm de LT (Figura 2). Para utilizar un criterio más conservador en la interpretación de los resultados, el resto de los análisis será realizado tomando en cuenta solo a la población de hembras cuyas tallas fueran iguales o superiores 380 mm LT (n = 353). De esta manera se aseguró el no incluir en el análisis a hembras descritas microscópicamente como maduras, sin que en realidad lo estuvieran.

Estos resultados coinciden con lo observado en el análisis de IGS para las hembras sexualmente activas (Figura 3). Allí se puede apreciar un primer incremento en dicho valor hacia el día 18 de enero (8,95; coincidiendo con la luna llena de ese mes), fecha después de la cual se observa una caída en el índice, con lo cual se sospecha que ha ocurrido un desove. Este valor aumenta hasta alcanzar un máximo promedio de 9,88 el 20 de febrero (4 días después de la luna llena), fecha en la que se sospecha se presenta el segundo evento de desove.

El número total de óvulos medidos en el presente estudio fue de 14.700, observándose que el diámetro de los mismos osciló entre 0,35 y 1,29 mm (vitelogénicos entre 0,3 y 0,6 mm e hidratados entre 0,7 y 1,29 mm). En la Tabla 1 se observa que el intervalo de diámetros se amplia entre los días 18 y 21 de enero, y 19 y 20 de febrero, sospechándose que entre esas fechas ocurre el desove.

Las pruebas de Chi-cuadrado confirman las diferencias en la distribución de frecuencias de diámetros en los ovocitos examinados en los diferentes días del mes de enero ($X^2 = 10088,05$; g.l = 208 y p = 0,00000) y febrero ($X^2 = 7593,13$; g.l = 169 y p = 0,00000), así como el análisis de residuales estandarizados realizado entre los días 12 y 31 de enero del 2003 y entre los días 19 y 20 de febrero se asocian positiva y de forma estadísticamente significativa con los diámetros de ovocitos comprendidos entre 0,70 y 1,00 mm (ovocitos hidratados).

El análisis microscópico de las gónadas se limitó a las hembras maduras, maduras activas y posiblemente desovadas, colectadas entre los días 17 al 24 de enero y 19 y 20 de febrero de 2003, a fin de confirmar la apreciación obtenida en base a la evidencia anterior, de que entre estas fechas es que ocurre el desove (Figura 4). Así se puedo apreciar que en el día 17 de enero predominan los ovocitos maduros activos sobre los inmaduros y maduros inactivos, evidenciando esto la presencia de un ovario maduro. Para el día 18 se observaron ovocitos hidratados, mientras que los ovocitos maduros inactivos presentaron una menor frecuencia. Sin embargo, la presencia simultanea del grupo de ovocitos maduros activos, hidratados y folículos post-ovulatorios se puede presentar como evidencia de una ovulación asincrónica. Lo mismo se puede apreciar en los cortes correspondientes a los días 20 y 21 de febrero, donde se observa una clara predominancia numérica de los ovocitos hidratados respecto a los otros estadios (Figura 4).

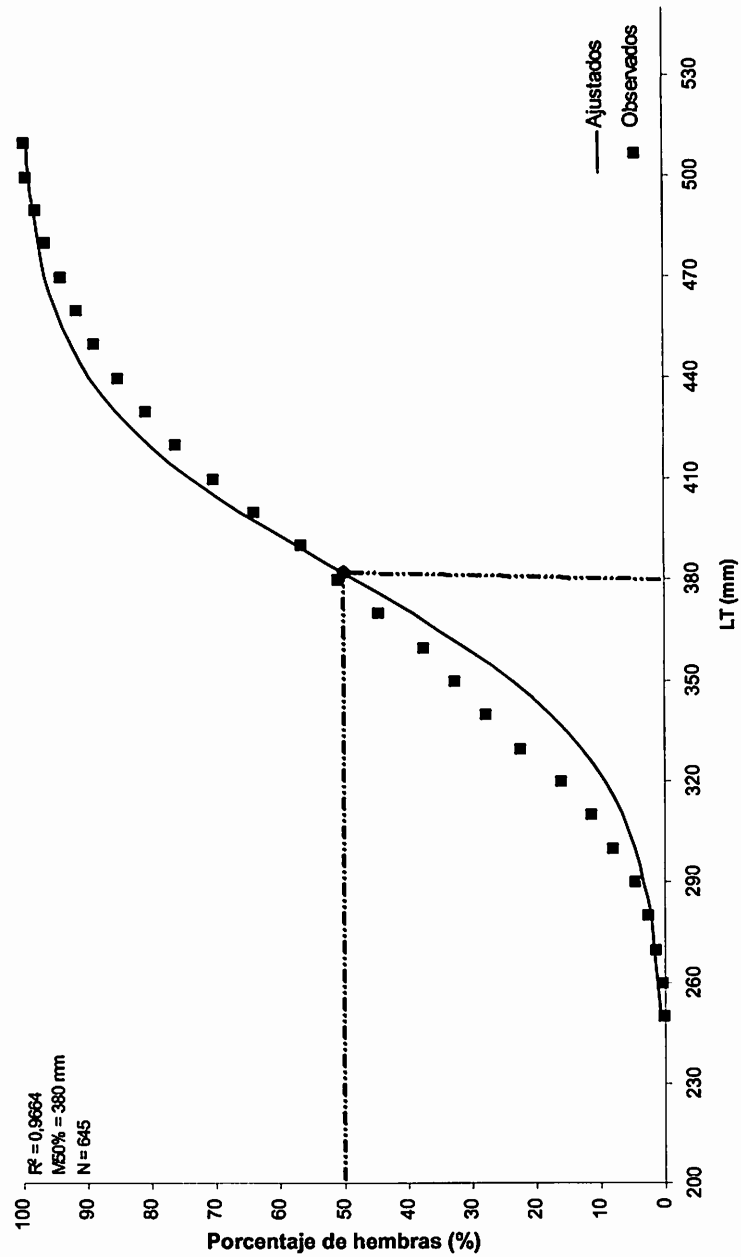


Figura 2. Relación entre la talla y el porcentaje de hembras de *E. guttatus*, capturadas entre el 12 de enero y el 20 de febrero de 2003. La línea continua corresponde a la curva que predice la función logística. El punto de inflexión muestra la talla a la cual el 50% de la población de hembras se encuentra sexualmente madura.

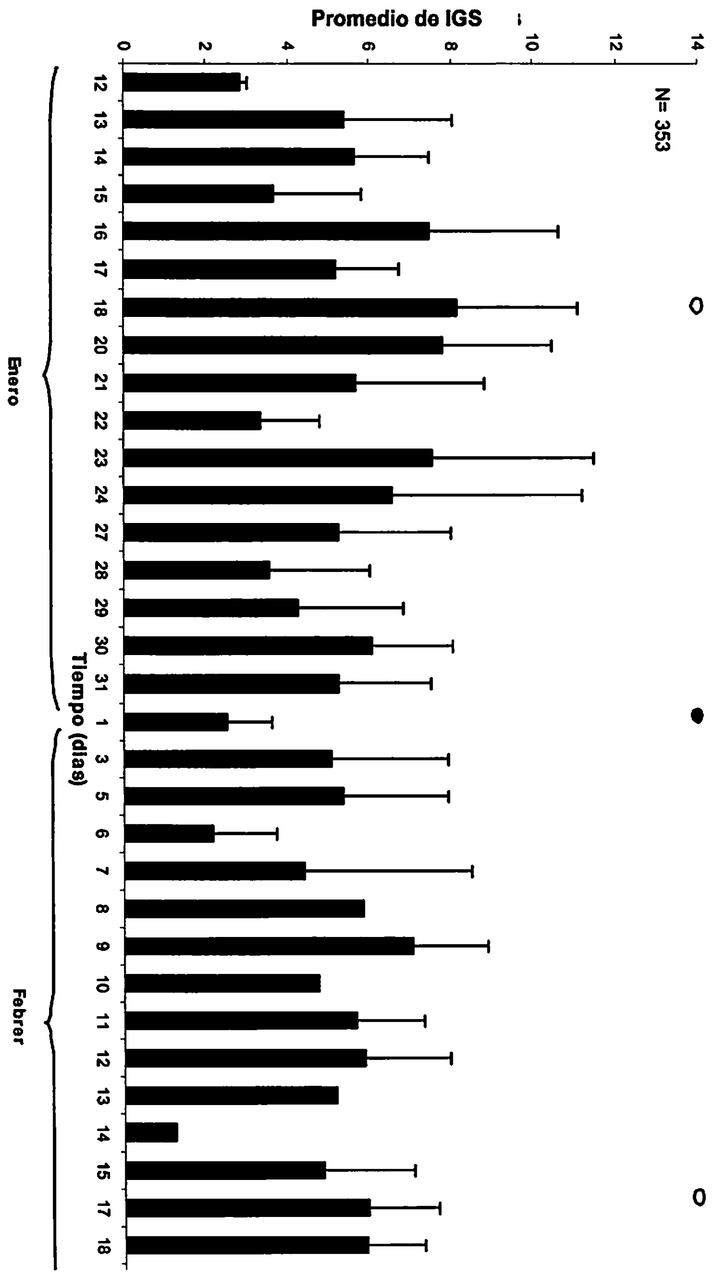


Figura 3. Valor promedio de Índice Gonadosomático y desviación estándar para los ovarios de las hembras capturadas entre el 12 de enero y el 20 de febrero de 2003. Los círculos claros representan la luna llena y el oscuro a la luna nueva. Las barras representan los valores de desviación estándar.

Figura 4. Histogramas de descripción microscópica de los ovocitos presentes en las gónadas de las hembras de *E. guttatus*, realizadas entre el 17 al 24 de enero y del 19 al 20 de febrero de 2003. Los números sobre las barras indican el numero de ovocitos contados en sus respectivos estadios.

Para estimar la fecundidad potencial anual y relativa se utilizaron ovarios de hembras maduras a partir de la talla a la cual madura el 50% de la población, descartando todas aquellas que fueron capturadas después del 17 de enero y 17 de febrero, ya que a nivel histológico sus gónadas presentaron signos de haber desovado y las invalida para este tipo de análisis.

En general, la fecundidad potencial anual reflejó un valor promedio de 1.470.803 ± 176.356,81 ovocitos (Tabla 2). Sin embargo, la fecundidad potencial anual en el mes de enero osciló entre 547.912 y 4.170.310 óvulos con una media de 1.638.770 ± 176.213,89 óvulos. Es de hacer notar que la hembra de mayor talla capturada fue la misma que exhibió mayor valor de fecundidad potencial anual. La fecundidad potencial en el mes de febrero fue menor que la de enero y varió entre 340.767 y 2.278.187 óvulos, con una media de 1.278.842 ± 176.520,14 óvulos (Tabla 2).

DISCUSIÓN

Al comparar la estructura de tallas de las hembras capturadas en los meses de enero y febrero, se observó que las primeras fueron significativamente más grandes que las segundas. Esta diferencia, que no había sido reportada previamente por los otros autores que han trabajado con la especie, parece sugerir que son las hembras de mayor tamaño las que podrían estar dominando el desove en el mes de enero, quedando relegadas las de menor talla a desovar en febrero. Sin embargo, no se puede obviar el efecto de pesca sobre la población, ya que dicho comportamiento también fue observado en los machos. No obstante, se considera que la presión ejercida sobre el recurso es limitada en la zona y pareciera ser poco probable que la misma pudiese estar removiendo predominantemente a los individuos grandes de la población durante la actividad pesquera del mes de enero.

La hembra de menor talla con gónadas maduras fue de 270 mm LT. Este valor se encuentra por encima de lo registrado por Thompson y Munro (1978), así como por Bullock y Smith (1991) en Falfan (2003), quienes encontraron hembras de *E. guttatus* maduras de entre los 240 y 250 mm de LT. Por su parte, Cervigón (1991) reporta que las hembras de esta especie comienzan a reproducirse a partir de los 260 mm de LT.

Por su parte, la talla a la cual se estimó madura el 50% de la población de hembras fue de 380 mm de LT. Este resultado fue significativamente mayor al observado por Sadovy et al. (1994), quien reporta una talla de madurez de 215 mm de LT. La menor hembra descrita macroscópicamente por esta autora como madura fue de 195 mm de LT. La diferencia entre ambos valores posiblemente pueda estar influida por la excesiva explotación pesquera a que ha sido sometida la población de esta especie en Puerto Rico (Sadovy et al. 1994), a diferencia de la estudiada en este trabajo.

Según la observación macroscópica realizada en los ovarios de *E. guttatus* se encontró una clara dominancia de hembras cuyas gónadas se encontraban maduras y maduras activas. Esto es el reflejo de una clara cercanía a un evento de desove en el periodo comprendido entre los meses de enero y febrero, lo cual ya había sido reportado por otros autores trabajando en el área del Caribe (Thompson y Munro 1978, Pérez-Villarroel 1982, Sadovy et al. 1994).

Tabla 2. Valores de fecundidad potencial anual (F.P.A) de hembras de *E. guttatus* capturadas entre el 14 al 17 de enero y del 11 al 17 de febrero del 2003 en el Parque Nacional Archipiélago los Roques (LT = Longitud total, PT = Peso total, PG = Peso de la gónada, D.E = Desviación Estándar, IGS = Índice Gonadosomático. Las letras resaltadas en negritas en el sub. total y total indican los valores promedios.

Nº	Día	LT (mm)	PT (gr)	PG (gr)	F.P.A	D. E	IGS
1	14/01	395	850	26,5	560.031	106713,22	3,12
2	14/01	380	710	26,5	547.912	117160,43	3,73
3	14/01	420	1400	108,4	2.115.190	234418,07	7,74
4	14/01	473	1400	112	1.819.067	185738,02	8,00
5	14/01	418	1400	51,5	838.878	80835,38	3,68
6	15/01	440	1600	81,2	1.360.852	413655,20	5,08
7	15/01	420	930	58,1	943.633	56739,47	6,25
8	16/01	485	1700	163,2	2.977.628	239156,14	9,60
9	16/01	405	750	91	1.157.118	107742,31	12,13
10	16/01	520	2100	234,5	4.170.310	226790,60	11,17
11	16/01	461	1400	131,4	2.300.847	366674,79	9,39
12	16/01	440	1300	115,6	2.005.620	248128,82	8,89
13	17/01	420	1100	49,1	1.114.297	175337,98	4,46
14	17/01	420	1100	57,1	1.157.275	92358,85	5,19
15	17/01	460	1600	95,4	1.7085.57	44903,64	5,96
16	17/01	470	1200	78,6	1.443.109	123069,40	6,55
Sub. Total Enero					**1.638.770**	**176.213,89**	

Nº	Día	LT (mm)	PT (gr)	PG (gr)	F. P. A.	D. E.	IGS
1	11/02	423	1400	94,41	1.698.818	162.059,24	6,74
2	11/02	400	1000	65,26	1.120.018	570.98,03	6,53
3	11/02	390	810	49,61	976.200	191.807,96	6,12
4	11/02	440	1200	45	1.000.500	120.271,57	3,75
5	12/02	385	710	27,4	613.463	101.694,82	3,86
6	12/02	450	1000	79,13	1.454.898	362.859,15	7,91
7	12/02	410	950	64,55	1.348.158	365.817,64	6,79
8	12/02	470	1600	115,84	2.278.187	565.405,22	7,24
9	13/02	410	900	46,58	1.679.879	113.421,63	5,18
10	14/02	390	650	80,9	1.112.934	278.29,78	12,45
11	15/02	470	1300	86,49	1.482.651	123.173,02	6,65
12	15/02	465	1500	83,5	1.328.605	59.672,57	5,57
13	15/02	400	950	15,58	340.767	65.250,11	1,64
14	17/02	390	950	66,14	1.468.709	154.921,20	6,96
Sub. Total Febrero					**1.278.842**	**176.520,14**	
Total					**1.470.803**	**176.356,81**	

Estos resultados se pueden apreciar con mayor grado de exactitud al examinar los valores promedios de IGS tanto en el presente trabajo (los cuales fueron establecidos en una base de muestreo diaria), como en los de Pérez-Villarroel (1982) y Shapiro et al. (1993) trabajando con muestreos mensuales o Sadovy et al. (1994) trabajando con una base muestral semanal, lo que permite concluir que esta especie desova de manera predominante en los días alrededor de las lunas llenas de enero y febrero. Esta sincronía de desove con las fases lunares ha sido reportada para varias familias de peces, tales como: Serranidae, Carangidae, Lutjanidae, Pomacentridae y Acanthuridae. Por su parte, Taylor (1984) sugiere que la luz de la luna pudiera mejorar o favorecer las condiciones para la puesta, aumentando las probabilidades de sobrevivencia de huevos, larvas pelágicas y adultos.

Sin embargo, para poder precisar la frecuencia de desove, los días que dura esta actividad y cual es el tipo de desove que presenta la especie (parcial o total) es necesario recurrir al análisis diario de la distribución de frecuencia de diámetro de los ovocitos, así como a la observación microscópica de los cortes histológicos de los ovarios. Mediante este procedimiento se estableció la existencia de dos grupos de ovocitos, cuyos diámetros variaban de 0,3 a 0, 6 mm (ovocitos maduros) y de 0,7 a 1,29 mm (ovocitos hidratados). Estos resultados coinciden con lo registrado por Thompson y Munro (1978) para la especie, quienes señalan que el diámetro de los ovocitos vitelogénicos destinados a la puesta durante esa temporada reproductiva se encuentra entre 0,7 y 0,9 mm. Por su parte, Colin et al. (1987) igualmente señalan que los óvulos hidratados de *E. guttatus* son de forma esférica y el diámetro máximo alcanza 0,97 mm.

Uno de los aspectos relevantes del trabajo histológico en base diaria es que permite establecer con bastante precisión el momento del inicio y fin de determinado evento reproductivo. En ese sentido se pudo apreciar que el proceso de ovogénesis se desarrolla de manera sincrónica, hasta llegar el momento de la hidratación. Según los resultados del presente estudio, la evolución sincrónica de la ovogénesis alcanza su máxima definición durante el día de luna llena de enero y febrero, lo cual también coincide con los días en que se observan los mayores valores promedio de IGS y la descripción macroscópica revela la presencia de una mayor proporción de hembras maduras activas.

Sin embargo, el procedimiento histológico refleja que el proceso de ovulación o hidratación de los ovocitos es de tipo asincrónica, lo cual explica la presencia, en una misma gónada de óvulos en estadio maduro avanzado, junto con óvulos hidratados y folículos post-ovulatorios. En todo caso, el presente estudio señala que la totalidad del proceso se extiende por unos cuatro días (máximo 6), desde el momento en que aparecen los primeros ovocitos hidratados hasta que desaparece el último folículo post-ovulatorio.

Queda entonces claro que un individuo de esta especie puede presentar desoves parciales a lo largo de los días que dura el ciclo reproductivo lunar. Esto tiene una explicación inclusive fisiológica, ya que existe una limitación física que impide la hidratación simultanea de todos los óvulos, evitando así la expansión exagerada de la cavidad abdominal e interfiriendo con otros órganos o procesos vitales (Murua y Saborido-Rey 2003).

La existencia de un espacio o hiato entre los ovocitos maduros (destinados a la puesta en la temporada reproductiva) y los ovocitos inmaduros (que se pueden apreciar en esa categoría de diámetro a lo largo del todo el año), sumando a los análisis histológicos de las gónadas, permiten concluir que la mayoría de los ovocitos vitelogénicos destinados a la puesta son establecidos al inicio de la temporada reproductiva y que la fecundidad de la especie es determinada.

Esto coincide con la evidencia recabada en estudios previos. Sadovy et al. (1994) fue la primera en concluir esto, basándose en la descripción macroscópica de los ovarios y la medición de los óvulos maduros (vitelogénicos). Por su parte, Falfán (2003) concluye la existencia del tipo de fecundidad determinada basándose en la presencia, como en este estudio, de un espacio existente entre la distribución de diámetros de los ovocitos inmaduros y las maduras destinado a la puesta.

Lo que no queda claro con el presente estudio, ni tampoco mediante el análisis de estudios previos es si una determinada hembra libera sus óvulos a lo largo de ciclos lunares continuos o lo hace en el transcurso de uno solo de estos eventos. Según Watanabe et al. (1995) y Head et al. (1996), hembras de *E. striatus* tratados con hormonas para asegurar el proceso de ovulación, fueron capaces de desovar de forma consecutiva a lo largo de la estación reproductiva, a intervalos no menores de 28 días entre estas. De acuerdo a Watanabe (Comm. pers.), el remanente de ovocitos maduros que permanece en el ovario de una hembra después del primer evento reproductivo no permite explicar el elevado número de óvulos que será desovado en el segundo ciclo, lo cual hace sospechar que existe el reclutamiento de nuevos ovocitos maduros a partir del stock previtelogénico y el tipo de fecundidad seria indeterminado.

El presente estudio no comparte este punto de vista, pues considera que la manipulación con hormonas podría haber alterado el desarrollo normal de la ovogénesis en las hembras de esta especie. Sin embargo, recomienda altamente el seguimiento de individuos particulares a lo largo de toda una temporada reproductiva, a fin de cuantificar de manera directa el número de ovocitos que se libera en cada puesta y si lo hace de manera consecutiva o exclusiva a lo largo de los ciclos lunares del periodo reproductivo.

En este sentido, Luckhurst (Comm. pers.) ha realizado estudios de marcaje y recaptura en individuos de *E. guttatus* en Bermuda, habiendo podido determinar la presencia de estos en una agregación a lo largo de dos periodos reproductivos continuos. Lo que su diseño experimental no le ha permitido establecer es el sexo de esos individuos o si habían estado participando de manera activa y consecutiva en los mismos.

Partiendo del hecho que la fecundidad es de tipo determinada, la fecundad potencial anual de esta especie en aguas del Parque Nacional Archipiélago Los Roques osciló entre 340.767 y 4.170.310 óvulos (n = 30). Es de hacer notar que el valor promedio de la fecundidad potencial anual del mes de febrero es inferior a la del mes de enero, pudiendo esto atribuirse a que en febrero desovan las hembras de menor talla o que las hembras grandes ya habían liberado un lote de óvulos durante la agregación del mes de enero.

En este sentido es recomendable que para futuros estudios de dinámica poblacional y/o el establecimiento de modelos pesqueros se utilicen los valores del mes de enero, ya que no hay garantía de que alguna de las hembras utilizadas para estimar fecundidad en febrero, no hayan liberado una buena parte de sus óvulos previamente.

Los valores de fecundidad potencial anual registradas en el presente estudio son similares a los encontrados por Falfán (2003) en Banco Campeche, los cuales oscilaron entre 721.776 y 3.087.331 óvulos (n = 36) para hembras cuyas tallas estuvieron entre 320 y 440 mm respectivamente. Por su parte, Sadovy (1993) reporta valores de fecundidad, en aguas de Puerto Rico, que variaron entre 89.870 y 1.189.317 óvulos (n = 16), aunque esta autora trabajó con hembras en un intervalo de tallas inferior al utilizado en el presente trabajo (206 y 483 mm de L.T).

Por su parte, Thompson y Munro (1978) reportaron para Jamaica valores de fecundidad que oscilaron entre 96.982 y 379.350 óvulos (n = 6), pero se desconoce si las hembras utilizadas en dicho trabajo, cuyos tallas variaron entre 260 y 410 mm de L.T, estaban cercanos al pico reproductivo. Se conoce que la talla es determinante en el número de óvulos que puede contener un ovario, siendo este, como hemos visto, mayor a medida que el pez sea más grande (Bagenal 1967). Además, pueden existir variaciones de fecundidad entre diferentes localidades en función de la época del año en que se realizó el muestreo, la disponibilidad de alimento, el estrés, la temperatura del agua y otros factores ambientales (Bagenal 1967).

LITERATURA CITADA

Bagenal, T.B. 1967. A short review of fish fecundity. Pages 89-110 in: S.D. Gerkin (ed.). *The Biological Basis of Fresh Water Fish Production.* Blackwell Scientific Publications. Oxford, England.

Bulla, L. [2003]. Técnicas Cuantitativas. El análisis de residuos en tablas de contingencia. Material mecanografiado. IESA, Caracas, Venezuela. 8 pp.

Cervigón, F. 1991. *Los Peces Marinos de Venezuela. Vol I. 2da. Edición.* Fundación Científica Los Roques, Caracas, Venezuela. 423 pp.

Colin, P.L., D.Y. Shapiro, and D. Weiler. 1987. Aspects of the reproduction of two groupers, *Epinephelus guttatus* and *E. striatus* in the West Indies. *Bulletin of Marine Science* **40**:220-230.

Falfán, V.E. 2003. Estudio de la fecundidad del mero colorado *Epinephelus guttatus* (Linnaeus, 1758) del Banco de Campeche. Centro de Investigaciones y de Estudios Avanzados del Instituto Politécnico Nacional. Trabajo Especial de Grado. Universidad de Mérida, Mérida, México.

Head, W.D., W. Watanabe, S.C. Ellis, and E.P Ellis. 1996. Hormone induced multiple spawning of captive Nassau grouper broodstock. *Progressive Fish Culturist* **58**:65-69.

Htun-Han, M. 1978. The reproductive biology of the dab *Limanda limanda* (L.) in the North Sea: gonosomatic index, hepatosomatic index and condition factor. *Journal of Fisheries Biology* 13(3):369-378.

Hunter, R.J. and B.J. Macewicz. 1985. Measurement of spawning frequency in multiple spawning fishes. Pages 79-94 in: R. Lasker (ed.). *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to northern anchovy, Engraulis mordax.* NOAA. Tech. Rep. NMFS 36.

Hunter, R.J., B.J. Macewicz., N.C. Lo, and C.A. Kimbrell. 1992. Fecundity, spawning, and maturity of female dover sole *Microstomus pasificus*, with an evaluation de assumptions and precision. *Fisheries Bulletin U.S. 90:101-128.*

Murua, H. and F. Saborido-Rey. 2003. Female reproductive strategies of marine fish species of the north atlantic. *Journal of Northwest Atlantic Fisheries Science* **33**:23-31.

Pérez-Villarroel, A.J. [1982]. Desarrollo gonadal en el mero tofía *Epinephelus guttatus* L: (Serranidae). Trabajo Especial de Grado. Universidad Central de Venezuela, Caracas, Venezuela.

Prager, M.H., J.F. O'Brian, and S.B. Saila. 1987. Using lifetime fecundity to compare management strategies: a case history for strip bass. *North American Journal of Fish Management* **7**:403-409.

Sadovy, Y. [1993]. Spawning Stock Biomass per Recruit: *Epinephelus guttatus* (Puerto Rico). Caribbean Fisheries Management Council. Unpubl. MS.

Sadovy, Y., A. Rosario, and A. Roman. 1994. Reproduction in an aggregating grouper, the red hind, *Epinephelus guttatus*. *Environmental Biology of Fishes* **41**:269-286.

Shapiro, D.Y., Y. Sadovy, and M.A. McGehee. 1993. Periodicity of sex change and reproduction in the red hind, *Epinephelus guttatus*, a protogynous grouper. *Bulletin of Marine Science* **53**(3):1151-1162.

Sokal, R.R. and F.J. Rohlf. 1995. *Biometry: The Principles and Practice of Statistics in Biological Research, 3rd Edition.* W. H. Freeman and Co., New York, New York USA. 887 pp.

Taylor, H.M. 1984. Lunar Synchronization of fish reproduction. *Transactions of the American Fisheries Society* **113**:484-493.

Thompson, R. and J.L. Munro. 1978. Aspects of biology and ecology of Caribbean reef fishes: Serranidae (hinds and groupers). *Journal of Fish Biology* **12**:115-146.

Watanabe, W.O., S.C. Ellis., E.P. Ellis., W.D. Head., C.D. Kelley., A. Moriwade., C-S. Lee., and P.K. Bienfang. 1995. Progress in controlled breeding of Nassau grouper (*Epinephelus striatus*) broodstock by hormone induction. *Aquaculture* **138**:205-219.

BLANK PAGE

Preliminary Investigations into the Red Hind Fishery in the British Virgin Islands

NEWTON ERISTHEE[1,2], ELIZABETH KADISON[3],
PETER A. MURRAY[4], and ALBION LLEWLYN[1]
[1]*Conservation and Fisheries Department*
Ministry of Natural Resources and Labour
Road Town Tortola British Virgin Islands
[2]*Centre for Resource and Environmental Studies Programme*
University of the West Indies
Cave Hill, Barbados
[3]*University of the Virgin Islands*
St. Thomas, USVI.
[4]*OECS Environment and Sustainable Development Unit*
Morne Fortuné, P.O. Box 1383
Castries, Saint Lucia, West Indies

ABSTRACT

Four potential *Epinephelus guttatus* (red hind spawning) aggregation sites were sampled in the Southeast of Tortola during full moons of January and February 2002. These sites were re-sampled in 2003 with the addition of another site in the North of Tortola. Three of the sites in the South and the one in the North were historical aggregation areas located with the assistance of local fishers. The sites were fished with hand lines, spear guns, and fish traps. Site B produced 67 red hind, many of which were in a mature active reproductive state. The male to female ratio at the site was 1:2.9. A dive on site B revealed a structurally complex habitat dominated by flattened overhanging stony corals and a depth of 40 to 42 meters. The other three sites sampled did not produce as many fish as site B and had much more skewed sex ratios. The size distribution for red hind appears to be fairly similar for BVI, USVI, and Puerto Rico, however more large males were collected during our sampling than have been reported in those areas. Based on gonosomatic indices and reproductive stages, spawning is believed to have occurred during the week of January's full moon in 2002. Mean size of fish from Northern sites (33.6 ± 6.1 cm TL) was significantly different from fish caught at Southern sites (37.7 ± 6.5 cm TL), but not significantly different from the mean size of red hind landed at the BVI fishing complex (33.9 ± 5.81 cm TL). The following year between January and March, 220 red hind fish were tagged and released at spawning aggregation sites in a preliminary attempt to examine spawning migration distances. No tagged fish were recaptured at the sites nor have they been reported captured in the territory. The results presented here are preliminary and are the initiation of a long-term study to assess the status of the red hind in BVI. Future research will focus on red hind movement within the territory, and migration across territory boundaries on the insular shelf.

KEY WORDS: BVI, red hind, spawning aggregations

Investigaciones Preliminares sobre la Pesqueria de Tofia en Las Islas Virgenes Inglesas

Las Islas Virgenes Inglesas (BVI), USVI, y Puerto Rico se localizan en el mismo estante continental. Sin embargo, las poblaciones de tofia en BVI no han sido tan explotadas como los de USVI y Puerto Rico. Tofia tiene un alto valor comercial y en el año pasado represento aproximadamente 17% de la pecsca comercial arrecifal por peso en BVI. Con la desaparición virtual del mero gallina, es discutiblemente el pez arrecifal mas importante económicamente del territorio.

Datos limitados existen para las pesquerías de BVI, así que la condición del tofia esta incierta. En los 1990's, pescadores reportaron un descenso dramático en los números de tofia, junto con una disminución en el tamaño medio. En 1996, el Ministerio de Recursos cerro la pesquería para los meses de diciembre, enero, y febrero. Los efectos de este cierre no se han investigado.

Datos sobre la pesca se han colectado rutinariamente en BVI en el pueblo de Road Town desde noviembre 2001. En 2002, un estudio por el Departamento de Conservación y Pesquerías se empezo sobre la condición de tofia en las aguas de BVI. La primera fase del estudio concentró en obtener el ayuda de pescadores locales para localizar los agregaciones de desove, caracterizar la dinámica de los agregaciones, comparar la composición del tamaño con el tamaño medio en el BVI fuera de tiempos de desove, proporciones de sexo, y el tiempo y duración de los agregaciones de desove. La segunda fase concentró en un estudio de la marca y la recaptura en agregaciones de desove en el territorio.

PALABRAS CLAVES: Agregaciones de desove, tofia, tamaño

INTRODUCTION

Epinephelus guttatus (red hind), a protogynous hermaphrodite, forms short-term aggregations to spawn. The biology of the red hind is well studied and spawning aggregations have been identified in Puerto Rico and the U.S. Virgin Islands (USVI) (Garcia-Moliner 1986, Colin et al. 1987, Sadovy et al. 1994). In these areas, fish are known to aggregate in large groups on banks close to the edge of the insular platform during the months of January and February. Spawning occurs around the full moon, in small clusters containing one male and one to several females.

In 1990, a spawning aggregation closure was implemented off the island of St. Thomas in the USVI; a result of concerns that heavy fishing pressure on red hind during the spawning season had contributed to a marked decrease in the population size, average body size and male to female aggregation sex ratio (Beets and Friedlander 1992, Sadovy and Figuerola 1992, Sadovy et al. 1994). By 1997, studies indicated that the number and size of fish in the hind aggregation inside the closed area had increased, and a more even aggregation sex ratio was present (Beets and Friedlander 1999).

The British Virgin Islands (BVI), USVI and Puerto Rico are located on the same continental shelf. Red hind populations in BVI have not been exploited as heavily as they have been in USVI and Puerto Rico however. Red hind has a high commercial value and in the last year represented approximately 17 percent of the reef-fish by weight caught commercially in the BVI. With the virtual disappearance of the Nassau grouper, it is arguably the most economically important reef fish in the territory.

Limited catch data exist for BVI fisheries, so the status of the red hind stock is uncertain. Fish catch data has been routinely gathered from the Government Fishing Complex in Road Town since November 2001 and fishers have been asked to broadly indicate where they are fishing, using a four km^2 grid. A detailed database has been created of catch total and divided into total weight by species and sample length and weight. As sample weight and individual fish of each sample are linked to the grid square, maps can be derived to characterize various aspects of the fishery (Mills et.al 2003).

In the early 1990s fishers reported a dramatic decline in red hind numbers, along with a marked decrease in average size. Operating on the precautionary principal, the Ministry of Natural Resources and Labor, in 1996, closed down the hind fishery for the months of December, January and February. The effects of this closure have not been investigated.

In 2002, the status of red hind in BVI waters became the focus of a long-term study initiated by the Conservation and Fisheries Department. The first phase of the study focused on obtaining assistance from local fishermen to locate traditional red hind aggregation sites. Our objectives were to identify positive spawning areas and begin to characterize the spawning group dynamics, including size composition, sex ratios and timing and duration of aggregation and spawning. Comparison of fish size at spawning aggregations and fish landed at the BVI fishing complex could give insights on the status of redhind fish stocks in the BVI.

The following year the study focused on tagging redhind fish in a preliminary attempt to establish site fidelity of redhind in the BVI and distance they travel to spawning aggregations. Fish mark and recapture projects (visual, acouctic and satellite) have been successfully used in fish movement studies to estimate home ranges (Eristhee et al.) migration routes and distances of species of interest. Few studies have attempted to track fish from spawning aggregations. Colin (1992) tagged grouper and recaptured one 110 Km from where it was tagged. Carter et al. (1994) implanted an acoustic tag in a Nassau grouper at Caye Glory on the Belize barrier reef. Two years later the fish was recaptured in Yucatan, 240 km from where it was tagged. Sadovy (1994) recovered a tag two years after, 18 km from where the red hind had been tagged at a spawning site.

The limitations of visual mark and recapture projects are well documented; however, it remains the most simple and cost-effective technique for estimating migration routes and distances traveled by fish. Essentially, fish are captured measured and tagged with "spaghetti", nylon dart tags. When time and location of recapture is established, distance traveled as well as growth rate may be inferred if size and other morphometric data were recorded at the time of first capture.

MATERIALS AND METHODS

Landed Catch Data

Fish catch data have been routinely gathered from the Government Fishing Complex in Road Town since November 2001, and fishers have been asked to broadly indicate where they are fishing, using a four km^2. Data collectors visited the BVI fishing complex approximately three times a week, early in the mornings from November 2001 to March 2004. This enabled them to collect data from fish, delivered in the evening and early morning, prior to being processed at the fishing complex. Catches were separated by species, with each species being placed in individual trays. The total weight of each species was obtained using a digital industrial scale capable of taking measurements up to 1/10,000 of a gram.

Total lengths were measured for all red hind caught and the weight of individual fish was measured on a digital scale. 533 measurements of total length (L) and weight (W) of red hind caught in BVI waters were collected at the Fishing Complex. Additionally, 106 such pairs of data were collected as part of a study of spawning aggregations. Another 39 data pairs and 181 measurements of total length (L) were obtained as part of a tagging study carried out by the Fisheries Division of the Conservation and Fisheries Department. The size of Redhind landed at the BVI fishing complex were then compared with those caught at spawning aggregation sites around the territory.

Identification of Traditional Spawning Aggregation Sites

BVI fishers identified several potential spawning sites during informal interviews, all of which were marked and recorded. Logistics and weather limited our sampling efforts to the area southeast of Tortola, though one site in the Northeast was sampled in 2003. Mr. Warren Durant, and David Issac, commercial fishermen who have successfully fished red hind for over thirty years, directed and accompanied staff to several banks on the southeast edge of the BVI's offshore shelf and the North Anegada Bank that historically have held large numbers of fish around the full moons of December and January. An additional site was added after drift fishing a bank close to a historical site yielded several large ripe females. Figure 1 show sites sampled during the study.

Sixteen fish traps baited with squid were deployed on four sites. Traps were constructed of black plastic coated wire (51 mm^2 mesh) braced with cut birch branches. Trap dimensions were 0.9 x 1.2 x 0.5 m. Two buoys were tied to each trap with 45 m of polypropylene line. Traps were pulled, emptied and re-baited approximately every other day from 26 January 2002 until 27 February 2002 as weather permitted. By then, catches had declined, and most females had ovaries in post-spawning condition. After 4 February, two sites, which had caught very few fish, were not sampled as heavily. Some of the traps on these sites (A and D) were moved to the two sites that had produced more fish during the week of the full moon (B and C). SCUBA dives were made on site A on 25 January 2002 and site B on 6 February 2002. Both areas were filmed for later characterization of habitat. Five red hind were collected by spear gun during the dive at site B.

All fish collected by trap, spear gun or hook and line were taken to the laboratory for examination. They were measured to the nearest millimeter (fork length, FL), weighed to the nearest gram, and sexed. Ovaries and testes were staged macroscopically according to staging criteria from Sadovy et al. (1994). Ovaries were weighed to the nearest .01 g for gonosomatic index [GSI = 100(ovary weight/somatic weight)] analysis. Catch per unit effort for each site was calculated based on number of fish collected per trap pulled. Sex ratios were calculated for both the overall collection period and for each site. Average GSI for each collection date was calculated and the relative proportion of female individuals in each maturation stage on each collection date was determined.

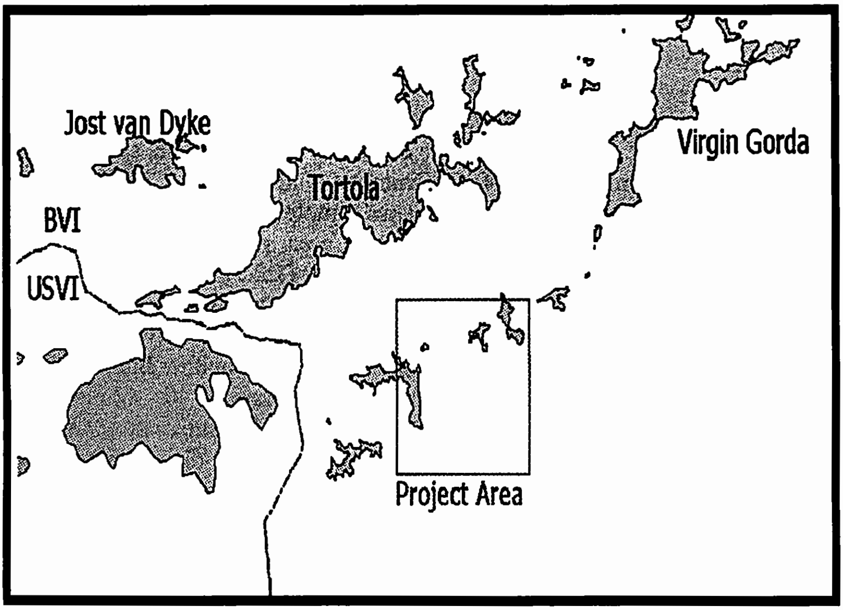


Figure 1. Map of the British Virgin Islands showing locations of the sites sampled for red hind in 2002 and 2003.

Spawning Migration Distances

In 2003, researchers in USVI reported successful in examination of redhind gonads using ultrasound technology (Rick Nemeth Pers. comm.). Sacrificing fish for GSI analyses was discontinued as concerns that aggressive sampling for macroscopic staging of gonads of redhind, at spawning aggregation sites may lead to critical reduction of aggregation numbers increased.

Redhind fish were caught at spawning aggregation sites around the territory, tagged, and released. Each fish was measured to the nearest millimeter, tagged through the dorsal musculature, swim bladders were deflated using a sterile hypodermic needle, and the fish were released. Each tag contained a unique identification number and contact information, should fishers recapture the fish. Each tag was color coded based on the location where the fish was caught to facilitate rapid identification of tagging location when the fish was recaptured. GPS coordinates of tagging locations were recorded and added to the Territory's Fish Catch Database to facilitate analysis of distance traveled to and from spawning aggregation sites.

Statistical Analyses

Statistical analyses were carried out using SPSS 11.0 statistical package. Data were tested for normality and homogeneity of variance, and in some instances transformed using natural log so as to conform to the conditions necessary for parametric testing.

RESULTS AND CONCLUSION

Traditional Spawning Aggregation Sites

During the study, 121 red hind were caught by hook and line, spear gun or fish trap in th southern part of the BVI. Number of fish caught, CPUE, and sex ratio all differed significantly in the four sites sampled. Site B, the bank found by drift fishing near the historical aggregation area, produced the most fish, highest CPUE, and closest ratio of males to females (1:2.9).

We believe site B to be an active spawning site. During a dive on the site, eight days after January's full moon, we observed over 60 relatively large red hind, the majority suspended over coral bottom. The fish neither hid nor swam away when approached. The site is a relatively small bank in 40 - 42 meters of water, dominated by stony corals and sponges. The substrate is highly complex with many places for fish to escape predators. A dive at the nearby site A was less promising. The bank was 30 - 32 meters deep, had a much less structurally complex habitat, and few red hind were observed. Site C, approximately 4 kilometers to the southwest, produced 32 fish, most of which were in a mature active reproductive stage during the week of full moon. The sex ratio was highly skewed towards females however. This bank may be an over-exploited historic spawning bank, or may be close to a more active spawning aggregation. Site D produced only six fish, five of which were males. This is no reason to believe that any spawning activity was occurring on this site. There was significant difference in mean size of fish caught by the different gear types, with larger fish being caught by traps (Table 1. $F = 10.31$ $p < 0.01$), possibly because traps formed refuges on the bottom during aggregations; however when all logistics were considered the use of handlines was the preferred method of fish capture.

Table 1. Showing means, size ranges and results of ANOVA comparisons of redhind fish caught in the BVI when grouped by gear type, sex and origin.

Grouping Factors		Observations (N)	Means ± SD (cm)	Size Range (cm)	Test Statistic	P-Value
	Handline	10	31.7 ± 5.0	25.2 – 41.7		
Gear	Spear Guns	5	46.4 ± 3.2	41.4 – 50.1	F= 10.31	< 0.01
	Trap	94	37.7 ± 6.0	25.8 - 52.8		
Sex	Males	21	44.8 ± 5.1			< 0.01
	Females	84	35.4 ± 5.4		t= 6.91	
				25.3 – 48.9		
	N. Spag. Site	204	33.6 ± 6.1	20.0 – 56.0		
* Origin	S. Spag Site	138	37.7 ± 6.5	23.0 – 52.8	F= 23.35	< 0.01
	BVI Fishing Complex	533	33.9 ± 5.8	21.0 – 67.1		

When the data was grouped by sex, (Table 1) mean length of males was 44.8 ± 5.1 cm (n = 21) and ranged from 33.9 cm to 52.8 cm FL and females (n = 84) had a mean length of 35.4 ± 5.4 cm and ranged from 25.2 to 48.9 cm FL. Males were significantly larger than females (independent t test: $t = 6.91$, $p < 0.01$). Length frequencies for males and females are shown in Figure 2. Size ranges found for males and females were similar to those seen in Puerto Rico and USVI (Sadovy 1994, Beets and Friedlander 1999), with the exception of some larger males being present in BVI samples. The sex ratio over the study period was 1:4.0, significantly different from unity ($p < 0.005$, chi-square). Spawning activity appeared to occur around full moon in January in 2002. Female GSIs and the proportion of mature active ovaries over time show a peak within a week of full moon (Figure 3 and 4).

A traditional spawning bank in the Northern region of the BVI produced 204 fish, with a mean length of 33.6 ± 6.1 cm; ranging from 20.0 to 56.0 cm (Table 1). Fifty percent of the fish at this site were caught in one hour of fishing. Fish are only caught at this site during January and March, (David Issac Pers. comm.). ANOVA, followed by Tukey HSD test revealed that a significant difference exist between the size of fish caught at Southern spawning aggregation sites, Northern spawning aggregation site and fish landed at the BVI Fishing complex. No significant difference was identified between fish caught at Northern spawning aggregation sites and those landed at the BVI fishing Complex. This result could indicate that the majority of redhind landed at the BVI fishing complex comes from the Northern part of the territory, and that redhind populations in the Northern part of the territory may be separate and distinct from those in the Southern part of the territory.

Evidence for this may be provided by genetic and tagging studies. Mean size of fish in the North is smaller than those in the Southern part of the territory (Table 1) possibly because of heavier fishing pressure at Northern fishing grounds, as evidenced by reported fishing locations provided by fishers as part if data collected at the BVI fishing complex. The proximity of Southern spawning aggregation sites to international shipping lanes may provide some protection for red hind as fishers are reluctant to place fish traps in areas where they are frequently lost to boat traffic.

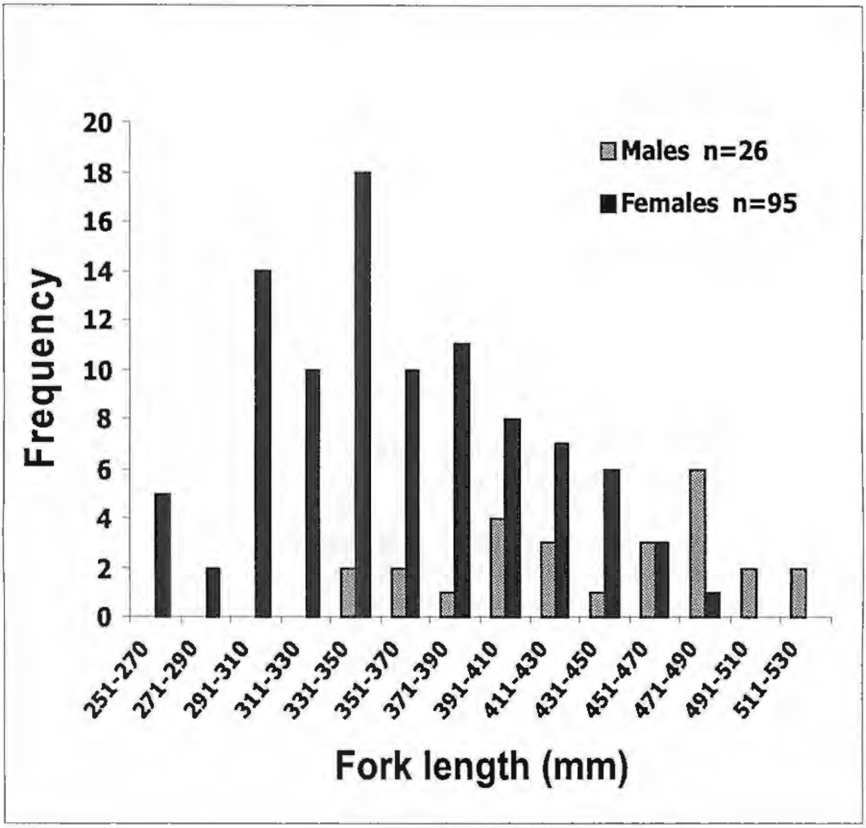


Figure 2. Size frequency distribution of male and female red hind collected in the BVI during 2002. Sample sizes (n) of each sex are given.

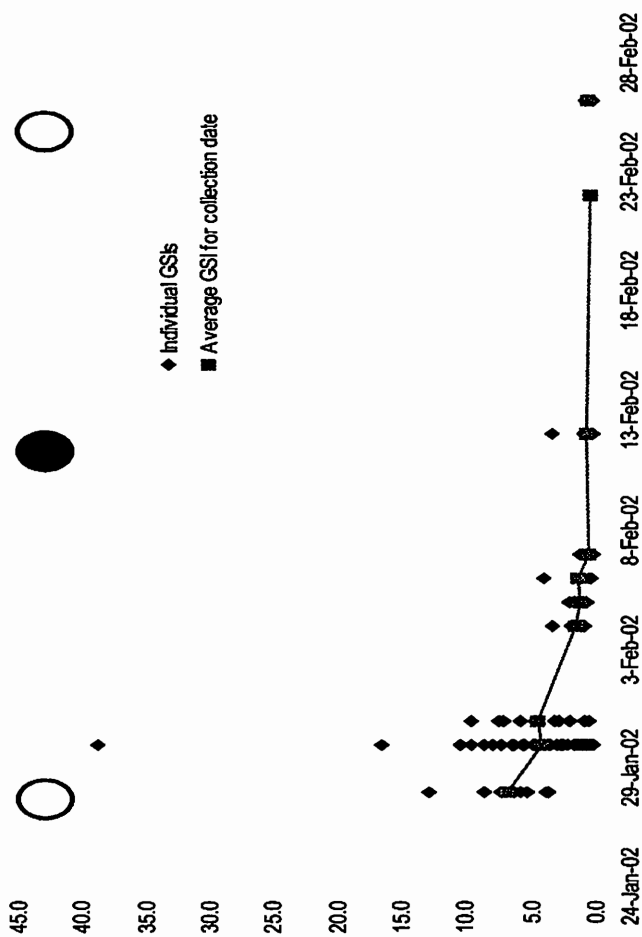


Figure 3. Frequency of female red hind that are maturing (F2), mature active (F3) and post-spawning (F4) for each collection day. Open circles indicate full moon and closed circle new moon.

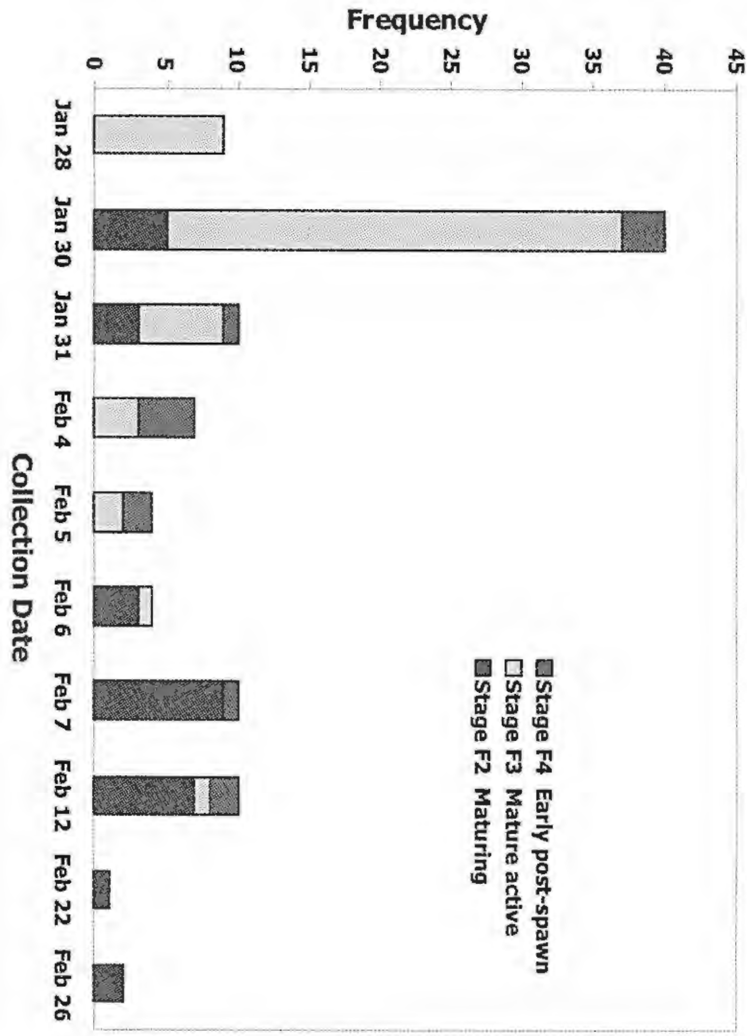


Figure 4. Frequency of female red hind and the stage of gonads for each collection day, maturing (F2), mature active (F3) and post-spawning (F4).

Spawning Migration Distances

Two hundred and twenty (220) fish were tagged during the spawning aggregation months (January – March) 2003. Mean size of fish tagged was 33.2 ± 6.0 cm ranging in size from 20.0-56.0 cm. No tagged fish were recaptured. It is possible that fish were preyed on, when released, by large predators often seen at spawning aggregation sites. Innovative methods of returning fish to the bottom after tagging may play a role in ensuring recaptures in future tagging studies.

Analysis of the small data set represents only a preliminary examination of questions to be addressed in assessing the status of red hind in BVI waters. A larger data set would provide a more rigorous examination of the results presented here. Sustaining red hind populations in BVI waters are not only critical for BVI fisheries, but could play a key role in keeping populations on other areas of the shelf (i.e. USVI and Puerto Rico) at sustainable levels. The west moving Caribbean current and associated eddies are complex and poorly understood, but "upstream" banks on the common insular shelf could conceivably supply recruits to areas as far away as Hispanola. Future research will focus on genetic differences and similarities across the shelf, a continued examination of spawning migration distances, and determining whether year round aggregation site closures would be a more effective management tool for red hind in the BVI than the currently imposed seasonal closure.

ACKNOWLEDGMENTS

Mr. Warren Durant, David Issac and Mr. Sylvester Edwin; Essau Ross, The Nature Conservancy, also CFD staff, especially Mr. Bertrand Lettsome, Ms Lecia Rubaine, Arlinton Pickering, Sam Davies and Mr. A. Mills.

LITERATURE CITED

Beets, J. and A. Friedlander. 1992. Stock analysis and management strategies for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* **42**:66-80.

Beets J. and A. Friedlander. 1999. Evaluation of a conservation strategy: A spawning aggregation closure for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands. *Environmental Biology of Fishes* 55:91-98.

Carter, J., G.J. Marrow, and V. Pryor. 1994. Aspects of the ecology and reproduction of Nassau grouper *Epinephelus striatus. Proceedings of the Gulf and Caribbean Fisheries Institute* **43**:65-111.

Colin, P.L.., D.Y. Shapiro, and D. Weiler . 1987. Aspects of the reproduction of two species of groupers, *Epinephelus guttatus* and *E. striatus* in the West Indies. *Bulletin of Marine Science* **40**:220-230.

Colin, P.L. 1992. Reproduction of the Nassau Grouper, *Epinephelus striatus* (Pisces: Serranidae) and its relationship to environmental conditions. *Environmental Biology of Fishes* **41**:269-286.

Eristhee, N. and H.A. Oxenford. 2001. Home range size and use of space by Bermuda Chub (*Kyphosus secatrix L.)* in two marine reserves in the Soufriere Marine Management Area, St. Lucia. *Journal of Fish Biology* **59** (A):152-177.

Garcia-Moliner, G.E. 1986. Aspect of the social spacing, reproduction and sex reversal in the red hind, *Epinephelus guttatus*. M. Sc. Thesis. University of Puerto Rico. Mayaguez, Puerto Rico. 104 pp.

Mills, A.P., N. Eristheé, and A. Llewellyn. 2003. GIS in Fisheries Management in the British Virgin Islands – issues and practicalities. *Proceedings of the Gulf and Caribbean Fisheries Institute* **56**:395-410.

Sadovy,Y. and M. Figuerola. 1992. The status of the red hind fishery in Puerto Rico and St. Thomas, as determined by yield-per-recruit analysis. *Proceedings of the Gulf and Caribbean Fisheries Institute* **42**:23-38.

Sadovy, Y., M. Figuerola, and A. Roman. 1992. Age and growth of red hind. Epinephelus guttatus, in Puerto Rico and St. Thomas. *Fisheries Bulletin U.S.* **90**:516-528.

Sadovy, Y., A. Rosario, and A. Roman. 1994. Reproduction in an aggregating grouper, the red hind, *Epinephelus guttatus*. *Environmental Biology of Fishes* **41**:269-286.

Shapiro, D.Y., Y. Sadovy, and M.A. McGehee. 1993a. Size, composition, and spatial structure of the annual spawning aggregation of the red hind. *Epinephelus guttatus* (Pisces: Serranidae). *Copeia* **1993**:367-374.

Preliminary Analysis of Age, Growth, and Reproduction of Coney (*Cephalopholis fulva*) at Bermuda

TAMMY M. TROTT
Marine Resources Division
PO Box CR52
Crawl CRBX, Bermuda

ABSTRACT

Groupers have historically been an important component of the Bermuda fishery. The coney (*Cephalopholis fulva*) comprised almost 50% of the total landed weight of all grouper species in Bermuda from 1991 – 2003. In light of this significant contribution to fishery landings and because little is known about the fishery biology of the coney, a study was initiated in January 2000.

One of the principal components of this study was to examine age and growth. Opaque rings on polished transverse sections of sagittal otoliths were used to estimate age. Fish were collected by hook and line from several locations on the Bermuda reef platform. Fork lengths of conies sampled ranged from 151 mm to 384 mm. Age estimates, determined for 997 specimens, ranged from 2 to 28 years with wide variability in the length-at-age. There was a significant positive correlation between otolith weight (OW) and age estimates which will enable the use of OW as a proxy for age of conies in future stock assessments.

The other important aspect of the study was to characterize the sexual pattern and reproductive biology of the coney. Gonads were examined histologically to confirm sex and reproductive condition. The results confirm protogynous hermaphroditism in this species. Of the 998 fish sexed, 46.1% were female, 40.1% were male and 13.8% were transitional fish. There was considerable overlap in the length distributions of males (mean length 256 mm FL ± 28 mm SD), females (mean length 232 mm FL ± 34 mm SD) and transitionals (mean length 241 mm FL ± 30 mm SD) and the overall sex ratio was female biased (1.15F:1M). The reproductive season was from April to July inclusive with peak spawning occurring in June.

KEY WORDS: Coney, *Cephalopholis fulva*, age, growth, reproduction, Bermuda

Edad, Crecimiento y Reproducción de la Cherna Cabrilla (*Cephalopholis fulva*) en Bermuda

Históricamente las chernas han constituido un componente importante en la pesquería de Bermuda. La cherna cabrilla (*Cephalopholis fulva*) agrupa prácticamente el 50% del total del peso efectivo en muelle de todas las especies de chernas, desde el año 1991 – 2003. A la luz de esta importante contribución a los desembarques pesqueros, y debido a que se conoce muy poco acerca de la biología pesquera de la cherna cabrilla, se inició un estudio en Enero de 2000.

Uno de los componentes principales de este estudio lo constituyó el examen de la edad y el crecimiento. Los anillos opacos en las secciones transversales pulidas del otolito sagital se utilizaron para estimar la edad. Los peces se capturaron con anzuelo y cordel en diferentes localidades de la plataforma del arrecife de Bermuda. Alrededor de 1000 chernas cabrilla fueron muestreadas con longitudes de bifurcaciones que fluctuaron entre 154 mm y 384 mm. Los estimados de edad fluctuaron entre los 2 y 28 años con gran variabilidad de talla con relación a la edad. Hubo una importante correlación positiva entre el peso del otolito y los estimados de edad lo cual permitió la utilización del peso del otolito como un representante para la edad de las chernas cabrilla en futuras evaluaciones del stock.

Otro aspecto importante del estudio fue la caracterización de los patrones sexuales y la biología reproductiva de la cherna cabrilla. Se examinaron las gónadas microscópicamente para confirmar el sexo e identificar los peces de transición. Los resultados confirman el hermafroditismo protógeno en esta especie. De los 998 peces examinados, el 46.1 % perteneció a las hembras, el 40.1 % a los machos y el 13.8 % fueron peces de transición. Hubo un considerable solapamiento en las distribuciones de longitud de los machos (la longitud promedio fue de 255 mm FL ± 28 mm SD), hembras (la longitud promedio fue de 232 mm FL ± 34 mm SD), y los de transición (la longitud promedio fue de 240 mm FL ± 28 mm SD) y el coeficiente de sexo global fue sesgado por las hembras (1.15F:1M). La temporada reproductiva fue desde abril a julio con un pico de desove en el mes de junio.

PALABRAS CLAVES: Cherna cabrilla, *Cephalopholis fulva*, edad, crecimiento, reproducción, Bermuda

INTRODUCTION

Epinepheline groupers are an important and valuable fishery resource and have historically dominated the Bermuda fishery and the fisheries of many Caribbean countries, Florida, the Gulf of Mexico and southeastern United States. However, due primarily to intense fishing pressure, the stocks of many large groupers have drastically declined (Sadovy 1994, Luckhurst 1996). At Bermuda several large grouper species such as the Nassau grouper (*Epinephelus striatus*) and the yellowfin grouper (*Mycteroperca venenosa*) have become commercially extinct.

With the decline of large grouper landings in Bermuda from 1975-1981 and a subsequent fishpot ban in 1990, there was a substantial increase in the landings of small groupers such as the coney (*Cephalopholis fulva*) and the Creole fish (*Paranthias furcifer*) because, in part, due to their ability to be readily taken by hook-and-line fishing (Luckhurst 1996). Fisheries statistics collected from local fishermen show that from 1991 to 2003, the coney alone comprised almost 50% of the total landed weight of groupers.

Relatively little is known about the biology of this species and before the present study, there had been limited research conducted on *C. fulva* at

Bermuda. A greater understanding of the fishery biology of the coney is essential in order to assess the stock around Bermuda and to make informed fishery management decisions.

MATERIALS AND METHODS

Cephalopholis fulva samples for this study were collected monthly in 2000 and 2001 by hook-and-line fishing from several locations on the Bermuda reef platform. Specimens collected from opportunistic sampling (n = 109) conducted in 1998 and 1999 were also included in analyses. The majority of the sampling was conducted on board the Bermuda Government research vessel *R/V Calamus* with the aid of several Fisheries staff. Samples were taken in water depths ranging from 11 to 42 metres. Captured specimens were immediately placed on ice and later brought back to the laboratory and weighed to the nearest 0.1 g. Fork length (FL), which is essentially equal to total length (TL) in coney due to the convex caudal fin shape, and standard length (SL) were measured to the nearest 1 mm. Occasionally, due to time constraints, specimens were frozen and processed at a later date.

Age and Growth

Sagittal otoliths were removed from specimens using forceps after a vertical cut was made with a large knife through the skull just anterior to the pre-opercle. The otoliths were then washed thoroughly in fresh water, dried and stored in vials until processing. Individual otoliths were weighed to the nearest 0.0001g.

There was no significant difference between the weights of the left and right otoliths so the left otolith was chosen for analysis. Otoliths were processed following the methods of Secor et al. (1991). They were embedded in Araldite epoxy resin and left to harden for at least 24 hours. A 2- to 3-mm transverse section, that included the otolith core, was cut using an Isomet, low-speed, diamond blade saw and secured to a microscope slide by Crystal Bond adhesive. Otolith sections were then hand polished in order to clearly define presumed annuli. Presumed annuli were counted by two independent readers for a subset of otoliths (n = 275) using a compound microscope and then compared. If there were any discrepancies in age for any reading, that otolith was read again independently. If there was still no agreement, an age for the otolith was reached through discussion and consensus. The remaining otoliths were read by one reader.

Attempts were made to validate presumed annuli by chemically marking the otoliths. Fish held for age validation were caught by hook-and-line in September 2000. Following capture, a total of 15 fish were fresh water dipped for four minutes to rid them of ectoparasites, and following which they were tagged with Floy T-bar anchor tags inserted into the musculature below the dorsal fin rays on the left side. They were then injected with Promycin (oxytetracycline hydrochloride - OTC) in the abdominal area at an approximate dosage of 0.1 cm^3 per 100 g of wet body weight. All fish were put in a 1,000 L open water tank system with natural temperature fluctuations and fed on a diet of squid and anchovies. Most fish died by December 2000 but four fish survived for seven months. Otoliths from these fish were examined under the microscope using ultra-violet light to detect the OTC mark in order to determine post-injection growth.

The von Bertalanffy growth parameters were estimated from observed length-at-age data by non-linear regression analysis fitting the von Bertalanffy growth model ($L(t) = L\infty*[1\text{-exp}\{-K*(t-t_0)\}]$). Data from one locality on the Bermuda platform (n = 330) were excluded from this analysis due to unexplained abnormally high variability of length-at-age of coney at this location.

Sexual Pattern and Reproductive Seasonality

The sex of *C. fulva* during non-spawning periods was difficult to ascertain macroscopically, therefore, all sex determinations were made by microscopic examination. Gonads were removed, weighed to the nearest 0.01g and preserved in Davidson's solution for a minimum of 48 hours. They were then transferred to 50% ethanol for a minimum of 48 hours and subsequently stored in 70% ethanol in preparation for histological processing at a later date (Hinton 1990).

The posterior portion of the gonad was used for histological analysis. Preserved tissues were embedded in paraffin, cut in cross-section at 7 µm, stained with double-strength Gill hematoxylin, and counterstained with eosin-y. Processed sections were examined microscopically by two independent readers, and there was general agreement on the interpretation of the gonad structure.

Sex and sexual maturity were determined by adapting the histological criteria of sexual development of McGovern et al (1998) (Table 1). Sexual pattern was assessed using the criteria outlined in Sadovy and Shapiro (1987).

Coney fork length data was not normally distributed so lengths of males, females and transitionals were compared by an ANOVA on log-transformed data. Chi-square tests were used to determine if observed sex ratios differed significantly from a 1:1 ratio.

Only mature females, for which reproductive stage was certain, were used to determine reproductive seasonality in coney. Females with hydrated oocytes or postovulatory follicles were considered to be in spawning condition. Mean gonadosomatic index (GSI) was used to assess relative changes in reproductive state during the year. The GSI index was calculated using the formula:

$$GSI = [GW/(TW-GW)] \times 100$$

where GW = gonad weight and TW = total wet weight.

The temperature of the water just above the reef substrate was recorded using a Stowaway Waterproof Temperature Logger. This environmental variable may be important to some groupers in determining time of spawning (Colin 1992).

Table 1. Histological criteria used to determine sex and reproductive stage in coney (adapted from McGovern et. al,1998).

Reproductive stages	Histological Criteria	
	Females	**Males**
Immature	Previtellogenic oocytes; no evidence of atresia; differentiated from resting females by lack of muscle and connective tissue bundles in lamellae, oogonia more abundant along periphery of lamellae, thinner ovarian wall, smaller ovarian transverse section and shorter lamellae.	Possible primary males. Immature males as described by Moe (1969) were considered late transitionals as sexual transition not yet complete.
Mature, resting	Previtellogenic oocytes; traces of atresia; differentiated from immature females by presence of muscle and connective tissue bundles in lamellae, oogonia less abundant along periphery of lamellae, thicker ovarian wall, larger ovarian transverse section and more elongated lamellae.	Empty lobules and sinuses with little or no spermatocyte development.
Developing	Oocytes undergoing cortical aveoli formation through late vitellogenesis (migratory nucleus and partial coalescence of yolk globules).	Spermatogenesis occurring; cysts of primary and secondary spermatocytes through some accumulation of spermatozoa in lobules and peripheral sinuses within the gonadal wall.
Developing, recent spent	Developing stage as described above with the addition of postovulatory follicles.	
Running ripe	Coalescence of yolk globules complete; presence of hydrated oocytes.	Predominance of spermatozoa in lobules and peripheral sinuses with little or no spermatogenesis occurring.
Spent	More than 50% of the vitellogenic oocytes in alpha or beta stages of atresia.	Some residual spermatozoa in lobules and peripheral sinuses with no spermatogenesis occurring.
Transitional	Proliferation of testicular tissue (spermatogonia through limited spermatogenesis) within lamellae of spent or resting ovary; development of peripheral sinuses in musculature of ovarian wall.	

RESULTS

Age and Growth

Age estimations were determined for 997 specimens. All otoliths exhibited an alternating pattern of opaque rings and translucent zones. Opaque rings were counted as presumed annuli (Figure 1). Attempts to validate rings as annuli met with limited success. Out of the four specimens that survived seven months of the age-validation experiment, OTC marks were only visible in two specimens. Some growth was observed distal to the OTC mark and the last presumed annulus on these specimens. This observation tends to support the hypothesis that rings are deposited annually but is not a validation.

Estimated coney ages ranged from 2 to 28 years and sizes ranged from 151 mm to 384 mm FL. The oldest specimens were male with ages ranging from 4 to 28 years. Female ages ranged from 2 to 22 years but the majority (97%) were between the ages of 2 and 12 years. Transitionals (see sexual pattern section) ranged from 4 to 23 years of age with the majority (94%) between the ages of 4 and 12 years (Figure 2).

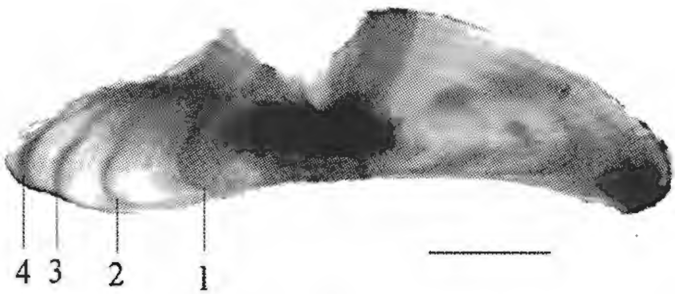


Figure 1. Transverse sagittal otolith section of a coney, 198 mm FL, estimated to be four years old. Scale bar = 0.5 mm.

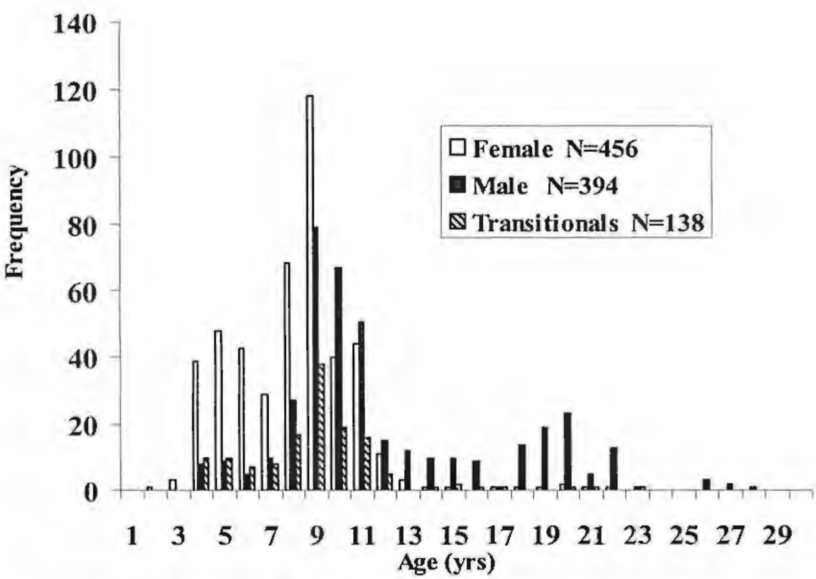


Figure 2. Age distribution of male, female and transitional coney at Bermuda

There was wide variability in the length-at-age of the fish sampled (Figure 3) thus length was not a good predictor of age. The length of the oldest fish sampled (28 years) was 295 mm FL, while the largest fish sampled (384 mm FL) was only eight years old.

Although there was not a good correlation between length and age, there was a positive correlation between otolith weight and age ($r^2 = 0.73$; Figure 4). This relationship will allow for the use of otolith weight as a proxy for age in future stock assessments such as suggested for lane snapper (*Lutjanus synagris*) (Luckhurst et al. 2000).

The equation that best describes this relationship for coney is:

$$OW = 0.0025*age + 0.00161$$

The equation that shows the relationship between total body weight (W) and fork length (FL) is:

$$W = 0.000011*FL^{3.0749} (N = 982, r^2 = 0.9622)$$

The von Bertalanffy growth parameter estimates obtained from observed lengths at age were as follows:

$L\infty = 280.86 \pm 3.5862$ SE
$K = 0.20 \pm 0.0196$ SE
$t_0 = -1.21$ years ± 0.5922 SE

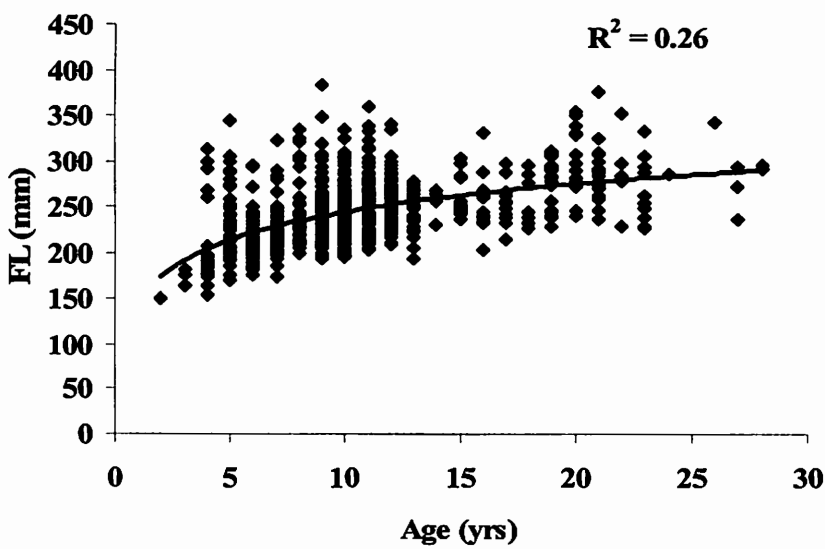


Figure 3. Fork length by age of coney at Bermuda

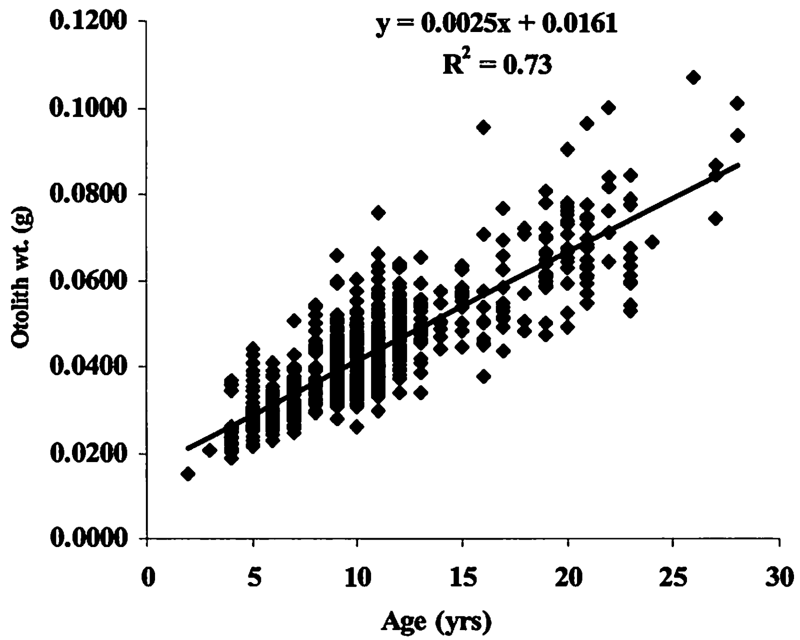


Figure 4. Otolith weight vs. age of coney at Bermuda

Sexual Pattern and Reproductive Seasonality

Out of the 998 conies sexed, 460 (46.1%) were female and fork lengths of these specimens ranged from 151 mm to 384 mm. A total of 400 fish (40.1%) were male with fork lengths of specimens ranging from 190 mm to 353 mm. Transitionals accounted for 13.8% (138 individuals) of the total sexed fish (Figure 5). Fork lengths of transitional specimens ranged from 194 mm to 375 mm.

There was considerable overlap in the length distributions of males, females and transitionals and the mean lengths between the sexes were significantly different (ANOVA, $F = 70.06$, $p = <0.001$). The mean length of males was 256 mm FL (± 28 mm SD). Female mean length was 232 mm FL (± 34 mm SD) and mean length of transitionals was 241 mm FL (± 30 mm SD) (Figure 6).

The overall sex ratio was slightly female biased (1.15F:1M, n = 860, $\chi^2 = 4.19$, $P = 0.04$). During the non-reproductive months the female bias was much greater (1.75F:1M, N=478, $\chi^2 = 35.36$, $P<0.0001$), however, during the reproductive season (April - July), males significantly outnumbered females (0.69F:1M), N=382, $\chi^2 = 12.83$, $p = 0.0003$).

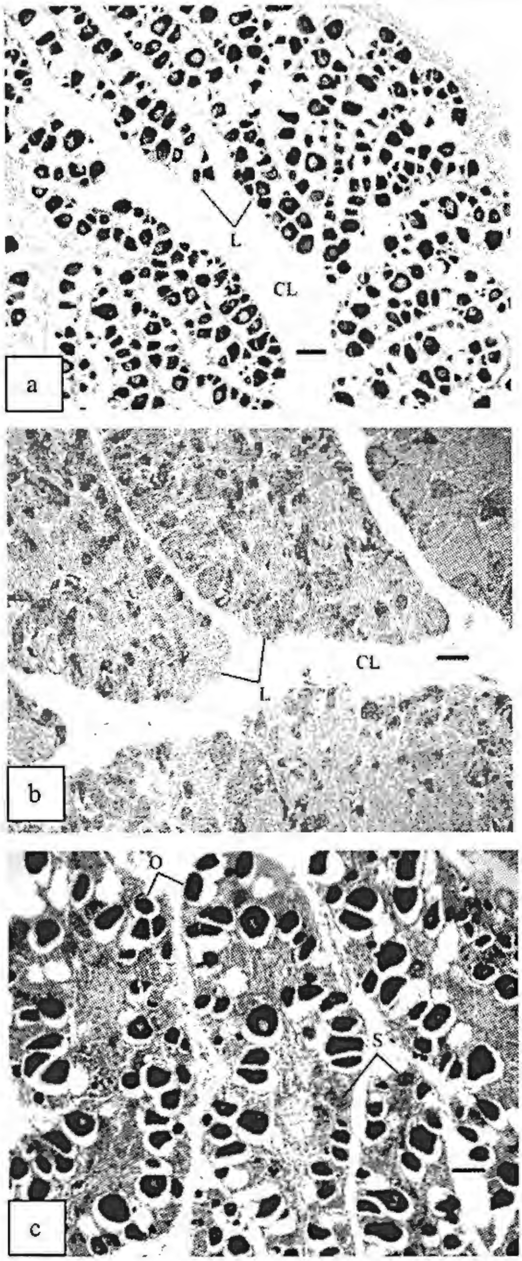


Figure 5. Cross-sections of gonads of *C. fulva* (a) Ovary with central lumen and lamellae of female, 235 mm FL (b) Testis with central lumen and lamellar structure of male, 274 mm FL and (c) Transitional gonad of individual, 252 mm FL. Symbol key: L = lamellae; CL = central lumen; O = oocyte (ovarian tissue); S=cysts of spermatogenic cells (testicular tissue). Scale bar = for (a) & (b), 100 μm; for (c) 50 μm.

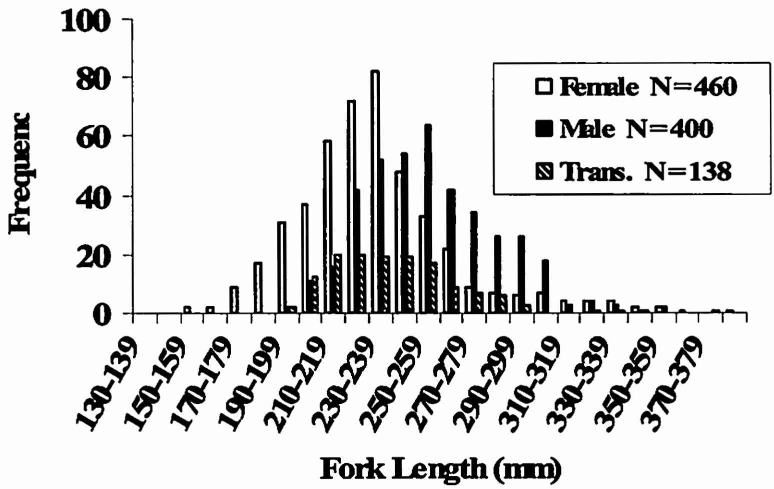


Figure 6. Length frequency distribution of male, female and transitional coney at Bermuda.

Female and male conies followed a similar pattern of sexual activity. Gonadal development occurred as early as February (Figure 7) but most reproductive activity commenced in April. Peak spawning occurred in June. Many males were still in spawning condition in July although only one spawning female was caught during this month. By August most fish were in a resting stage and from August until March, there was little reproductive activity. Many resting females were also recorded from July and spent fish were noted during the whole reproductive season. Transitional fish were found during all months of the year.

The GSI plot confirms the summer spawning season with the highest GSI values occurring in June (Figure 8). The mean monthly water temperature during the sampling period ranged from a low of 18.9°C in March to a high of 28.2°C in August. Spawning appeared to occur at temperatures between 22 °C - 26 °C.

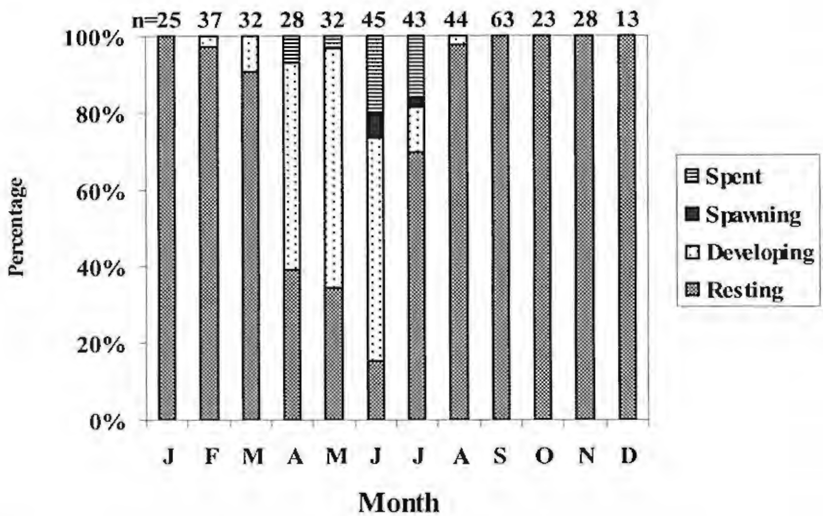


Figure 7. Percentage composition of female coney reproductive stage by month (n = 413)

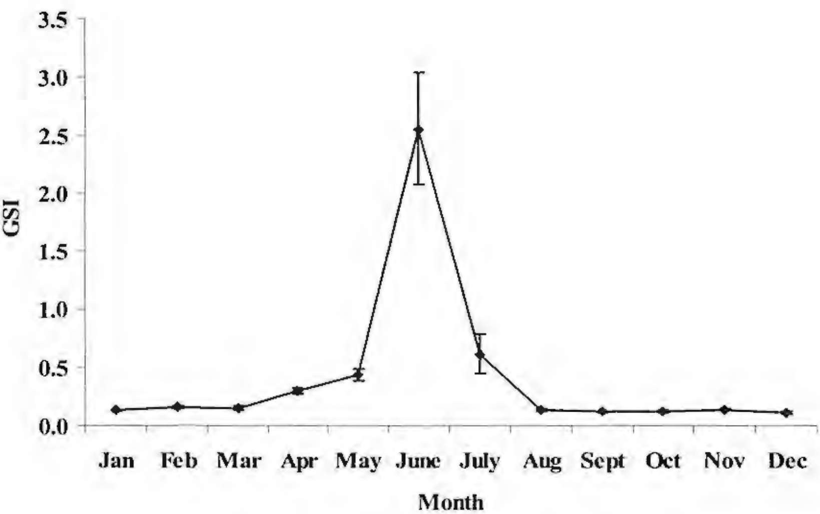


Figure 8. Mean gonadosomatic index (GSI) plot (±SE) of female coney at Bermuda

DISCUSSION

Age and Growth

The maximum age of 28 years observed in coney at Bermuda is much older than previously indicated for this species. Potts and Manooch (1999) observed a maximum age of only 11 years for coney from the Southeastern United States with reported size ranges that were similar to those from Bermuda (150 mm to 397 mm TL).

Estimates of $L\infty$ and K for coney at Bermuda were also much lower than those estimated by Potts and Manooch ($L\infty = 372$ and $K = 0.32$) for coney from the Southeastern United States and those estimated by Thompson and Munro (1978) for coney from Jamaica ($L\infty = 340$ and $K = 0.63$). This would suggest that coney at Bermuda attain a smaller asymptotic size and are much slower growing than coney in the USA and Caribbean. It must be noted that the sample size from the present study was substantially larger than that of Potts and Manooch's sample (n = 55) and thus would have better captured the natural variability of growth in coney.

Although age estimates are preliminary in this study, it is felt that they are reasonable due to the high legibility of the otoliths, the occurrence of other long lived fish species at Bermuda (Luckhurst 2000, unpublished data) and the validation of annuli by OTC markings in a similar grouper, the red hind, *Epinephelus guttatus*, at Bermuda (Luckhurst Pers. comm.).

Sexual Pattern and Reproductive Seasonality

The presence of transitional individuals, testes that retained an ovarian lumen and lamellar structure and sperm sinuses in the gonadal wall confirmed previous indications of protogynous hermaphroditism in *C. fulva* (Sadovy and Shapiro 1987, Smith 1959, Smith 1965). Transitionals showed wide variability in the proportion and stages of development of ovarian and testicular tissue, which implied a succession from ovary to testis. Many transitionals also contained muscle and connective tissue bundles which are indicative of prior spawning as a female (Sadovy and Shapiro 1987, Shapiro et al. 1993).

The percentage of transitionals found during this study (13.8%) was very high compared to the < 3% found for many other grouper species (Shapiro et al. 1993, Bullock and Murphy 1994, Bullock et al. 1996, Brule et al. 1999, Mackie 2000, Chan and Sadovy 2002). Siau (1994), however, also found a high percentage of transitionals (10.8%) for a similar species, *Cephalopholis taeniops* (blue-spotted grouper) from the East Atlantic and Marino et. al (2001) found that 9% of *Epinephelus marginatus* (dusky grouper) from the southern Mediterranean were transitionals. Both studies, however, found that transitionals occurred primarily outside of the reproductive period. This is unlike the present study where transitionals were observed throughout the whole year. Shapiro et al. (1993) found that in red hind, *Epinephelus guttatus,* from Puerto Rico transitionals also occurred throughout the year.

Many grouper species are monandric protogynous hermaphrodites (Smith 1959, Smith 1965, Moe 1969, Thompson and Munro 1978, Shapiro 1987, Shapiro et al. 1993, Brule et al. 1999) and typically demonstrate bimodal size or age frequency distributions and female biased adult sex ratios (Sadovy and

Shapiro 1987). In some species, though, it has been discovered that males may develop directly from juveniles. This is the case with *Cephalopholis taeniops* (Siau 1994), the chocolate hind, *Cephalopholis boenak* (Chan and Sadovy 2002) and the catface rockcod, *Epinephelus andersoni* (Fennessy and Sadovy 2002). In *C. taeniops and E. andersoni*, mature males were observed that were smaller than mature females.

In *C. fulva* at Bermuda, there was broad overlap in fork lengths among the sexes but males were significantly larger than females. There was, however, no difference in the modal age of the sexes, which was nine years for males, females and transitionals.

While the overall sex ratio was female biased, the degree of bias was not great and was heavily influenced by a male bias observed during reproductive months. It is suspected that this male bias may have been caused by the more aggressive nature of males during spawning time in bait competition.

Diagnosis of the type of protogyny exhibited in coney was impeded by the lack of juveniles in the sample and thus the inability to detect if there was any development of males from the juvenile phase. Out of all of the specimens collected for this study, only one fish was considered to be immature (although there were many females for which maturity was uncertain). It is evident then that the size of first maturity for coney at Bermuda is below the size at which the fish recruit to the hook-and-line fishery (approx. 150 mm FL), and that examining juveniles will help to determine the sexual pattern of this species.

The summer reproductive season observed for coney in this study is consistent with previous indications for this species (Luckhurst unpublished data) and that found for other fish species at Bermuda (Bardach et al. 1958, Smith 1958, Luckhurst 1996). Thompson and Munro (1978) documented a much longer reproductive season for coney from Jamaica (November to July).

Fisheries Management

Presently there are no fisheries management restrictions in place for coney at Bermuda. Although the coney has been heavily targeted for many years by both commercial and recreational fishers, it would appear from this study that the stock is still healthy. A large proportion of the sampled fish were 10+ years. The presence of these older year classes suggests that fishing mortality is not yet high enough to remove these individuals from the population.

The fact that the majority of the fish sampled during this study were mature fish may lend some insights into the continued abundance of this species around Bermuda. It would appear that, as suggested by Chan and Sadovy (2002) for *Cephalopholis boenak*, the small size of sexual maturation in *C. fulva* at Bermuda makes it less susceptible to fishing pressure. This is because these fish have an opportunity to reproduce before being captured by the line fishery. Before the fish pot ban of 1990, fish catches of coney in fish pots had increased dramatically from 1984 – 1989 (Luckhurst 1996), however, small fish may have been able to escape and thus again have a chance to spawn before being caught. Beets et. al (1994), documented a minimum length of capture of 100 mm TL for coney from the pot fishey at St. Croix, U.S. Virgin Islands. The study also indicated that total catches of this species were declining in this area and supported recommendations on increases in fish pot mesh size so that small fish could escape and have a chance to reproduce.

Chan and Sadovy (2002) also suggest another reason why small grouper species such as the coney have been able, in some cases, to remain abundant. They reason that with the overfishing of larger groupers, predation and interspecific competition would have been reduced, thus allowing smaller species to flourish.

While it does not appear that coney at Bermuda require any specific management action at this time, the present study will provide the basis for monitoring and assessing the status of the population into the future.

LITERATURE CITED

Bardach, J.E., C.L. Smith, and D.W. Menzel. 1958. Bermuda fisheries research program final report, Bermuda Trade Development Board, Hamilton, Bermuda. 59 pp.

Beets, J., A. Friedlander, and W. Tobias. 1994. Stock analysis of coney in the U.S. Virgin Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* 43:403-416.

Brule, T., C. Deniel, T. Colas-Marrufo, and M. Sanchez-Crespo. 1999. Red grouper reproduction in the Southern Gulf of Mexico. *Transactions of the American Fisheries Society* 128:385-402.

Bullock, L.H. and M.D. Murphy. 1994. Aspects of the life history of the yellowmouth grouper, *Mycteroperca interstitialis,* in the eastern Gulf of Mexico. *Bulletin of Marine Science* 55(1):30-45.

Bullock, L.H., M.F. Godcharles, and R.E. Crabtree. 1996. Reproduction of yellowedge grouper, *Epinephelus flavolimbatus,* from the eastern Gulf of Mexico. *Bulletin of Marine Science* 59(1):216-224.

Chan, T.T.C. and Y. Sadovy. 2002. Reproductive biology, age and growth in the chocolate hind, *Cephalopholis boenak* (Bloch, 1790), in Hong Kong. *Marine and Freshwater Research* 53:791-803.

Colin, P.L. 1992. Reproduction of the Nassau grouper, *Epinephelus striatus* (Pisces: Serranidae) and its relationship to environmental conditions. *Environmental Biology of Fishes* 34:357-377.

Fennessy, S.T. and Y. Sadovy. 2002. Reproductive biology of a diandric protogynous hermaphrodite, the serranid *Epinephelus andersoni. Marine and Freshwater Research* 53:147-158.

Hinton, D.E. 1990. Histological techniques. Pages 191-211 in: C.B. Schreck and P.B. Moyle (eds.). *Methods for Fish Biology.* American Fisheries Society, Bethesda, Maryland USA. 684 pp.

Luckhurst, B.E. 1996. Trends in commercial fishery landings of groupers and snappers in Bermuda from 1975 to 1992 and associated fishery management issues. Pages 286-297 in: F. Arreguin-Sanchez, J.L Munro, M.C. Balgos and D. Pauly (eds.). *Biology, Fisheries and Culture of Tropical Groupers and Snappers.* ICLARM Conference Proceedings No. 48. 449 pp.

Luckhurst, B.E., J.M. Dean, and M. Reichert. 2000. Age, growth and reproduction of the lane snapper *Lutjanus synagris* (Pisces: Lutjanidae) at Bermuda. *Marine Ecology Progress Series* 203:255-261.

Mackie, M. 2000. Reproductive biology of the halfmoon grouper, *Epinephelus rivulatus,* at Ningaloo Reef, Western Australia. *Environmental Biology of Fishes* 57:363-376.

Marino, G., E. Azzurro, A. Massari, M.G. Finoia, and A. Mandich 2001. Reproduction in the dusky grouper from the southern Mediterranean. *Journal of Fish Biology* 58:909-927.

McGovern, J.C., D.M. Wyanski, O. Pashuk, C.S. Manooch III, and G.R. Sedberry. 1998. Changes in the sex ratio and size at maturity of gag, *Mycteroperca microlepis,* from the Atlantic coast of the southeastern United States during 1976-1995. *Fisheries Bulletin* 96:797-807.

Moe, M. 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 10:1-95.

Munro, J.L. and R. Thompson. 1978. Aspects of the biology and ecology of Caribbean reef fishes: Serranidae (hinds and groupers). *Journal of Fish Biology* 12:115-146.

Potts, J.C. and C.S. Manooch III. 1999. Observations on the age and growth of graysby and coney from the southeastern United States. *Transactions of the American Fisheries Society* 128(4):751-757

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. and D.Y. Shapiro. 1987. Criteria for the diagnosis of hermaphroditism in fishes. *Copeia* 1987(1):136-156.

Secor, D., E.H. Laban, and J.M. Dean. 1991. Manual for otolith removal and preparation for microstructural examination. Technical Publication 1991-01, Belle W. Baruch Institute for Marine Biology and Coastal Research, Columbia, South Carolina USA. 85 pp.

Shapiro, D.Y. 1987. Reproduction in groupers. Pages 295-327 in: J.J. Polovina and S. Ralston (eds) .*Tropical Snappers and Groupers: Biology and Fisheries Management.* Westview Press, Boulder, Colorado USA.

Shapiro, D.Y., Y. Sadovy, and M.A. McGehee. 1993. Periodicity of sex change and reproduction in the red hind, *Epinephelus guttatus,* a protogynous grouper. *Bulletin of Marine Science* 53(3):1151-1162.

Siau, Y. 1994. Population structure, reproduction and sex change in a tropical East Atlantic grouper. *Journal of Fish Biology* 44:205-211.

Smith, C.L. 1959. Hermaphroditism in some serranid fishes from Bermuda. *Papers of the Michigan Academy of Science Arts and Letters* 44:111-119.

Smith, C.L. 1965. The patterns of sexuality and the classification of serranid fishes. *American Museum Novitates* 2077:1-20.

BLANK PAGE

A Fecundity Study of Gag, *Mycteroperca microlepis* (Serranidae, Epinephelinae), from the Campeche Bank, Southern Gulf of Mexico

JORGE TREJO MARTÍNEZ, THIERRY BRULÉ, and TERESA COLÁS-MARRUFO
Centro de Investigación y de Estudios Avanzados del IPN Unidad Mérida
Antigua Carretera a Progreso Km. 6
A.P. 73 "Cordemex", C.P. 97310
Mérida, Yucatán, México

ABSTRACT

The gag grouper, *Mycteroperca microlepis,* is the third most commercialized serranid species in the southern Gulf of Mexico. However, production volumes and the current fishery status of the Campeche Bank's stock are uncertain. This study focuses on the fecundity of the specie, a novel contribution towards understanding its reproductive biology and also providing valuable information on the stock for the southern Gulf of Mexico. Females from the 212 analyzed ranged from 45 cm to 111 cm furcal length (FL). Gonads were fixed in Bouin's liquid for histological examination and Gilson's liquid for the measurement and quantification of oocytes. Gag is a multiple spawner with an indeterminate fecundity: no hiatus was observed between previtellogenic (20 – 119 µm) and vitellogenic oocytes (75.3 µm – 1015.5 µm) during its maturation and spawning periods. The oocyte size-frequency method determined stage V oocytes (211.7 – 509.3 µm) as the most advanced batch of oocytes. The minimum diameter limit established for stage V oocytes was recorded at 290 µm. Absolute batch fecundity estimates were based on females ranging from 72 to 105 cm FL sampled during April 1996 through August 1999. The maximum absolute batch fecundity estimate obtained was 4,270,250 ova for a female of 97 cm FL, with a minimum of 170,610 ova for a female of 72 cm. The average absolute batch fecundity was 1,649,675 ± 1,145,305 SD oocytes per female, a high variability which has also been observed for other grouper species, for example the red grouper, *Epinephelus morio*. The best predictor of absolute batch fecundity for *M. microlepis* from the Campeche Bank was gonad weight.

KEY WORDS: Fecundity, grouper, spawning, *Mycteroperca microlepis*

Fecundidad en la Cuna Aguají *Mycteroperca microlepis*, (Serranidae, Epinephelinae), del Banco de Campeche, sur del Golfo de México

El mero cuna aguají, *Mycteroperca microlepis,* es la tercera especie de serránido de importancia comercial en el sur del Golfo de México. Sin embargo, los volúmenes de su producción y el estado actual del stock del Banco de Campeche son inciertos. Este estudio estuvo enfocado en la estimación de la fecundidad de la especie, a efectos de conocer su biología reproductiva y proveer información sobre el stock del sur del Golfo de México. La longitud furcal (LF) de las hembras varió de 45 cm a 111cm para los 212 organismos analizadas. La cuna aguají, presenta desoves múltiples con una fecundidad indeterminada: durante los períodos de maduración y desove, no se observó ningún hiato entre los ovocitos previtelogénicos (20 – 119 µm) y los vitelogénicos (75.3 – 1015.5 µm). Los ovocitos del estadio V (211.7 – 509.3 µm) constituyeron el lote más avanzado. El límite del diámetro mínimo estimado para los ovocitos del estadio V fue 290 µm. La estimación de la fecundidad absoluta estuvo basada en hembras cuyas tallas fluctuaron entre 72 y los 105 cm LF, colectadas durante el periódo de abril de 1996 a agosto de 1999. La estimación de la fecundidad absoluta máxima por lote fue de 4,270,250 ovocitos para una hembra de 97 cm de LF con un mínimo de 170,160 ovocitos para una hembra de 72 cm de LF. La fecundidad absoluta promedio por lote estimada fue de 1,649,675 ± 1,145,305 SD ovocitos por hembra, presentando una alta variabilidad similar a la de otras especies de meros como por ejemplo el mero rojo, *Epinephelus morio*. El peso de la gónada fue considerado el mejor predictor de la fecundidad absoluta por lote para *M. microlepis* del Banco de Campeche.

PALABRAS CLAVES: Fecundidad, mero, desove, *Mycteroperca microlepis*

INTRODUCTION

The Yucatan Peninsula is a region characterized by its wide continental shelf, of which 50,000 square miles correspond to the Campeche Bank (Chávez 1994). This platform is also the most heavily fished grouper area, exploited both by inshore and offshore, commercial Mexican and Cuban fleets (Solís-Ramírez 1970, Arreguín-Sánchez et al. 1997). Yucatan's grouper landings comprised 91.5% of the entire national fishing grouper production in Mexico in 1995. The following year in this State 9,691 tons of groupers were landed, which comprised 90.5% of the total Mexican production of groupers (SEMARNAP 1997). From 1999 to 2000 grouper landings fluctuated between 10,125 tons and 11,045 (SAGARPA 2001). However, current grouper landings for the Yucatan State decreased to 8,182 tons in 2001 and 9,100 tons for 2002, indicating a decrease in production in recent years (SAGARPA 2002). Based on studies by Colás-Marrufo et al. (1998) and Tuz-Sulub (1999), 17 different species of groupers were identified for the Campeche Bank. Of these, the most important are the red grouper (*Epinephelus. morio*), the black grouper (*Mycteroperca bonaci*) and the gag grouper (*Mycteroperca microlepis*). However, the reproductive biology of reef fishery species has received remarkably little attention compared with other aspects of their natural history (Sadovy 1996).

Information on diverse aspects of the reproductive biology of a species is necessary in fishery regulations; for instance, in determining the minimum size of capture, seasons and/or zones for closed and open season (Tresierra and Culquichicon 1995). Fecundity relates to the number of eggs produced by a female and can be defined in many ways (Bagenal 1978, Kartas and Quignard 1984). Fecundity is a critical component of reproductive output and is included in stock assessments. It is evaluated in a number of ways but most commonly as total (standing stock of yolked oocytes), batch (number of hydrated oocytes released per spawning), and relative fecundities (fecundity divided by female weight) (Hunter et al. 1992, in Sadovy 1996). Fecundity influences population abundance, if the species abundance maintains itself more or less similar in time, it is expected to observe a similar proportion of the species from generation to generation (Tresierra and Culquichicon 1993).

Mycteroperca microlepis can be found in estuaries or seagrass beds for juveniles and in rocky bottoms for adults (Smith 1971, Vergara-Rodríguez 1976, Smith 1976, Bullock and Smith 1991, Heemstra and Randall 1993). Although studies have examined some aspects of gag reproduction, few have addressed fecundity. Currently for the Campeche Bank no analysis of fecundity has been done for *M. microlepis*. Therefore, due to this lack of information, the objective of the present study is to provide original data on the reproductive aspect for one of the most exploited groupers in Mexican waters for the Gulf of Mexico.

MATERIAL AND METHODS

Gag groupers collected for the present study were obtained from commercial catches carried out by fishing vessels from the port of Progreso, Yucatan. These catches were obtained monthly between April 1996 and August 1999, in 36 fishing sites located particularly in the eastern part of the Campeche Bank (Figure 1). Specimens were captured at depths of 30 to 120 m using long-line fishing gear. For each individual captured the following morphometric data were registered: furcal length (FL, in cm), taken from the extreme inferior mandible up to the middle posterior part of the caudal fin; total (ungutted) weight (TW, in g) and gutted (fish without digestive tract and gonads) weight (GW, in g).

Immediately following capture, gonads were extracted from all organisms and a sample was taken from the middle section of each one (approximately $1 cm^3$). These samples were fixed and conserved in Bouin's solution (Gabe 1968) and were thus used for histological observations. In the laboratory, weight of the gonads (gW) selected aboard vessels and conserved on ice, were recorded, including also, a fixed known sample weight (kW) between 20 and 30 g for each one placed in Gilson's liquid. These gonads were subsequently used in the counting of vitellogenic oocytes.

After fixing the gonads in Bouin, Gabe's (1968) classical histological technique was applied, which consists of the dehydration of the samples in 90% and 100% alcohol and embedding in paraffin at 58^0C. Sections of 6 micrometers (µm) in thickness were done using a semi-automatic microtome, finally, Gabe and Martoja's triple stain was applied before mounting these in a synthetic resin (60% Xylol) (Gabe, 1968).

Microscopic observations of the gonads collected confirmed the sex and sexual maturity class of the individuals captured. All female gonads were analyzed and classified according to sexual maturity categories, taking into consideration the evolutionary microscopic scale of stages in oogenesis proposed by Brulé et al. (1999; 2003) (Table 1). For this study, sexual classes defined by Brulé et al. (1999; 2003) were modified according to the criteria given in Table 2; females at resting, initial maturation, advanced maturation, spawning and postspawning.

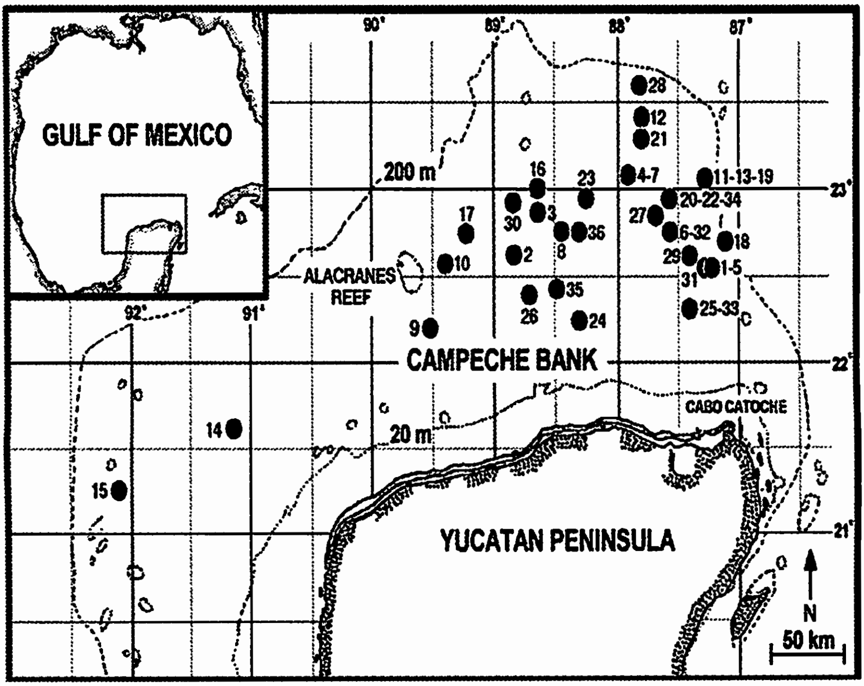


Figure 1. Geographic location of the Campeche Bank, in the Gulf of Mexico. Black round circles represent sampling sites for *M. microlepis.*

Relative frequencies for each stage of oogenesis present in the ovaries were determined using a methodology proposed by N'Da and Déniel (1993), so as to verify the fecundity pattern of the specie. This method requires, firstly, randomly counting and classifying 200 selected oocytes from histological sections pertaining to each female; done according to the oocyte microscopic scale of development (Table 1). Secondly, observations were made on a monthly basis for a year, following the relative percentages of each stage in oogenesis observed in the gonads.

Table 1. Microscopic characteristic stages in oogenesis for gag ovaries from the Campeche Bank (Brulé et al. 1999, 2003).

Stages in oogenesis	Microscopic characteristics
I. Primary oocyte	Nucleus with large central nucleus; nucleolus moves to the periphery of the nucleus during this stage
II. Immature oocyte	Nucleus with several nucleoli, one larger than the other, present around the nuclear periphery
III. Oocyte in primary vitellogenesis	Scattered vacuoles in cytoplasm around the nuclear margin and near the cellular periphery; thin zona radiata present
IV. Oocyte in early secondary vitellogenesis	Yolk droplets appear around vacuoles; cytoplasm divided in two concentric zones by a ring of yolk droplets filling <50% of the cellular volume; follicular layer well formed (granulosa, theca)
V. Oocyte in late secondary vitellogenesis	Yolk as numerous globules filling >50% of the cellular volume; vacuoles usually surround the nucleus and coalesce; migration of the nucleus to the animal pole in late stage; zona radiata remains as a broad striated band
VI. Hyaline oocyte	Oocyte hydrated; yolk as an homogeneous mass, lightly stained; thin and no striated zona radiata; nucleus not visible

Table 2. Characteristic histological patterns for sexual maturity classes as defined for gag females from the Campeche Bank (modified from Brulé et al. 1999).

Sexual maturity classes	Histological characteristics
1. Resting	Previtellogenic oocytes (stages I & II)
2. Initial maturation	Previtellogenic oocytes (stages I & II) Oocytes in primary vitellogenesis (stage III) Atretic oocytes scarce
3. Advance maturation	Previtellogenic oocytes (stages I & II) Oocytes in primary vitellogenesis (stage III) Oocytes in early and late secondary vitellogenesis (stages IV & V) Atretic oocytes present (At)
4. Spawning (partial)	Previtellogenic oocytes (stages I & II) Oocytes in primary vitellogenesis (stage III) Oocytes in early and late secondary vitellogenesis (stages IV & V) Hyaline oocytes (VI) and/or presence of postovulatory follicles (Pofs) Atretic oocytes present (At)
5. Postspawning (end of spawning)	Previtellogenic oocytes (stages I & II) Oocytes in primary vitellogenesis (stage III) and/or early and late secondary vitellogenesis (stages IV & V) residuals Numerous atretic oocytes present (At)

Due to an insufficient number of females with hyaline oocytes (stage VI), absolute batch fecundity was estimated using the egg-size frequency method of Hunter, et al. (1985) and Hunter and Macewicz (1985), respectively. As a result only stage V oocytes were used for absolute batch fecundity estimations. Using the following functions both absolute and relative batch fecundities were calculated, (Bagenal and Braum, 1978):

$$AF_{batch} = n \times \frac{A}{a} \times \frac{gW}{kW} \quad (1)$$

$$RF_{batch} = n \times \frac{A}{a} \times \frac{gW}{kW \times GW} \quad (2)$$

Where *AF* is the absolute batch fecundity, *RF* the relative fecundity, *n* the average number of hyaline or vitellogenic oocytes in both sub-samples of the ovary, *A* the volume of oocytes-water mixture (ml) in the ovary sample, *a* the volume of oocytes-water mixture (ml) of the ovary sub-sample, *gW* the weight of the gonad (g), *kW* the weight of the ovary sample (g), and *GW* the gutted weight of fish (g). Consequently absolute batch fecundity was regressed on *FL*, *gW* and *GW*.

RESULTS

Sex Identification and Length Frequency Distribution

From the total number (n = 212) of gag analyzed, histological examinations revealed that 75% (n = 161) individuals were females (Table 3) ranging in size from 45 to 111 cm TL (Figure 2). All females were considered in the analysis of the pattern of fecundity for the species, and 18 for estimating batch fecundity as a preliminary result on the fecundity of the gag stock from the southern Gulf of Mexico.

Oocyte Stage Diameters

Oocyte diameters of the six microscopic stages of oogenesis were determined. Stages I and II oocytes were classified as previtellogenic oocytes, and stages III to VI oocytes as vitellogenic oocytes (Table 1). Results are presented in Table 4.

Relative Percentage Frequency of Oocyte Stages

A qualitative analysis was performed for each female (n = 161) to determine the pattern of fecundity. The relative frequencies of the different stages of oocyte development observed during the annual sexual cycle of female gag are presented in Figure 3. Females presenting similar patterns of oocyte distribution, that is, with respect to oocyte stages were combined monthly in the same histogram (Figure 3). Following the aspect of the histograms and based on the criteria presented in Table 1, females were classified according to the five sexual classes defined in Table 2.

From June to September females were observed in a resting stage. In the following months (October to March), females were classified as being in an initial and/or advanced maturation stage. From January, to April, females were classified to be in spawning condition. Finally, from February to May females were in a state of postspawning.

Table 3. Total number of *M. microlepis* females used in histological examinations captured in offshore waters off the Campeche Bank, between April 1996 and August 1999.

	Females			
Month	**1996**	**1997**	**1998**	**1999**
Jan	-	3	19	-
Feb	-	3	11	-
Mar	-	-	3	2
Apr	5	-	-	7
May	8	1	1	11
Jun	-	6	8	-
Jul	-	11	6	-
Aug	-	15	4	1
Sept	-	7	-	-
Oct	-	12	-	-
Nov	1	6	-	-
Dec	3	7	-	-
Total = 161	17	71	52	21

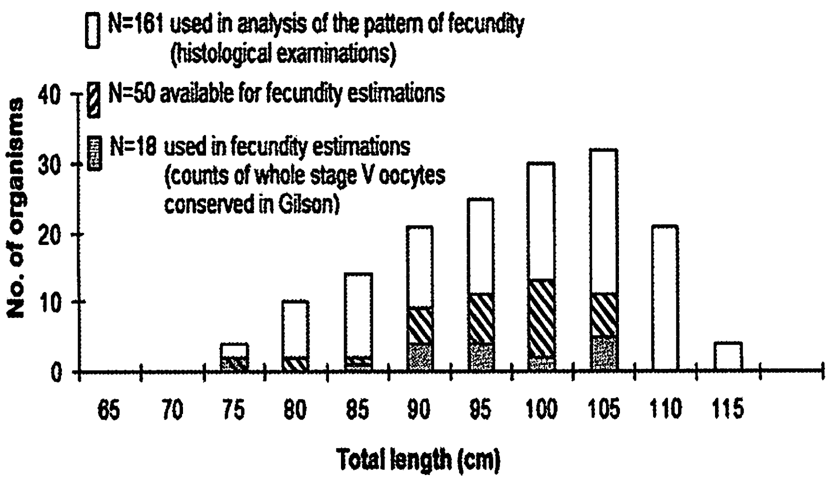


Figure 2. Frequency distributions of female lengths for gag *M. microlepis* from the Campeche Bank

Table 4. Average minimum and maximum diameter values (μm) of oocytes representative of the different stages in oogenesis. SD = Standard deviation. Diameter measurements were done from whole oocytes, freshly acquired from females that were collected.

Stage	Average ± SD (μm)	Oocyte diameters (μm) Range	
		Min	Max
Primary oocyte I & Immature oocyte II	68.5 ± 22.1	20.0	119.5
Oocyte in primary vitellogenesis III	136.6 ± 26.6	75.3	190.1
Oocyte in early secondary vitellogenesis IV	211.9 ± 29.1	159.3	296.6
Oocyte in late secondary vitellogenesis V	387 ± 59.5	211.7	509.3
Hyaline Oocytes VI*	920.5 ± 58.3	737.1	1051.1

During maturation and spawning periods, gag females presented in their ovaries two main groups of oocytes:

i) A reservoir of previtellogenic oocytes with:
   Primary oocytes (stage I)
   Immature oocytes (stage II)

ii) A group of vitellogenic oocytes destined for the stock with:
   Oocytes in primary vitellogenesis (stage III)
   Oocytes in initial secondary vitellogenesis (stage IV)
   Oocytes in late secondary vitellogenesis (stage V)
   Hyaline oocytes (VI)

From the histograms obtained during these periods of the sexual cycle of gag (Figure 3), no gap or hiatus was observed in the frequency distribution of oocyte stages between small previtellogenic oocytes (I and II) and large vitellogenic oocytes (III, IV, V, and VI). A continuous production of vitellogenic oocytes from the reservoir of previtellogenic was observed during the entire maturation and spawning periods of the species.

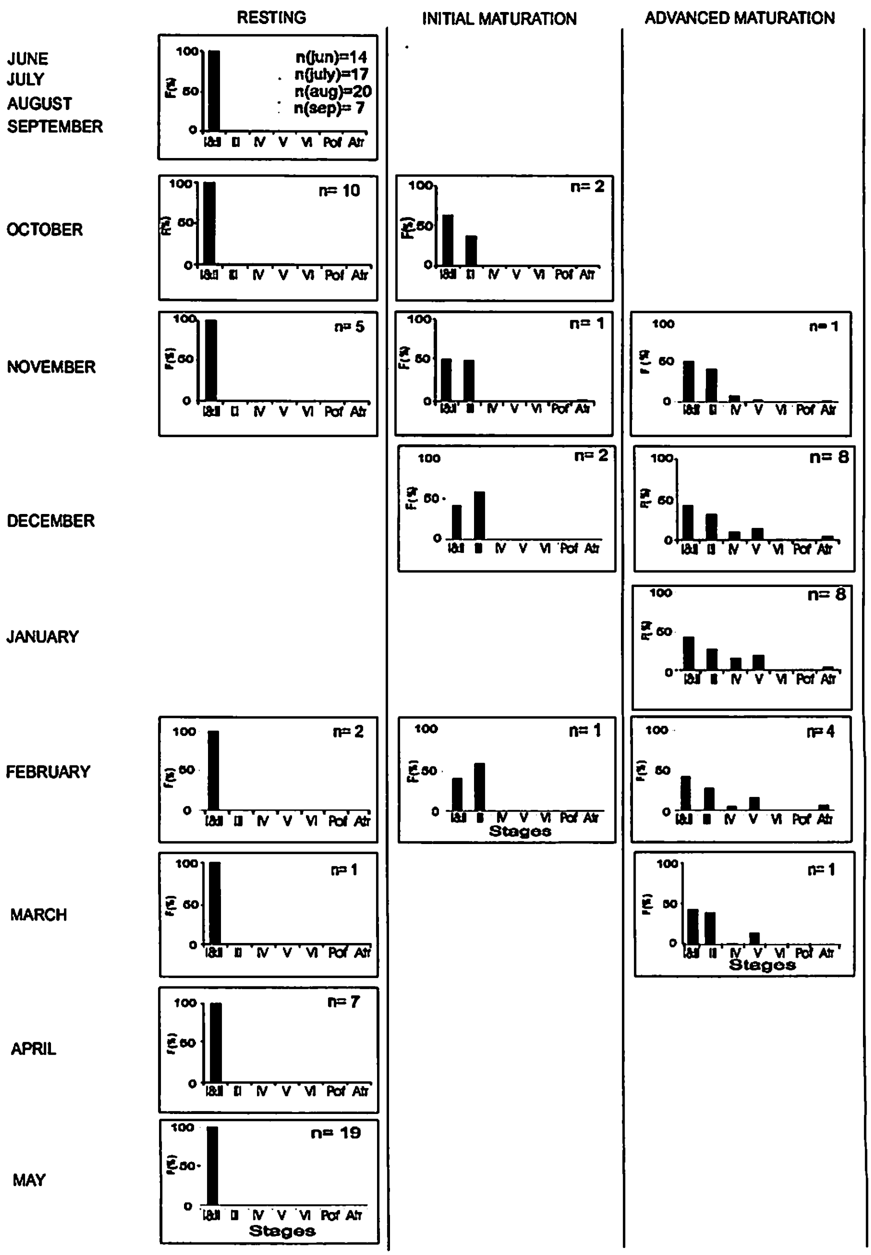


Figure 3. Evolution of the relative frequencies for the stages of oogenesis during the sexual cycle of *M. microlepis* from the Campeche Bank.

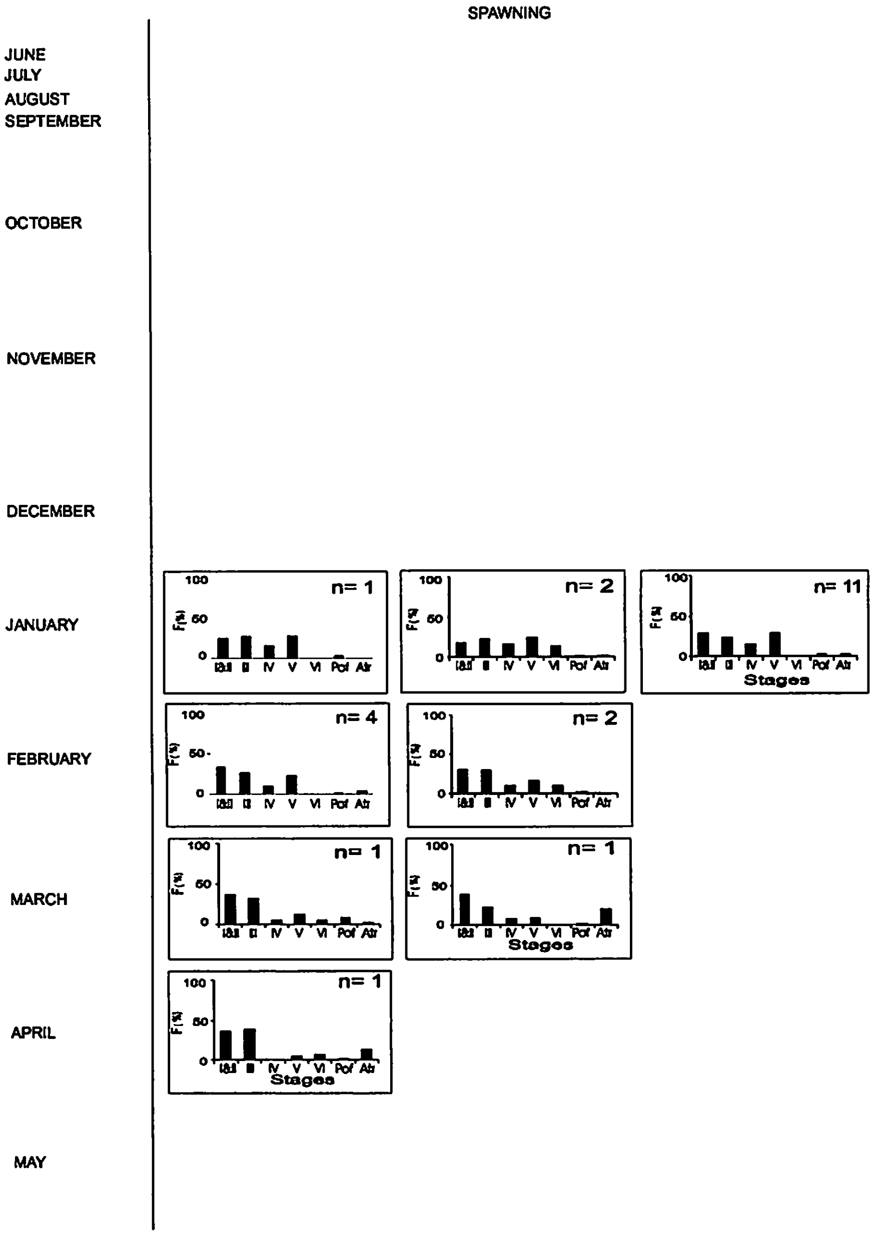


Figure 3. (continued)

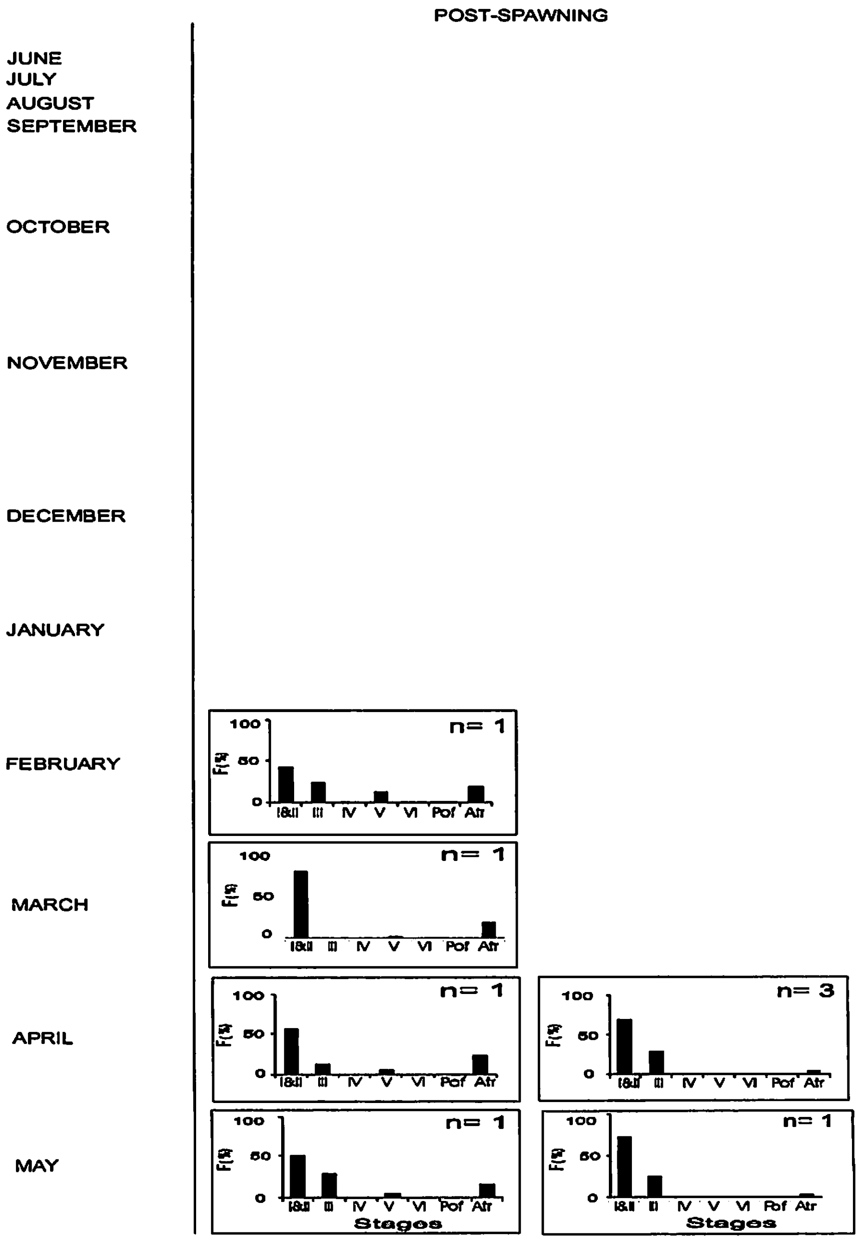


Figure 3. (continued)

Estimating Batch Fecundity

Diameter limits for stage V oocytes — Frequency distribution histograms of whole oocytes conserved in Gilson and obtained from ovaries of four selected females in spawning condition showed a multimodal distribution (Figure 4). Stage V was determined as the most advanced batch of oocytes required for batch fecundity estimates.

An evident overlap was observed between the largest diameter measurements recorded for stage IV oocytes and the smallest diameter measurements recorded for stage V oocytes (Figure 4). The occurrence of such an overlap made it necessary to establish a minimum diameter limit for stage V oocytes, recorded at 290 µm (Figure 5). All oocytes having diameters equal to, or above this value, not exceeding the maximum diameter established for stage V (509.3 µm), were considered in the quantitative estimation of batch fecundity.

The highlighted arrows clearly indicate that there is no gap or hiatus found between the size frequency distribution of stage I/II previtellogenic oocytes and stage III vitellogenic oocytes (Figure 4). This strongly confirms the pattern of fecundity analyzed through the distribution of the stages in oogenesis (Figure 3) during the sexual cycle of the species.

Absolute and Relative Batch Fecundities

Estimates of absolute and relative batch fecundities were analyzed for a total of 18 females of *M. microlepis* ranging from 72 to 105 cm FL and in weight from 4,950 to 14,350 g TW. Minimum and maximum fecundity estimates for this study are displayed in Table 4. Regression analysis showed significant positive linear correlations between absolute batch fecundity estimates (AF_{batch}) FL, TW, GW and gW. The gonad weight was the best predictor of absolute batch fecundity (Figure 6; AF_{batch}; r^2 = 0.7983, p < 0.0000).

Table 4. Average minimum and maximum diameter values (µm) of oocytes representative of the different stages in oogenesis. SD= Standard deviation. Diameter requirements were done from whole oocytes, freshly acquired from females that were collected

Stage	Average ± SD (µm)	Oocyte diameters (µm) Range Min	Oocyte diameters (µm) Range Max
Primary oocyte I & Immature oocyte II	68.5 ± 22.1	20.0	119.5
Oocyte in primary vitellogenesis III	136.6 ± 26.6	75.3	190.1
Oocyte in early secondary vitellogenesis IV	211.9 ± 29.1	159.3	296.6
Oocyte in late secondary vitellogenesis V	387 ± 59.5	211.7	509.3
Hyaline Oocytes VI*	920.5 ± 58.3	737.1	1051.1

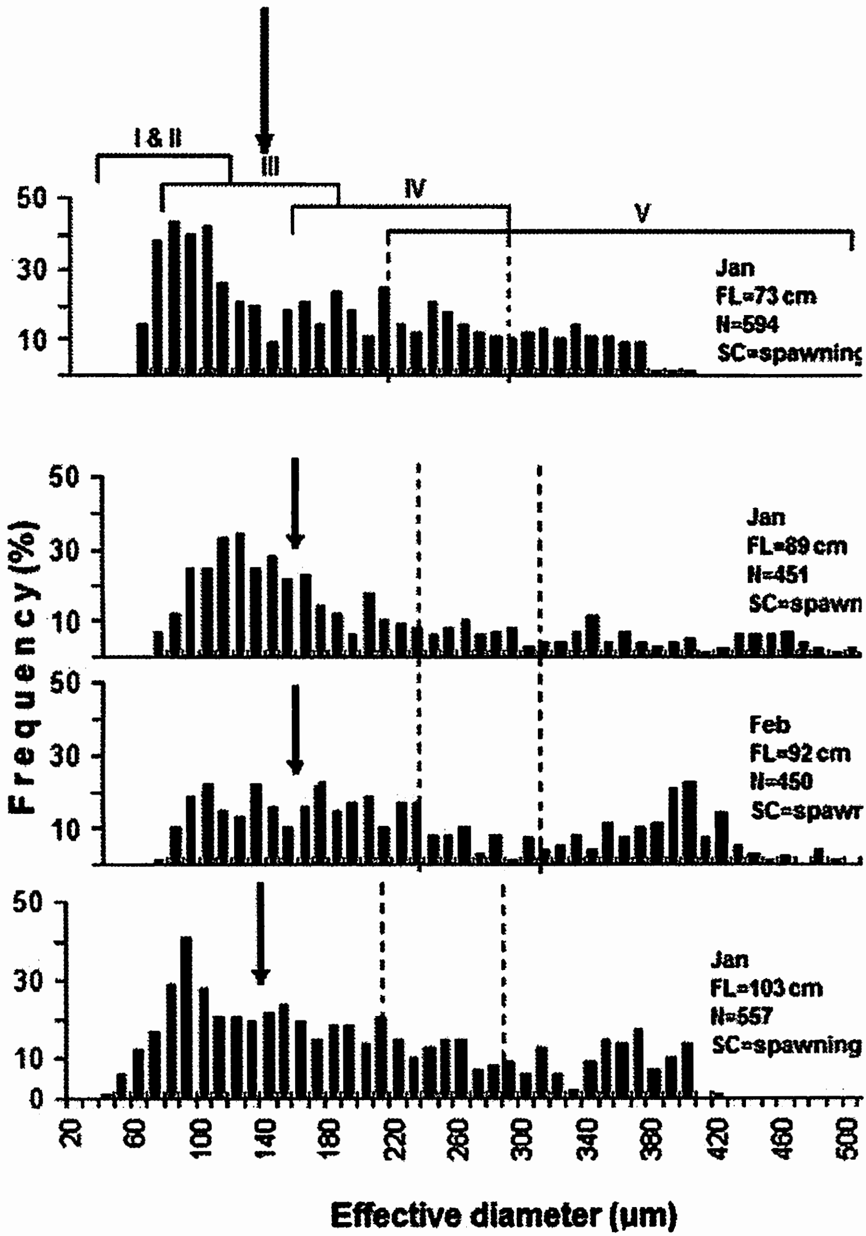


Figure 4. Histograms of diameter frequency distribution obtained through measurements of whole oocytes separated and conserved in Gilson's liquid, for four females from the Campeche Bank. FL= furcal length; N= number of oocytes measured; SC= sexual class.

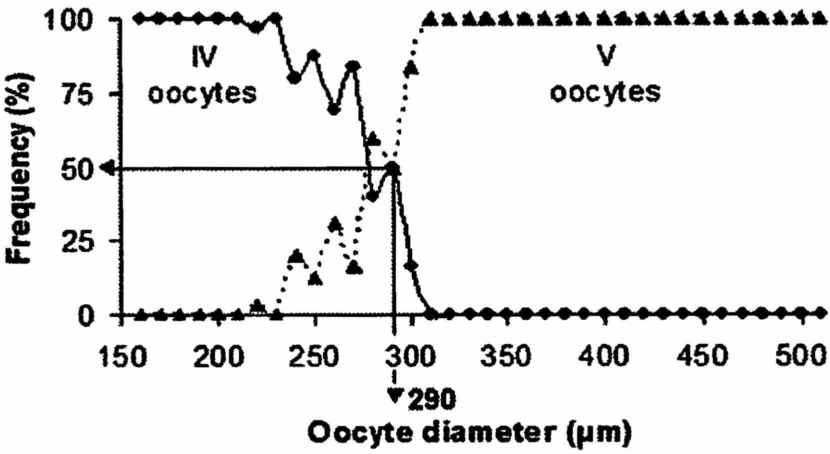


Figure 5. Minimum diameter of stage V oocytes considered for batch fecundity estimates obtained through histological examination of ovaries of female gag *M. microlepis* from the Campeche Bank.

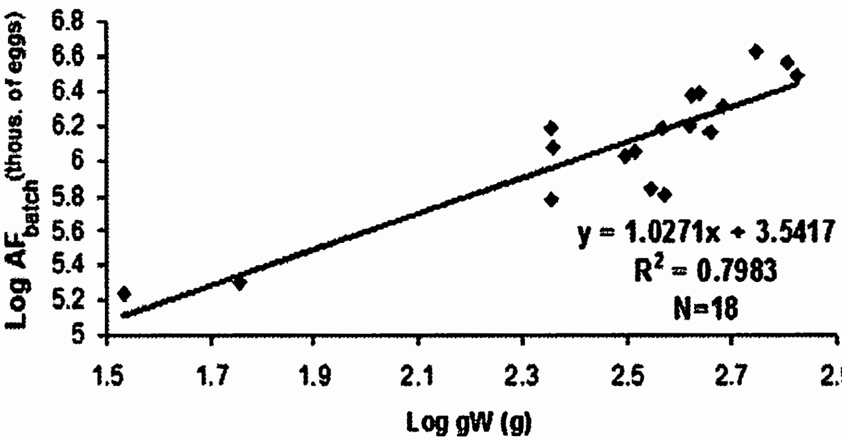


Figure 6. Relationship between log absolute batch fecundity - log female gonad weight for *M. microlepis* from the Campeche Bank.

DISCUSSION

Fecundity is usually defined as the number of ripening eggs found in the female just prior to spawning (Bagenal, 1978). As mentioned before, this biological aspect is a critical component of reproduction output and is included in stock assessments. Despite the importance of estimating fecundity, little reliable information is available for tropical fishes.

The traditional evidence for determinate fecundity is the presence of a major gap (hiatus) in oocyte maturity stages or size classes between the oocytes matured for the season and the reservoir of immature oocytes present year-round in the ovary (Yamamoto 1956, in Hunter and Macewicz 1985). The presence of such a gap in oocyte classes in females taken at the beginning of the season seems to be adequate proof that the standing stock of oocytes is a measure of maximum annual fecundity, as long as the gap is not between a batch of hydrated oocytes and other yolked oocytes.

The absence of such a discontinuity in oocyte classes is evidence for indeterminate fecundity. A continuous distribution of vitellogenic oocytes were observed during maturation and the spawning periods from histograms of diameter frequency distribution obtained from histological examination of oocytes; no apparent presence of a hiatus. The relative percentage frequencies calculated for females (n = 161) provided a qualitative analysis of the succession in maturation stages during the sexual cycle of the species, from females resting to females at post-spawning.

Histograms of diameter frequency distribution obtained through the volumetric method (whole vitellogenic oocytes), determined also a continuous distribution of diameters beginning with oocytes at the previtellogenic stages, I and II to the vitellogenic stage V of oogenesis. These results along with those obtained from histological examinations and relative percentage frequencies appear to be similar in nature.

The presence of distinct clusters of oocytes of various diameters and stages of development (including stage I and stage II oocytes) in gag ovaries throughout maturation and spawning periods, indicated that this species is a multiple-indeterminate spawner (batch spawner) with an indeterminate fecundity. These spawning and fecundity pattern characteristics displayed by gag from the Campeche Bank are similar to the results obtained by Collins et al. (1998) for a gag stock from the northeastern Gulf of Mexico and Koenig et al. (1996) for a gag stock from the eastern Gulf of Mexico.

In multiple-spawning fish species with indeterminate annual fecundity, the only useful fecundity measurement is the number of eggs produced in a single spawning batch (batch fecundity) (Hunter et al. 1985). The present study uses the volumetric method to estimate batch fecundity. According to Hunter et al. (1985), the volumetric method may be used in batch fecundity estimates if the eggs constituting the batch are identified using the oocyte size-frequency method.

However, gag samples for the Campeche Bank displayed an insufficient number of females with hyaline oocytes. Thus, for batch fecundity estimates in the present study the more time-consuming oocyte size-frequency distribution method was applied (Macgregor in Hunter et al. 1985). In this method, a size frequency distribution of oocytes was constructed and the most advanced modal group of oocyte size classes (mode composed of the largest oocytes) was determined by inspection.

This method usually gives results similar to those based on counts of hyaline oocytes if females with highly advanced oocytes are used (Hunter and Goldberg 1980, Laroche and Richardson 1980, in Hunter et al. 1985).

This methodology was also applied by Ganias et al. (2004) for the Mediterranean sardine. These authors stated that, at least for the Mediterranean sardine, simple identification of tertiary and migratory nucleus stages by microscopic examination of whole oocytes and their subsequent use in batch fecundity analysis may possibly offer a low-cost alternative to the hydrated oocyte method.

An indeterminate fecundity pattern along with the most advanced batch of vitellogenic stage V oocytes present in the ovaries of female gag allowed the estimation of absolute fecundity. Absolute batch fecundity estimates (n = 18) for the present study ranged from 170,610 to 4,270,250 stage V oocytes. These estimates came from gag 72 - 97 cm FL; 4,950 -12,300 g TW; and 34.09 - 555.7 g gW. Collins et al. (1998) report batch fecundity estimates (n = 39), for gag females from the northeastern Gulf of Mexico ranging between 10,864 and 865,295 hyaline oocytes; 69.0 – 106.5 cm FL; 4500 – 16,500 g TW; 23.4 - 871.9 g gW.

Due to the fact that fecundity is highly variable both within species and between years (Bagenal 1978), its estimation requires wide size ranges of individuals and clear explanations of methods. Consideration is also necessary of factors that may curtail potential fecundity such as parasitism and oocyte atresia (resorption of eggs prior to spawning) (Sadovy 1996).

The causes of variations in fish fecundity are also related to population density, temperature, food supply, stress, and other environmental effects (Bagenal 1978). This therefore, probably explains the possible fluctuations in fecundity estimates obtained by different authors for the same species from different regions.

There were significant positive linear relationships between absolute batch fecundity estimates (AF_{batch}) and FL, GW, TW, and gW. The best predictor of batch fecundity was gonad weight. This does not concur with results obtained by Bagenal and Braum (1978) and Snyder (1992), who proposed that length, is the best predictor of fecundity rather than fish weight or gonad weight. Bagenal (1978) stated that a close relationship is usually found between fecundity and length. This author pointed out that the length of a given fish does not change significantly as much as that of its weight. For example, the somatic weight changes significantly towards spawning.

However, Collins et al. (1998) also show that along with length, age, and gutted body weight, express positive linear correlations towards batch fecundity estimates. Other authors (Ludwig and Lange 1975) in Bagenal (1978) proposed a statistical model using age-length interaction which was more predictive of fecundity than length alone with Northern mottled sculpins, *Cottus bairdi*.

Collins et al. (2002) also obtained absolute batch fecundity estimates for a red grouper, *Epinephelus morio,* stock from the eastern Gulf of Mexico ranging between 24,300 to 2,322,517 hydrated oocytes. Absolute batch fecundity estimates obtained for a tropical species population, the red snapper, *Lutjanus campechanus,* from the northeastern Gulf of Mexico, ranged from 458 to 1,704,736 hydrated oocytes (Collins et al. 1996). The present study provides similar results as compared to those obtained by the above authors, with absolute batch fecundity estimates ranging from 197,400 to 4,270,250 stage V oocytes.

Gag is suspected to migrate to spawning sites in the Gulf; however, no direct observations have been documented on these aggregations. Spawning migrations are implied from the consistent annual timing and location of the aggregations, as reported by Koenig et al. (1996).

Groupers exhibit complexities of reproductive biology that make them particularly susceptible to over-fishing such as hermaphroditism and spawning aggregations. Gag is known as a protogynous hermaphrodite and possibly exhibits spawning aggregations as mentioned previously. Hence, this species is vulnerable to heavy fishing activity. McGovern et al. (1998) reported that changes in life history aspects of gag from the Gulf of Mexico were attributed to steadily increasing fishing pressure.

However, little information is available on the reproductive output and production volumes for gag from the Campeche Bank. As reported, gag represents one of three commercially important serranid species heavily exploited in the southern Gulf of Mexico (Colás Marrufo et al. 1998) and is considered a highly fecund species according to Sadovy (2001). Thus, there is no doubt that efficient fishery regulations must be set in place by the proper authorities to monitor, manage, and conserve gag populations in the southern Gulf of Mexico. Mace and Hudson (1996), in Sadovy (2001) state that it is critical for conservation biologists and fishery managers to collaborate, for despite differences in perspectives, extinction in the case of conservation biologists and sustainability for fishery managers, there is much common ground.

Nevertheless, evidence for batch or multiple spawning is derived from direct observations of repeated spawning of individually identified females or through indirect methods, such as macroscopic examination of eggs (oocytes) size, and stages in development (Sadovy 1996). Direct observations are difficult, and assessment of spawning frequency is further complicated at least in some long-lived species; for example individual adults of *M. microlepis* may not spawn every year (Sadovy 1996).

Sadovy (1996) also mentioned that for indeterminate multiple spawning species the assessment of potential annual egg output is fraught with difficulties because it requires knowledge both of the number of eggs produced each time a female spawns, and the number of times it spawns per year.

LITERATURE CITED

Arreguín-Sánchez, F., M. Contreras, V. Moreno, R. Valdés, and R. Burgos 1997. La pesquería de mero (*Epinephelus morio*) de la Sonda de Campeche, México. Pages 307-332 in: D. Flores-Hernandez, P. Sanchez-Gil, J.C. Seijo and F. Arrequín- Sánchez (eds.). *Análisis y Diagnóstico de los Recursos Pesqueros Críticos del Golfo de México*. Universidad Autónoma de Campeche. EPOMEX Serie Científica, 7. 496 pp.

Bagenal, T.B. 1978. Aspects of fish fecundity. Pages 77-101 in: S.D. Gerking (ed.). *Methods for Assessment of Fish Production in Fresh Waters.* Blackwell Scientific Publications, Oxford, England.

Bagenal, T.B. and E. Braum. 1978. Eggs and early life history. pp. 165 – 201 in: T.B. Bagenal (ed.). *Methods for Assessment of Fish Production in Fresh Waters.* Blackwell Scientific Publications, Oxford, England.

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.

Brulé, T., C. Déniel, T. Colas-Marrufo, and X. Renan. 2003. Reproductive biology of gag in the southern Gulf of Mexico. *Journal of Fish Biology* **63**:1505-1520.

Bullock, L.H., and G.B. Smith. 1991. Seabasses (Pisces: Serranidae). *Proceedings of the Hourglass Cruises* **8**:2.

Chávez, E. A. 1994. Los recursos marinos de la Península de Yucatán. Pages 1-2 in: A. Yañez- Arancibia (ed.). *Recursos Faunísticos del Litoral de la Península de Yucatán.* Universidad Autonoma de Campeche. *EPOMEX Serie Científica* 2. 136 pp.

Colás-Marrufo, T., T. Brulé, and 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.

Collins, L.A., A.G. Johnson, and C.P. Keim. 1996. Spawning and annual fecundity of red snapper (*Lutjanus campechanus*) from the northeastern Gulf of Mexico. Pages 174-188 in: F. Arreguín-Sánchez, J.L. Munro, M.C. Balgos, and D. Pauly (eds.). *Biology, Fisheries and Culture of Tropical Groupers and Snappers.* ICLARM Conference Proceedings 48. Manila, Philippines. 449 pp.

Collins L.A., A. G. Johnson, C.C. Koenig, and M.S. Baker Jr. 1998. Reproductive patterns, sex ratio, and fecundity in gag, *Mycteroperca microlepis* (Serranidae), a protogynous grouper from the northeastern *Gulf of Mexico Fisheries Bulletin* **96**:415-427.

Collins, L.A., G.R. Fitzhugh, L.A. Lombardi-Carlson, H.M. Lyon, W.T. Walling, and D.W. Oliver. 2002. Characterization of red grouper (Serranidae: *Epinephelus morio*) reproduction from the eastern Gulf of Mexico. NMFS. SFSC: Contribution Series 2002-07.

Gabe, M. 1968. *Techniques Histologiques*. Masson et Cie (ed.). Paris, France. 1113 pp.

Ganias, K., S. Somarakis, A. Machias, and A. Theodorou. 2003. Pattern of oocyte development and batch fecundity in the Mediterranean sardine. *Elsevier Scientific Fisheries Research* **67**:13-23.

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.* FAO Fisheries Synopsis No. 126 Vol. 16. FAO, Rome, Italy.

Hunter, J.R., N.C.H. LO, and R.J.H. Leong, 1985. Batch fecundity in multiple spawning fishes. Pages 67-77 in: R. Lasker (ed.), *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax.* U.S. Department of Commerce, NOAA Technical Report NMFS 36.

Hunter, J.R. and B.J. Macewicz. 1985. Measurement of spawning frequency in multiple spawning fishes. Pages 79-94 in: R. Lasker (ed.). *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax.* U.S. Department of Commerce, NOAA Technical Report NMFS 36.

Sadovy, Y. 1996. Reproduction of reef fishery species. Pages 15-59. in: N.V. C. Polunin and C.M. Roberts (eds.). *Reef Fisheries.* Chapman and Hall, London, England.

Kartas, F. and J.P. Quignard. 1984. La fécondité des poissons téléostéens. Collection de Biologie des Milieux Marins 5 Masson, Paris, France. 121 pp.

Koenig, C.C., F.C. Coleman, L.A. Collins, Y. Sadovy and P.L. Colin. 1996. Reproduction in gag (*Mycteroperca microlepis*) (Pisces: Serranidae) in the Eastern Gulf of Mexico and the consequences of fishing spawning aggregations. Pages 307-323 in: F. Arreguín-Sánchez, J.L. Munro, M.C. Balgos, and D. Pauly (eds.). *Biology, Fisheries and Culture of Tropical Groupers and Snappers.* ICLARM Conference Proceedings 48, Manila, Philippines. 449 pp.

Laroche, J.L. and S.L. Richardson. 1980. Reproduction of northern anchovy, *Engraulis mordax*, off Oregon and Washington. Pages 67-77:in J.R. Hunter, N.C.H. LO, and R.J.H. Leong, 1985. Batch fecundity in multiple spawning fishes. in: R. Lasker (ed.). *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax.* U.S. Department of Commerce, NOAA Technical Report NMFS 36.

Ludwig, G.M. and E.L. Lange. 1975. The relationship of length, age, and age-length interaction to the fecundity of the northern sculpin *Cottus bairdi.* Pages 77-101 in: S. D. Gerking (ed.). *Aspects of Fish Fecundity.* Blackwell Scientific Publications, Oxford, England.

Mace, G.M. and E.J. Hudson. 1999. Attitudes toward sustainability and extinction. *Conservation Biology* **13**:242-246.

McGovern, J.C., D.M. Wyanski, O. Pashuk, C.S. Manooch II, and G.R. Sedberry. 1998. Changes in the sex ratio and size at maturity of gag, *Mycteroperca microlepis,* from the Atlantic coast of the southeastern United States during 1976-1995. *Fisheries Bulletin* **96**:797-807.

MacGregor J.S. 1957. Fecundity of the Pacific sardine (*Sardinops caerulea*). Pages 67-77 in: R. Lasker (ed.). *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax*. U.S. Department of Commerce, NOAA Technical Report NMFS 36.

N'Da, K., and C. Déniel, 1993. Sexual cycle and seasonal changes in the ovary of the red mullet, *Mullus surmuletus*, from the southern coast of Brittany. *Journal of Fish Biology* **43**:229-244.

Sadovy, Y. 1996. Reproduction of reef fishery species. Pages 15-59 in: N.V.C. Polunin and C.M. Roberts (eds.). *Reef Fisheries*. Chapman and Hall, London, England.

Sadovy, Y. 2001. The threat of fishing to highly fecund fishes. *Journal of Fish Biology* **59**:90-108.

SAGARPA 2001. *Anuario Estadístico de Pesca 2000*. México D.F. 268 pp.

SAGARPA 2002. Anuario estadístico de pesca 2002. México D.F. http://www.sagarpa.gob.mx.

SEMARNAP 1997. (Secretaría de Medio Ambiente, Recursos Naturales y Pesca). Anuario estadístico de pesca 1996. SEMARNAP, México City. 241 pp.

Smith, C.L. 1971. A revision of the American grouper: *Epinephelus* and allied genera. *Bulletin of the American Museum of Natural History* **142**:67-241.

Smith G.B. 1976. Ecology and distribution of Eastern Gulf of Mexico reef fishes. Florida Marine Research Publications No:19 pp.

Snyder, D.E. 1992. Fish eggs and larvae. Pages 165-197 in: L.A. Nielsen and D.L. Johnson (eds.). *Fisheries Techniques*. American Fisheries Society, Bethesda, Maryland USA.

Solís-Ramírez, M. 1970. The red grouper fishery of Yucatán Peninsula, Mexico. *Proceedings of the Gulf and Caribbean Fisheries Institute* **22**:122-129.

Tresierra, A. A., and Z. Culquichicón. 1993. Biología Pesquera. Editorial Libertad. Trujillo – Perú. 232 – 250 pp.

Tresierra, A. A., and Z. Culquichicón. 1995. Manual de Biología Pesquera. Trujillo – Perú. 56 – 68 Pp.

Tuz-Sulub, A.N. 1999. Composición, distribución e importancia pesquera de los serranidos (subfamilia: Epinephelinae) en el Banco de Campeche Yucatán, México. Tesis de Licenciatura, Universidad Autónoma de Yucatán, Mérida, México. 77pp.

Vergara-Rodríguez, R. 1976. Nuevos registros para la ictiofauna cubana. III. *Poeyana* **150**:1-7.

Yamamoto, K. 1956. Studies on the formation of fish eggs. I. Annual cycle in the development of ovarian eggs in the flounder, *Liopsetta obscura*. Pages 79-94 in: Lasker (ed.). *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax*. U.S. Department of Commerce, NOAA Technical Report NMFS 36.

BLANK PAGE

Lessons Learned from Measuring Ageing Precision of Simulated Fish Populations

RICHARD S. MCBRIDE, KRISTIN L. MAKI, and JANAKA DE SILVA
Florida Fish & Wildlife Conservation Commission
Fish & Wildlife Research Institute
100 Eighth Avenue SE
St. Petersburg, Florida 33701-5095 USA

ABSTRACT

When ages of fish are estimated via examination of their hardparts (i.e., otoliths, scales, rays, etc.), the precision (i.e., reproducibility) of those age estimates can be measured in several ways. Percent precision in our study represents the percent of replicated age estimates (i.e., for the same fish) that agree exactly or within some appropriately narrow age range (e.g., ± 1 year). The average percent error and coefficient of variation are slightly different formulas designed to express the uncertainty of the average estimated age. One (two, or even all three) of these measures can be calculated for many fish to develop an index (or indices) of precision, which is used to evaluate the consistency for which ages have been estimated within a sample of fish. The correlation coefficient can also be used to measure the association between replicate ages for a sample of fish. All four measures may be used to evaluate use of a particular hard part or preparation technique to age fish or to compare the 'ease' of ageing one species versus another. The use of these measures is problematic for a variety of reasons, as has been shown for a number of "real" data sets from fishery labs. We used a simulated data set with different levels of variance to evaluate the utility of these four measures of precision. Using simulated data with known patterns of precision and bias that represent a number of anticipated scenarios has been missing in the discussion of the relative efficacy of these different measures of precision.

KEY WORDS: Age and growth, ageing error, precision

Las Lecciones Aprendidas de la Medición de Edad Precisas para Poblaciones Simuladas de Pescados

La precisión de estimaciones de edad para un solo pez, cuando estimado con diferentes estructuras biológicas (como otoliths, escalas, rayos de aleta, etc.), puede ser medido en maneras diferentes. El porcentaje de acuerdo es el por ciento de las estimaciones de edad replicadas que concuerdan exactamente o dentro de algún estrecha apropiadamente la gama de la edad (por ejemplo, ± 1 año). El promedio por ciento error y coeficiente de la variación son fórmulas diferentes diseñado para ajustar una variación por el promedio edad evaluada. Uno (dos o todos los tres) de estas medidas es promediado a través de muchos pescados para desarrollar un índice (o los índices) de la precisión, que se utiliza para evaluar la consistencia de edades estimadas dentro de una muestra de pescados. El coeficiente de la correlación se puede utilizar también para medir la asociación entre las edades replicadas para una muestra de pescados. Las cuatro medidas se pueden utilizar para evaluar una estructura biológica particular o diferentes técnicas de preparación para comparar 'la comodidad' de envejecimiento de una especie contra otro. El uso de estas medidas es problemático para una variedad de razones, como ha sido mostrado para varios conjuntos de datos de laboratorios de pesquería. Usamos un iueso de datos simulado con diferentes nievales de variación para evalúar completamente la utilidad de estas cuatro medidas de la precisión. Este enfoque – utilizando los datos simulados con pautas conocidas de la precisión y la tendencia que representan varios guiones anticipados – no ha tenido la discusión de la eficacia relativa de estas medidas diferentes de la precision.

PALABRAS CLAVES: La precisión de estimaciones, pescados

INTRODUCTION

Ageing of fish is a remarkably routine enterprise today. The most common method of ageing fish involves examining biological hardparts, particularly scales and otoliths, for bands that are laid down at regular time intervals (Campana and Thorrold 2001, Campana 2001). Confidence in age estimates determined via these methods is built by validating each method and using regular quality-control procedures to check for process errors and observation errors. Process error occurs when the selected hardpart contains an incomplete banding pattern; observation error occurs when the banding pattern cannot be unambiguously interpreted with a particular processing method. Process error is more likely to affect accuracy (i.e., difference between the estimated age and the known age); observation error is more likely to affect precision (i.e., agreement of replicate age estimates for the same fish) but can affect accuracy as well. Consideration of these errors is important because management and conservation policy decisions are increasingly formed based on age-structured data analyses of fish populations.

Routine quality-control procedures in production-ageing programs typically focus on measures of precision (e.g., Kimura and Lyons 1991) rather than measures of accuracy. The emphasis on precision has been criticized by Campana (2001) in cases where potential process errors have not been evaluated directly. In this paper we will be focusing on measures of precision, but we begin by stating our agreement with Campana (2001; p. 221) that 'precision cannot be used as a proxy for accuracy.' Accuracy issues must be dealt with first; otherwise, accounting for precision may not improve data quality. In routine production ageing, where there is (hopefully) little controversy about accuracy, measures of precision are used to compare the relative 'ease' of ageing one species over another or to compare the precision between readers within or between laboratories (Kimura and Lyons 1991, Campana 2001). A number of measures of precision are available (Campana 2001, Lai et al. 1996), but there is no consensus as to which one is most appropriate for determining precision. The index of percent precision (IPP) is the easiest measure to calculate and understand:

$$\text{IPP} = 100 \times \frac{F}{N}$$

where F is the number of fish whose replicated, estimated ages agreed within some range, and N is the number of fish whose age were estimated. The IPP is the traditional index of precision but is falling out of favor according to Campana's (2001) review. This reversal of fortune for IPP appears to have resulted from two contrasting examples provided by Beamish and Fournier (1981; p. 982):

i) If nearly all ages estimated by two readers agree within ± 1 year this may still lead to poor precision if the species has only a few year-classes (i.e., < 10), whereas
ii) If a similarly high percentage of estimated ages agreed to within ± 5 years, this may be good precision for another species that has many more year-classes (i.e., 50-100).

Beamish and Fournier (1981) proposed the index of average percent error (IAPE) as an alternative index that should be less dependent on absolute age of the fish:

$$\text{IAPE} = 100 \times \frac{1}{N} \sum_{j=1}^{N} \left(\frac{1}{R} \sum_{i=1}^{R} \frac{\left| Y_{ij} - \overline{Y}_j \right|}{\overline{Y}_j} \right) \quad (1)$$

where N is the number of fish aged, R is the number of replicated age estimates per fish, Y_{ij} is the ith age determination of the jth fish, and $\overline{Y}_j$ is the average age for the jth fish. As an alternative to the IAPE, Chang (1982) proposed using the index of the coefficient of variation (ICV) –

$$\text{ICV} = 100 \times \frac{1}{N} \sum_{j=1}^{N} \frac{\sqrt{\sum_{i=1}^{R} \frac{\left(Y_{ij} - \overline{Y}_j\right)^2}{R-1}}}{\overline{Y}_j} \quad (2)$$

as a ratio index that should further eliminate the effect of fish age on measures of precision. The ICV should not be confused with an actual coefficient of variation (i.e., of replicate age estimates for an individual fish: $CV = s \times 100 \,/\, \overline{Y}$

where s is the standard deviation:

$$s = \sqrt{\sum_{i=1}^{R} \frac{\left(Y - \bar{Y}\right)^2}{R-1}} \quad (3)$$

The ICV is a summation of individual *CV* values for age estimates of individual fish so that variations in age estimates within fish, among fish, and among age classes are all combined; this 'oversummarization' of variance sources is one of the criticisms of ICV (and the IAPE; Hoenig et al. 1995). Nonetheless, the ICV has been recommended by Campana et al. (1995) and Campana (2001), and the IAPE continues to appear in recent literature (Sulikowski et al. 2003, McDougall 2004). Hoenig et al. (1995) proposed a 'test of symmetry' approach to avoid this oversummarization problem. This approach tests for asymmetrical bias between the replicate, estimated ages (i.e., away from the table diagonal in an age frequency table). It uses a chi-square (X^2) approach in the form of the test statistic:

$$X^2 = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} \frac{\left(n_{ij} - n_{ji}\right)^2}{n_{ij} + n_{ji}} \quad (4)$$

where n_{ij} is the observed frequency in the *i*th row and the *j*th column and n_{ji} is the observed frequency in the *j*th row and *i*th column. When systematic differences occur away from the diagonal, then the test statistic will become large and will be eventually rejected. The degrees of freedom are equal to only the number of paired cells with actual values to compare (i.e., nonzeros in either one or both paired [n_{ij} *vs* n_{ji}] cells). Finally, Campana et al. (1995) introduced the use of the correlation coefficient (*r*) as a measure of precision, and although it does not appear to be widely used, we include it in these comparisons.

Given this cacophony of choices, which approach should be used? Missing from this debate is an evaluation of these various approaches based on simulated data with known properties. In the studies cited above, a common theme was to calculate and compare these different measures of precision using "real" datasets, using ages that may or may not have had been based on a validated ageing method so there was some, unknown level of inaccuracy of the ages. In this study we present examples from a simulated dataset where accuracy and precision are known. We are specifically interested in how varying levels of imprecision affect our perception of an ageing method or of each metric of precision, even if it is without bias.

METHODS

Ages of a sample of 60 fish were simulated. In the sample there were six fish for each of 10 age classes: 1 through 10. The age of each fish was estimated twice, so there were a total of 120 (i.e., 60 paired) estimated ages for each sample. Seven sample cases were examined: a null model and six simulated cases that contained increasing amounts of random variation in the estimated ages. In the null model, the estimated ages simply agreed with the known age of all fish. For the simulations, the "random" component varied fish ages between -1 and +1 year of the known age, and for each case, 30 runs were made. For each run, ICV, IAPE, IPP, and *r* statistics were estimated. IPP was calculated as the percentage of age estimates that agreed exactly. In case 1, both pairs of the estimated ages for one fish per age class were set to vary in a random manner; in case 2, both pairs of the estimated ages for two fish per age class were set to vary; this pattern was followed up to case 6, for which variations of all ages of all fish were randomly assigned (-1, 0, +1). In summary, the null model represented no aging error, and the alternative cases represented unbiased ageing, with increasing amounts of imprecision ranging from 17% to 100% of the ages being potentially incorrect (Figure 1).

Each of these six cases could illustrate a real situation in which most of the annuli are easy for an observer to read, but there might be one annulus that is difficult to read, so the observer is as likely to miss it as to see it or to add another annulus count. The nature of the variance in this example is homogeneous. The ageing method is not specified here but can be considered to result in direct annual ages from any one of a variety of biological hardparts.

RESULTS

In the null model (i.e., no ageing error), ICV and IAPE = 0, IPP = 100, and r = 1.0 (Figure 1). As simulated ageing error increased (i.e., from case 1 to case 6), ICV and IAPE increased and IPP and r decreased (Figures 1, 2). Average values of ICV for each case were two to three times higher than IAPE. In case 6 the average ICV was 19.7 (vs. IAPE = 7.0). Average values of IPP decreased across the widest range of absolute values: from 88.7 in case 1 to 32.1 in case 6. Average values of r decreased across a very narrow range of absolute values: from 0.986 in case 1 to 0.926 in case 6. IAPE had the greatest dispersion around each mean (*CV* ranged from 28.1 to 70.9% in each of the six cases), ICV had less variation (*CV*: 15.6 - 30.8%), IPP had even less (*CV*: 2.4-21.4%), and r had the least (*CV*: 0.464 - 1.25%).

Age-specific trends in ICV, IAPE, and IPP were evident in a number of simulations (Figure 3). Although these indices could be remarkably even across age-classes in some simulated runs (e.g., Figure 3I), ICV and IAPE usually demonstrated some declining trend with respect to age-class, and IPP was typically highly variable.

All four precision measures evaluated showed a strong linear relationship with each other, explaining as much as 90% of the variation between them (Figure 4). Coefficients of determination (r^2)were lowest when comparing IAPE to other indices (0.59 - 0.76), as might be expected because IAPE had the highest dispersion (see above regarding *CV* values). The relationship between the ICV and IAPE was very different for these simulated data than their relationship for real data plotted by Campana (2001; p. 223) (Figure 5).

In the simulated data, the inaccuracies in all six cases were designed to not have any bias with respect to repeated estimates of age, and the use of a test of symmetry confirmed that there was, in fact, no bias between paired age estimates (Table 1).

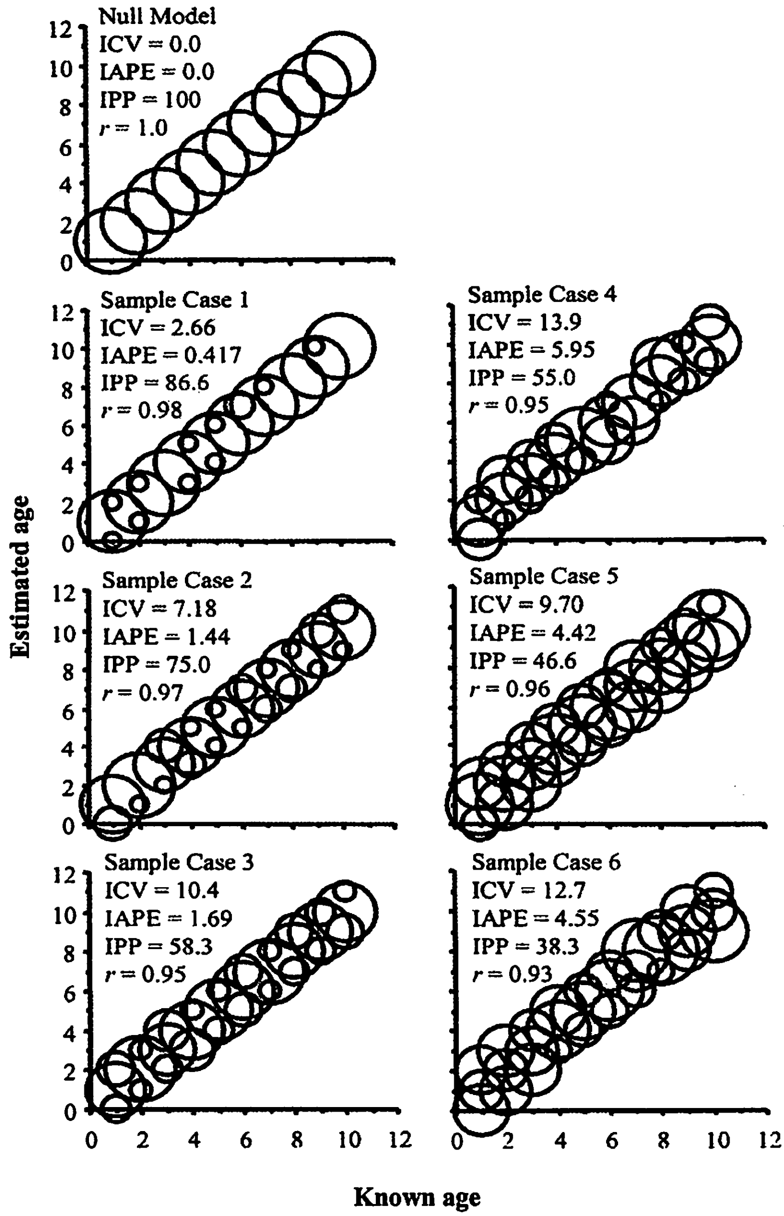


Figure 1. Bubble plots of the null model (i.e., no ageing error) and example runs of the six alternative cases, with increasing variability (increasing ageing error / decreasing ageing precision). The data plotted are for the last simulated run of 30 total runs per case (1-6) and are meant to be random examples (actual precision values for that particular run are also listed).

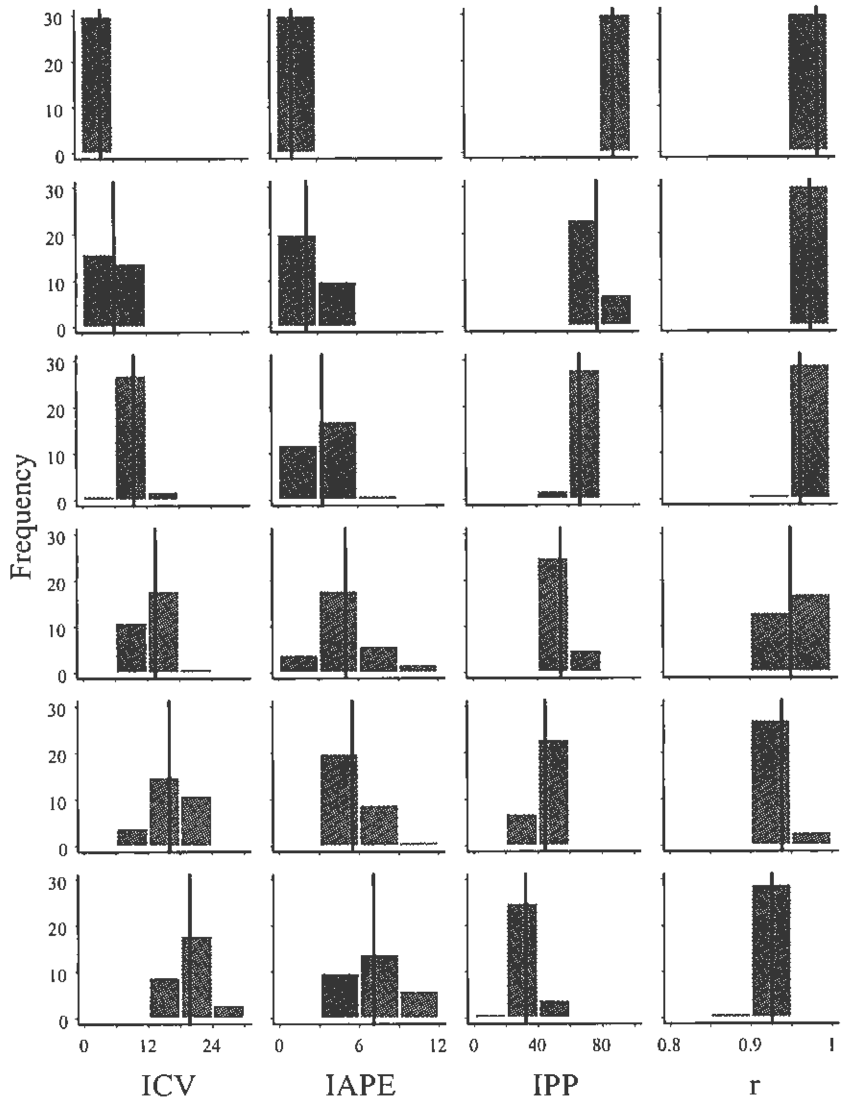


Figure 2. Histograms of three indices of precision and *r* generated from 30 simulated runs for each of 6 cases of increasing ageing error. The four indices are labeled (ICV, IAPE, IPP, *r*; left to right) and the cases are in order of increasing ageing error (case 1-6; top to bottom). The vertical bars represent the mean value for each case. See Figure 1 for scattergram examples of each case and the Introduction section for calculations of each index.

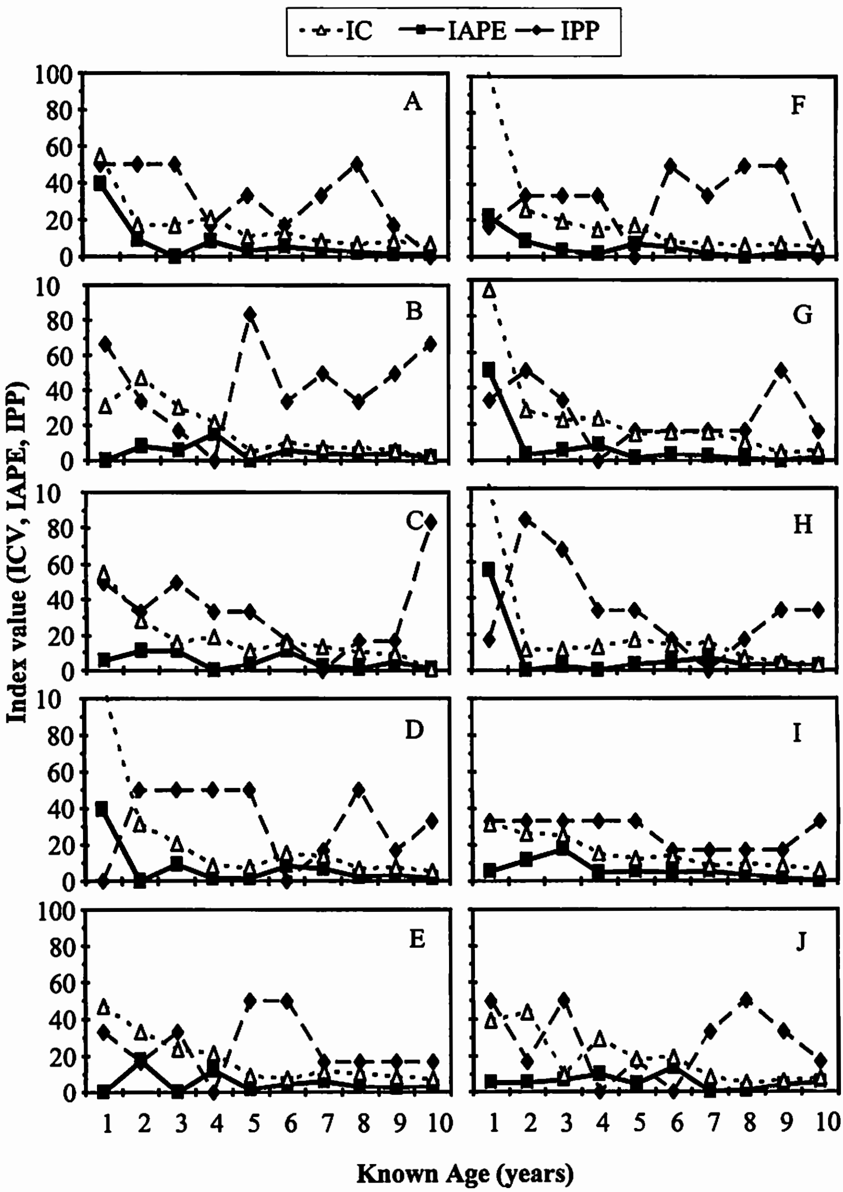


Figure 3. Ten random simulation runs (A-J) of age-specific patterns of ICV (triangles, short dash line), IAPE (squares, solid line), and IPP (diamonds, long dash line).

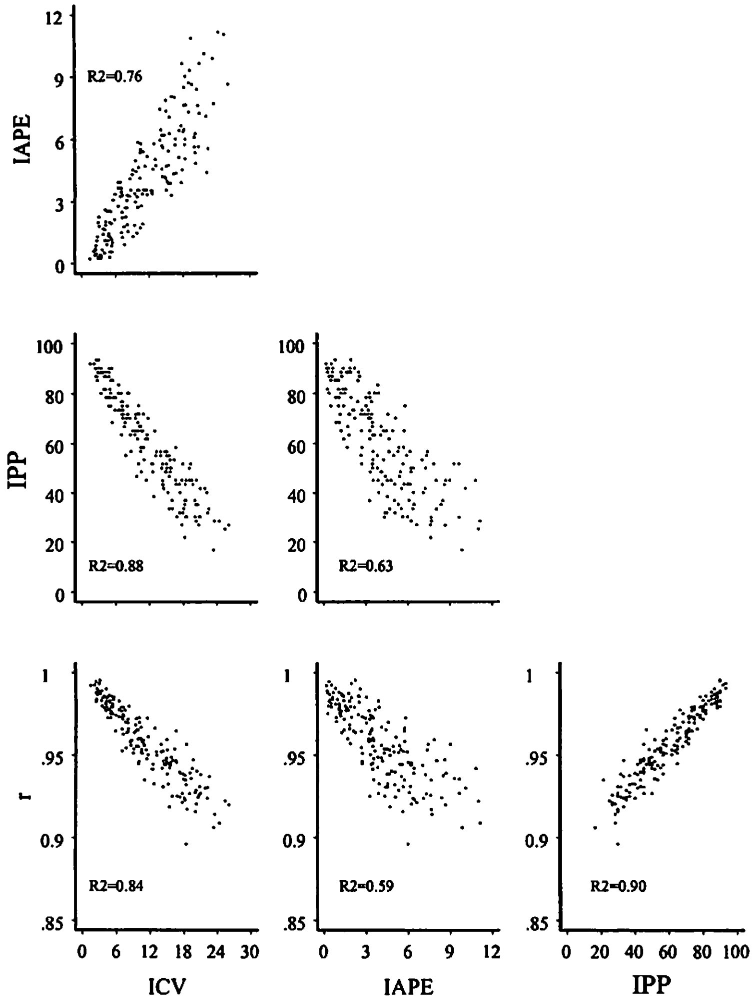


Figure 4. The association between all three indices and *r* with the corresponding coefficient of determination (r^2) between each variable. There are 180 data points per scattergram (30 simulations of six cases).

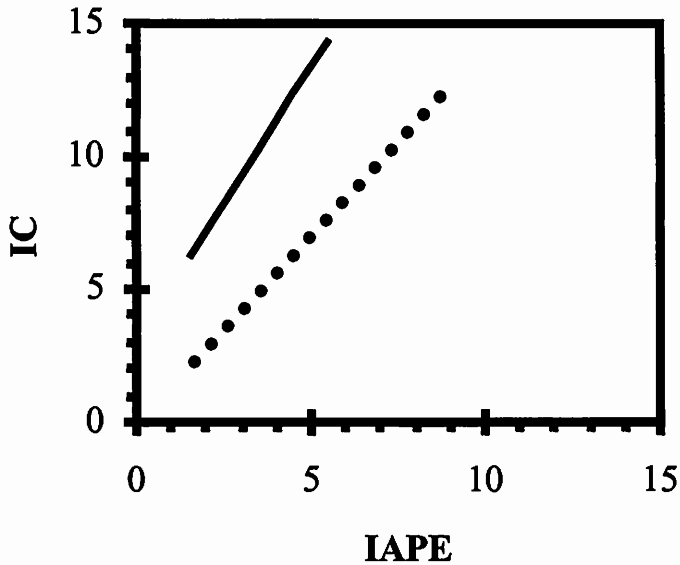


Figure 5. ICV regressed against IAPE as calculated for this simulated data (solid line) and for data from the literature (dotted line) as reported by Campana (2001; p. 223). The equation for the simulated data is ICV = 3.06 + 2.06 × (IAPE) and was calculated by least squared regression (see Fig. 4 [top panel] for actual data). The equation reported by Campana (2001) is ICV = -0.15 + 1.41 × (IAPE).

Table 1. (A) A random example of an age-frequency table that compares paired estimated ages for one simulated run of case 6 (see Methods for descriptions of the six cases).

	First estimated age (R1)											
R2	0	1	2	3	4	5	6	7	8	9	10	11
0	1	1										
1	2			1								
2	2		2	2	1							
3		2		1								
4			1	1	5	1	1					
5				1	2	1	3					
6						3	1	1	1			
7								1		1		
8								3	4		2	
9									2	3	2	
10											1	
11										3	1	

Table 1. (B) The chi-squared values (X^2) , degrees of freedom (df), and probability (P) for 20 simulated runs of case 6. In all 20 runs the null hypothesis (symmetry along the diagonal) was not rejected ($\alpha = 0.05$). This was anticipated because there was no bias introduced into the simulated data. The test results for the example above (A) are in the lower right-hand corner of (B).

X^2=	15.3	19.7	17.5	31.0	12.2	18.0	13.3	19.0	15.1	14.2
df=	16	18	20	22	16	16	17	18	16	16
P=	0.500	0.352	0.622	0.096	0.730	0.324	0.714	0.392	0.514	0.584
X^2=	14.9	25.2	18.3	19.0	17.7	13.2	23.9	18.7	21.2	24.0
df=	15	18	17	20	18	18	18	16	18	19
P=	0.461	0.120	0.368	0.522	0.478	0.780	0.159	0.286	0.269	0.196

DISCUSSION

All three indices (ICV, IAPE, and IPP) and *r* were correlated with one another. Campana (2001) also demonstrated that ICV and IAPE were correlated with each other, which should not be surprising because ICV merely replaces the average absolute deviation used in the IAPE with a standard deviation in its formulation (Chang 1968). Still, although these two indices should be related to each other, we urge caution in applying Campana's (2001) regression relationship between ICV and IAPE, because using our data, this relationship was very different from that reported by Campana (2001) (Figure 5). Regression equations between these three indices and *r* may be highly dependent on the specific data sets used, so generalizations may be misleading.

The importance of the correlations between the three indices and *r* is that they all say more or less the same thing. If so, then what guiding principles are there to choose one over the other? First, there should be sufficient range in the absolute value of an index to allow one to distinguish low precision from high precision. The correlation coefficient (*r*) had very little range from case 1 to case 6. Even for case 6, where every estimate of age could randomly be incorrect, the average *r* was quite high (0.926). To an untrained scientist, a report of $r > 0.9$ might very well be misconstrued as indicating very good precision, when it could actually indicate very poor precision. The effect of bias between paired reads may actually lower *r* even more, but our example did not have any bias with respect to known age.

Another guiding principle is that the index chosen should not have a high variability inherent in its formulation. The index with the highest relative variability, as measured by *CV*, was IAPE. This high variability probably results in the use of absolute deviation in the IAPE formula. In fact, use of the standard deviation in the formulation of ICV does appear to lower the variability of the ICV, which makes this index statistically more robust. The formulation of ICV also increases the range of ICV values between the six different cases, which we regard as generally a good quality (see above). The variability of IPP was lower than the variability of either IAPE or ICV, which was somewhat surprising because IPP has been criticized as having age-related bias for certain species (Beamish and Fournier 1981). Our finding of lower variability in the IPP may simply be the result of the modest longevity (10 years) of our hypothetical fish population and the homogeneity of variance that we imposed on the simulated data. In the future, we intend to rerun simulations that extend the maximum age out by several decades and includes heteroscedasticity. One of the central tenets of the superiority of one index of precision over another is that there are no age-specific trends in an index. In this particular example, it is then relevant to note that the age-specific variances of IPP are not particularly worse than those of ICV and IAPE.

IPP has a real advantage over ICV and IAPE: it is easy to interpret. It has obvious boundaries (0 - 100), and a value of 80% clearly means that 80% of the paired reads agreed and 20% did not. Only experienced otolithologists have a feeling for various values of ICV and IAPE. Campana (2001) helps remedy this to some degree by summarizing published values of ICV; he reported a median of 7.6 and a mode of 5. Of course, these values may be artificially low if researchers are reticent about publishing high values. The danger is that reviewers or editors may use these values as benchmark criteria for accepting or rejecting the quality of a study. In our simulated study, an ICV of about 5 was associated with case 2 (i.e., 1/3 of the otolith age estimates had the potential to vary $\pm$ 1 year). We agree with Campana (2001) that there is no *a priori* target value, and the criteria for evaluating a particular index value depend on the objective of each study.

Much has been said before about these indices, but most of this has been based on real datasets for which accuracy and bias were not known. Using simulated data with no bias with respect to known age, we varied the precision of paired age estimations. We included *r* in this comparison because it has a solid statistical basis, but the resulting values of *r* in this simulation strike us as misleading in terms of evaluating imprecision so we do not recommend its use. We find little difference between ICV and IAPE, except that ICV ranks higher because its formulation leads to greater values than the formulation for IAPE (i.e., greater absolute range of values between each case), and the statistical rigor of ICV accounts for greater stability of this index across age-classes. Finally, we conclude that much of the criticism directed at IPP may be unwarranted. All three indices, not just IPP, tend to oversummarize the data (Hoenig et al. 1995). IPP is easy to measure and easy to understand, which is an apparently unsung advantage. The cumulative effect of several papers (Beamish and Fournier 1981, Chang 1982, Kimura and Lyons 1991, Campana et al. 1995, Lai et al. 1996, Campana, 2001) criticizing IPP amounts to tossing the baby out with the bathwater.

Researchers have not stopped using IPP completely. An interesting trend in the literature is that IPP is used to screen datasets prior to calculating either IAPE or ICV. For example, Sulikowski et al. (2002) calculated IAPE only for those cases where within-fish variability was $\leq$ 2 years. Simpfendorfer et al. (2000) used an ordinal system for characterizing the readability of individual vertebrae, and calculated IAPE only for those that ranked above a certain value. IPP is used in these publications to improve the index of precision actually reported (i.e., as a stealth index to weed out specimens with markedly poor precision).

In this study, a test of symmetry approach was briefly introduced. In our example, it is somewhat trivial because the simulated data had no bias, so finding no bias was not unexpected. Using a test of symmetry to check for asymmetry between paired (but independent) age estimates by the same reader is also likely to be trivial, unless this reader changes some interpretive criteria between paired estimates. A test of symmetry is more commonly used to compare the age estimates of two readers (e.g., expert *vs.* novice) or between two biological hardparts (otoliths *vs.* scales). The value of such a test is that it sets up an age-frequency table, which graphically displays the data and then tests it for departures from symmetry. In comparison, the various indices of precision (ICV, IAPE, and IPP) do not measure any such bias. On the other hand, the test of symmetry does not provide a simple value for precision; in fact its formulation does not include the diagonal cells. We recommend that fishery scientists should evaluate ageing error using both an index of precision together with tests of symmetry.

In this study we present an artificial, or at least a restricted, example, but one with heuristic value. As mentioned above, we anticipate extending this simulation approach to include a greater variety of underlying models, particularly for greater longevity and other types of variance and bias with respect to known age. Here we simply point out that:

i) IPP has perhaps been overcriticized for some simple shortcomings that other, more complicated indices do little to overcome, and
ii) Running a test of symmetry in addition to calculating an index of precision provides a useful way for researchers to evaluate their age data.

ACKNOWLEDGMENTS

We thank the FWRI stock assessment group for comments on an early synthesis of these ideas and B. Muller and J. Tunnell for their reviews of the manuscript. We are also grateful to E. Sosa for translating the English abstract to a Spanish version. Support for RSM was provided, in part, by the Department of Interior, U.S. Fish and Wildlife Service, Federal Aid for Sport Fish Restoration, Grant Number F-106. Funding for this study was also supported in part by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (DOC-NOAA) award numbers NA17FF2882 (support for KLM) and NA16FG1221 (support for JdeS). The views expressed herein are those of the authors and do not necessarily represent the views of the DOC-NOAA.

LITERATURE CITED

Beamish, R.J. and D.A. Fournier. 1981. A method for comparing the precision of a set of age determinations. *Canadian Journal of Fisheries Aquatic Sciences* **38**:982-983.

Campana, S.E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. *Journal of Fish Biology* **59**:197-242.

Campana, S.E., and S.R. Thorrold. 2001. Otoliths, increments and elements: keys to a comprehensive understanding of fish populations? *Canadian Journal of Fisheries Aquatic Sciences* **59**:30-38.

Campana, S.E., M.C. Annand, and J.I. McMillan. 1995. Graphical and statistical methods for determining the consistency of age determinations. *Transactions of the American Fisheries Society* **124**:131-138.

Chang, W.Y.B. 1982. A statistical method for evaluating the reproducibility of age determination. *Canadian Journal of Fisheries Aquatic Sciences* **39**:1208-1210.

Hoenig, J.M., Morgan, M.J., and C.A. Brown. 1995. Analysing differences between two age determination methods by tests of symmetry. *Canadian Journal of Fisheries Aquatic Sciences* **52**:364-368.

Kimura, D.K. and J.J. Lyons. 1991. Between-reader bias and variability in the age-determination process. *Fisheries Bulletin, U.S.* **89**:53-60.

Lai, H.-L., V.F. Gallucci, D.R. Gunderson, and R. F. Donnelly. 1996. Age determination in fisheries: methods and applications to stock assessment. Pages 82-178 in: V.F. Ballucci, S.B. Saila, D.J. Gustafson, and B.J. Rothschild (eds.). *Stock Assessment: Quantitative Methods and Applications for Small-scale Fisheries*. CRC Press, Lewis Publishers, Boca Raton, Florida USA.

McDougall, A. 2004. Assessing the use of sectioned otoliths and other methods to determine the age of the centropomid fish, barramundi (*Lates calcarifer*) (Bloch), using known-age fish. *Fisheries Research* **67**:129-141.

Simpfendorfer, C.A., J. Chidlow, R. McAuley, and P. Unsworth. 2000. Age and growth of the whiskery shark, Furgaleus macki, from southwestern Australia. *Environmental Biology of Fish* **58**:335-343.

Sulikowski, J.A., M.D. Morin, S.H. Suk, and W.H. Howell. 2003. Age and growth estimates of the winter skate (*Leucoraja ocellata*) in the western Gulf of Maine. *Fisheries Bulletin, U.S.* **101**:405-413.

BLANK PAGE

What is the Common Problem that Makes most Biological Databases Hard to Work With, if not Useless to most Biologists?

RUNI VILHELM
MRAG Americas, Inc.
110 South Hoover Blvd., Suite 212
Tampa, Florida 33609-2458 USA

ABSTRACT

The manner by which a biologist collects, stores, and understands the relations between data is often completely different from the way a computer analyst views data. Even though databases are supposed to be relationally designed (i.e. built on relations between the data entities), this usually never happens. In real life, the biologist starts collecting data for a scientific purpose and then contacts a computer analyst (CA) in the IT department to help develop a database for the data collection schema *after* it has commenced. From a brief discussion with the biologist, the CA designs and implements a table structure (database). The product then gets turned over to the biologist, and it is now up to the biologist to understand the relations that the CA had in mind when developing the database. The database will not be the helpful tool it was intended to be; instead, it is often a troublesome data storage system that the biologist is stuck with in the future. To make matters worse, the database is rarely documented and if/when the CA leaves/retires from the organization no one will completely understand the database structure.

Thus, what is a relational database design? Is it (1) a design that promotes the relations and business rules of the collected data, or (2) a normalized relational design that the Computer Analyst creates from theories he/she has read about in a computer book? Most databases are constructed based on (2). However, this makes most databases hard to work with if not useless to most biologists. So how can this be changed? To construct a database that will be successfully used, concepts from both (1) and (2) must be included when designing the database structure. This presentation will focus on how this can be achieved.

KEY WORDS: Databases, design

Cual es el Problema Común que Ocasiona que la Mayoría de los Bancos de data Biológica sean Difíciles de Utilizar o sean Inefectivos para la Mayoría de los Biologos?

A pesar de que los bancos de data están supuestos a tener un diseño de relación (e.g., elaborados en relaciones de data entre las entidades), usualmente no es así. En la realidad el biólogo comienza a recopilar la data con un propósito científico, y luego se pone en contacto con un analista de data (CA, por sus siglas en inglés) que lo ayude a desarrollar un banco de data para el esquema de la data recogida después de haber comenzado ésta. Despues de tener una breve discusión con el biólogo, el CA diseña e implementa una tabla de estructura (banco de data). El producto es entonces devuelto al biólogo, y le corresponde a éste entender las relaciones que el CA tiene en mente al desarrollar el banco de data. El banco de data no será entonces el instrumento de ayuda productivo que se tenía pensado, mas bien se convierte en un problemático sistema para guardar la data que no es productivo. Peor aún, el banco de data es muy pocas veces documentado y si en algún momento el CA se retira o abandona la entidad, no habrá nadie que entienda completamente la estructura del banco de data.

Por lo tanto, ¿que es un diseño de banco de relación de data? (1) Es un diseno que promueve las relaciones y reglas de trabajo de la data recogida? O (2) un diseño de relación normalizado que el analista crea basado en teorías que él o ella han leído en un libro de computadora? La mayoría de los bancos de data están construidos basados en la 2. Sin embargo esto hace que la mayoría de los bancos de data sean difíciles o imposibles de utilizar por la mayoría de los biólogos. ¿Como se puede cambiar esto? Para construir un banco de data que se pueda utilizar efectivamente se deben incluir ambos conceptos, el 1 y 2, al diseñar la estructura del banco de data. El enfoque de esta presentación va dirigido a lograr este propósito.

PALABRAS CLAVES: Bancos de data, diseñar

INTRODUCTION

Computers 20 years ago were simply not powerful enough to handle the processing of data, especially the relational database model (which we will explore shortly). As computers began to advance, databases began the snowball effect we see now. We are just beginning to perceive the utter power of in-depth database systems and the power of which these systems can implement.

Before you can begin to design a database, you must understand the underlying concepts and theories of why databases are used and how they are created. I will give you an explanation of what a database is, the relational database model and structured query language.

Databases are the primary form of storage in both today's online and offline worlds. Databases are used to store millions of different types/ combinations of information including product details, employees, personal address books, news, etc.

Before you can begin using a database however, you must understand the underlying concepts and theories of why databases are used and how they are created.

OVERVIEW OF THE RELATIONAL MODEL

The relational model was formally introduced by Dr. E. F. Codd in 1970 and has evolved since then through a series of writings. The model provides a simple, yet rigorously defined, concept of how users perceive data. The relational model represents data in the form of two-dimension tables. Each table represents some real-world person, place, thing, or event about which information is collected. A relational database is a collection of two-dimensional tables.

In the relational model, a database is a collection of relational tables. A relational table is a flat file composed of a set of named columns and an arbitrary number of unnamed rows. The columns of the tables contain information about the table. The rows of the table represent occurrences of the "thing" represented by the table. A data value is stored in the intersection of a row and column.

PROPERTIES OF THE RELATIONAL TABLES

Values are Atomic

This property implies that columns in a relational table are not repeating group or arrays. Such tables are referred to as being in the "first normal form" (1NF). The atomic value property of relational tables is important because it is one of the cornerstones of the relational model.

Column Values are of the Same Kind

In relational terms this means that all values in a column come from the same domain. A domain is a set of values which a column may have. For example, a *Monthly Salary* column contains only specific monthly salaries. It never contains other information such as comments, status flags, or even weekly salary.

Each Row is Unique

This property ensures that no two rows in a relational table are identical; there is at least one column, or set of columns, the values of which uniquely identify each row in the table. Such columns are called primary keys and will be discussed in more detail in a moment. This property guarantees that every row in a relational table is meaningful and that a specific row can be identified by specifying the primary key value.

The Sequence of Columns is Insignificant

This property states that the ordering of the columns in the relational table has no meaning. Columns can be retrieved in any order and in various sequences. The benefit of this property is that it enables many users to share the same table without concern of how the table is organized. It also permits the physical structure of the database to change without affecting the relational tables.

The Sequence of Rows is Insignificant

This property is analogous to the one above but applies to rows instead of columns. The main benefit is that the rows of a relational table can be retrieved in different order and sequences. Adding information to a relational table is simplified and does not affect existing queries.

Each Column has a Unique Name

Because the sequence of columns is insignificant, columns must be referenced by name and not by position. In general, a column name need not be unique within an entire database but only within the table to which it belongs.

Relationships and Keys

A relationship — is an association between two or more tables. Relationships are expressed in the data values of the primary and foreign keys.

A *primary key* — is a column or columns in a table whose values **uniquely identify** each row in a table.

A *foreign key* — is a column or columns whose values are the same as the primary key of another table. You can think of a foreign key as a copy of primary key from another relational table. The relationship is made between two relational tables by matching the values of the foreign key in one table with the values of the primary key in another.

Keys — are fundamental to the concept of relational databases because they enable tables in the database to be related with each other. Navigation around a relational database depends on the ability of the primary key to unambiguously identify specific rows of a table. Navigating between tables requires that the foreign key is able to correctly and consistently reference the values of the primary keys of a related table.

Data Integrity

Data integrity means, in part, that you can correctly and consistently navigate and manipulate the tables in the database. There are two basic rules to ensure data integrity; *entity integrity* and *referential integrity*.

The entity integrity — rule states that the value of the primary key can never be a null value (a null value is one that has no value and is not the same as a blank). Because a primary key is used to identify a unique row in a relational table, its value must always be specified and should never be unknown. The integrity rule requires that insert, update, and delete operations maintain the uniqueness and existence of all primary keys.

The referential integrity — rule states that if a relational table has a foreign key, then every value of the foreign key must either be null or match the values in the relational table in which that foreign key is a primary key.

Normalization

Normalization is a design technique that is widely used as a guide in designing relational databases. Normalization is essentially a two step process that puts data into tabular form by removing repeating groups and then removes duplicated data from the relational tables.

Normalization theory is based on the concepts of **normal forms**. A relational table is said to be a particular normal form if it satisfied a certain set of constraints. There are currently five normal forms that have been defined. In this section, we will cover the first three normal forms that were defined by E. F. Codd.

The goal of normalization is to create a set of relational tables that are free of redundant data and that can be consistently and correctly modified. This means that all tables in a relational database should be in the third normal form (3NF). A relational table is in 3NF if and only if all non-key columns are (a) mutually independent and (b) fully dependent upon the primary key. Mutual independence means that no non-key column is dependent upon any combination of the other columns. The first two normal forms are intermediate steps to achieve the goal of having all tables in 3NF. In order to better understand the 2NF and higher forms, it is necessary to understand the concepts of functional dependencies and lossless decomposition.

Simply stated, normalization is the process of removing redundant data from relational tables by decomposing (splitting) a relational table into smaller tables by projection. The goal is to have only primary keys on the left hand side of a functional dependency. In order to be correct, decomposition must be lossless. That is, the new tables can be recombined by a natural join to recreate the original table without creating any spurious or redundant data.

SQL (STRUCTURED QUERY LANGUAGE)

A discussion of databases would not be truly complete without touching on SQL, the database language of choice for most relational database systems. Usually pronounced as see-kwel, SQL was first conceived at IBM's laboratories in the early 1970s, where it was named sequel, not SQL. Only in the 1980s was the language renamed to SQL, an acronym for its complete name, Structured Query Language.

Databases use queries. Queries interact with the database to extract, update, insert and delete records, or otherwise work with the database's data.

COMMON DATABASE DESIGN FLAWS

Sampling Process

In real life the biologist starts collecting data for a scientific purpose and then contacts a computer analyst (CA) in the IT department to help develop a database for this data collection schema after it has commenced.

From a brief discussion with the biologist, the CA designs and implements a table structure (database). The product then gets handed over to the biologist and it is now up to the biologist to understand the relations that the CA had in mind when developing the database. The database will not be the helping tool it was intended to be, it will rather be a troublesome data storages that the biologist will be stuck with in the future.

To make things even worse, the database is rarely documented, and if/ when the CA leaves/retires from the organization, no one will completely understand the database structure.

A Protocol and Database for Monitoring Transient Multi-species Reef Fish Spawning Aggregations in the Meso-American Reef

WILLIAM D. HEYMAN[1] and GREGORY ADRIEN[2]
[1]*Department of Wildlife and Fisheries Sciences*
Texas A&M University
College Station, Texas 77843-2258 USA
[2]*Adrien Consulting*
16701 Leocrie Place
Woodbridge, Virginia 22191 USA

ABSTRACT

Most commercially important Caribbean reef fish species reproduce within transient spawning aggregations in specific times and places. Fishers have long recognized and capitalized on this behavior, and heavy fishing pressure on spawning aggregations has led to declines and extirpations around the Caribbean, particularly for Nassau grouper. For the same reason that spawning aggregations are attractive to fishers, they are also an opportunity for managers to monitor the populations. To maximize this opportunity, we developed, tested, and produced a standardized protocol and accompanying database for monitoring transient reef fish spawning aggregations. The protocol includes both fisheries dependent and independent techniques for data collection as well as physical oceanographic measures. The accompanying database and user manual are designed intimately with the monitoring protocol, providing easy data entry and data retrieval via generation of reports. The system design allows upgrading to a web-based, SQL-server platform that can handle data from around the world. The protocol has been adopted by the World Bank's Meso-American Barrier Reef Systems Project (MBRS) for Belize, Mexico, Honduras and Guatemala.

KEY WORDS: Database, monitoring, spawning aggregations

Protocolo y Base de Datos para el Monitoreo de Agregaciones Reproductivas Transitorias de Múltiples Especies de Peces Arrecifales en el Arrecife Mesoamericano

La mayor parte de las especies de peces arrecifales del Caribe con valor comercial se reproducen en períodos y lugares específicos dentro de las agregaciones reproductivas transitorias. Toda la producción reproductiva de los peces que utilizan esta estrategia ocurre dentro de estas agregaciones. El monitoreo de estas agregaciones puede servir como una manera eficiente de monitorear estas poblaciones cuando pasan a través de cuellos de botella físicos y temporales de gran importancia para sus ciclos de vida. No obstante, hasta ahora no hay un protocolo de monitoreo sistemático generalmente aceptado de estas agregaciones. Nosotros desarrollamos, probamos y produjimos un protocolo estandarizado y una base de datos que lo acompaña para el monitoreo de agregaciones reproductivas transitorias de peces arrecifales. El sistema de monitoreo ha sido adoptado como estándar por los cuatro países del arrecife mesoamericano, Belice, México, Honduras y Guatemala, a través del Proyecto de Sistemas de Arrecifes de Barrera Mesoamericanos del Banco Mundial.

El protocolo y la base de datos fueron desarrollados en colaboración bajo el liderazgo del Comité Nacional de Trabajo sobre Agregaciones Reproductivas de Belice y bajo los auspicios de The Nature Conservancy. El sistema se encuentra en desarrollo y uso en Belice desde el año 2000 y se usa para el monitoreo de 17 sitios de agregaciones reproductivas de múltiples especies realizado por equipos de 8 organizaciones, gubernamentales y no gubernamentales, de Belice e internacionales.

El protocolo detalla métodos dependientes e independientes de pesquerías así como técnicas de oceanografía física cuyo fin es monitorear las agregaciones reproductivas. La base de datos en Access que lo acompaña y el manual del usuario fueron diseñados en estrecha relación con el protocolo de monitoreo, para proveer un sistema sencillo de ingreso y recuperación de datos mediante la generación de informes. El sistema está diseñado para ofrecer en el futuro una aplicación adaptable con base en la red que utiliza una plataforma de servidor SQL para manejar datos de todo el mundo.

PALABRAS CLAVES: Agregaciones reproductivas, base de datos, monitoreo

INTRODUCTION

Tropical marine fisheries have sustained the livelihoods of coastal communities throughout the Meso-American Reef and the wider Caribbean for generations, but these resources are collapsing at an alarming rate throughout the region (Safina 1995, NRC 1999, Jackson et al. 2001). Fisheries in the Caribbean are diverse, generally targeting a variety of species simultaneously. These multi-species fisheries are particularly difficult to monitor and manage using traditional means. Of particular interest to the managers are the large predatory reef fishes such as snappers and groupers because of their value both as fishery products–prized by diners worldwide–and as a "draw" in the tourism industry–divers enjoy seeing large predators while diving and sport fishing. These larger reef fishes generally reproduce in transient spawning aggregations that occur at specific times and places (Munro et al. 1973, Thompson and Munro 1978, Johannes 1978, Thresher 1984, Domeier and Colin 1997, Colin et al. 2003). Fishers have capitalized on this behavior by fishing intensively at spawning aggregations (e.g., Craig 1969, Auil-Marshellek 1994). Early work described the Nassau grouper fishery at Caye Glory, Belize, where as many as 300 boats captured over 2,000 kg of gravid groupers per day (Craig 1969). More recent studies have further documented aggregations of other species and at other times (e.g., Carter et al. 1994, Auil-Marshellek 1994, Heyman 1996, Paz and Grimshaw 2001, Sala et al. 2001). Intensive fishing pressure on these aggregations has led to declines and, in several cases, extirpations (Fine 1990, Sadovy 1994, Paz and Grimshaw 2001, Sala et al. 2001, Luckhurst 2004).

Confounding the problems associated with declining fisheries resources are the limited resources for the study, monitoring, and regulatory enforcement of reef fisheries throughout the tropics. Though scientists have been aware of spawning aggregations for many years, funding and resource constraints have limited most studies to few locations, few techniques, short durations, and focus on a single species at a time–generally groupers (e.g. Smith 1972, Colin 1992, Aguilar-Perera 1994, Carter et al. 1994, Aguilar-Perera and Aguilar-Dávila 1996). These studies have provided excellent information about the sites, species, and temporal aspect studied; however, the lack of consistency among studies has resulted in insufficient data for broad-scale understanding of spawning aggregation dynamics, or as a basis for management decisions. An exception is the relatively well studied reef fish spawning aggregations in Belize.

Anecdotal information from fishers and managers and the overall insufficiency of data and management pertaining to spawning aggregations was cause for concern. Individuals and organizations realized the still present threat to Nassau grouper and the value of multi-species reef fish spawning aggregations, and formed the Belize Spawning Aggregations Working Committee (BSAWC) to foster good management. Given the large geographic spread and simultaneous occurrences of the many aggregations in Belize this effort was challenging. The BSAWC sponsored various nation-wide assessments, starting in 2001 and data from 17 sites in Belize were synthesized into an understanding of transient multi-species reef fish spawning aggregations at reef promontories (Heyman and Requena 2002). Based in part on these data, a country-wide collaborative effort of data collection, education, and consensus building culminated in legislation that was enacted to conserve 11 of these sites within marine reserves in Belize (GoB 2003a, Heyman 2004). The Belize example shows the positive result of shared data collection and synthesis utilized for management.

Though fishers supported the legislation, they were particularly concerned about the efficacy of the new laws. The BSAWC understood that a system to monitor the populations status and to measure the success of management programs was needed. The authors, working under the auspices of The Nature Conservancy, and with the input, testing, review, and support of the BSAWC, worked collaboratively to develop a monitoring protocol, database, and data sharing agreement that would serve the needs of Belize fishers and managers alike. The BSAWC knew that Caribbean fisheries were facing similar issues, and decided to expand the project scope to the Meso-American Reef (with partial support provided by the Meso-American Barrier Reef Systems (MBRS) project).

The system's broad design criteria were to provide reliable data for monitoring and management decision-making on a large number of multi-species spawning aggregation sites, each having seasonal and annual monitoring needs. The system also needed a tool to facilitate the exchange of information and learning across sites and long time periods, and thus, the system required the storage, retrieval, filtering, and output of various data sets. To be truly useful, the system had to rely on existing technical, financial, and human resources and be operated by local technicians of the four countries of the

Meso-American Reef–Mexico, Belize, Guatemala, and Honduras.

After the initial development was completed, it was shared at the 55th Annual Meeting of the Gulf and Caribbean Fisheries Institute in Tulúm, Mexico, November 2002. An open invitation was extended at that time for user contributions to what has become this final (2004) product. This paper describes the development, application, and use of the "Reef Fish Spawning Aggregation Monitoring Protocol for the Meso-American Reef and the Wider Caribbean" (Heyman et al. 2004) (hereafter referred to as the "Protocol") and the corresponding "Spawning Aggregation Database," hereafter referred to as the "Database."

MATERIALS AND METHODS

The BSAWC sought involvement of all available institutional, financial, and human resources to complete this project, including the Belize National Government, local and international NGOs, fishing cooperatives, small-scale commercial fishers, local marine reserves, international foundations, community groups, government technicians, marine reserve staff, fishers, dive guides, students, oceanographers, marine scientists, marine biologists, map makers, computer programmers, and computer operators. A complete list of supporting institutions (14) and the names of contributing persons (over 100) are found within the acknowledgements of the Protocol.

The BSAWC recognized the existence of standardized fishery dependent and independent monitoring techniques that had been or could be adapted for spawning aggregation monitoring (e.g. Samoilys 1997a, Zeller 1998, Colin et al. 2003, The Nature Conservancy 2003a,b). Techniques in the Protocol are largely derived from these and other published techniques (see Table 1), but with some modifications to account for the institutional, human, and financial resource constraints of the implementers.

Various software packages and computer hardware platforms were evaluated for their suitability to store, retrieve, and share spawning aggregation monitoring data. Every effort was made to build a system that relies on commonly available hardware and software within the region. Further, while the system was designed to be operated initially by a network of individual users on individual PCs, we recognized the need for eventual upgrading to a web-based system to foster regional collaboration.

RESULTS AND DISCUSSION

Protocol Methodologies and Sample Results

Standardized metrics measured over time and compared among sites provide managers with information on the health of various stocks and thus a basis for management decisions (Lindeman et al. 2001).

Fishery-dependent monitoring — techniques evaluate catch/effort, length frequency distribution, and gonosomatic indices based on measurements of fish caught within an aggregation. Changes in population size structure can be illustrated with these techniques, and provide an early indication of depletion. Size frequency changes can appear before changes in numbers become apparent. Studies of age and growth, genetics, and histology require morphometric measures (e.g., length and weight of individuals and gonads) and simultaneous sampling of various tissue or organ types for subsequent laboratory analysis. Methods for extraction of otoliths for age determination; gill, heart, or fin tissue for genetics; and gonads for histology or gonosomatic indices are provided in the Protocol and other references (Table 1). These metrics have been developed and standardized by many authors previously (Table 1.). Fishery-dependent studies help provide an accurate assessment of spawning times and strategies and assessments of population structure.

Fishery-independent techniques — are available for monitoring spawning aggregations that are not being fished and to document behavior. Techniques to evaluate physical and environmental factors that may affect spawning time, or location, or egg dispersal are included.

Perhaps the simplest and most valuable techniques involve the documentation of spawning aggregations using photography and video (Domeier and Colin 1997, Colin et al. 2003). Photography and video have shown spawning colorations, behaviors, and actual spawning events (e.g. Figure 1).

Underwater Visual Survey (UVS) techniques document reproductive seasonality, abundance, and variability in the reef fish spawning aggregation populations. The techniques described within the Protocol are similar to other studies (e.g. Samoilys 1997b, Beets and Friedlander 1999, Sala et al. 2001, Whaylen et al. 2004, Table 1) in which SCUBA divers collect data on the abundance and sizes of fishes within aggregations. Through subsampling or direct counts, observers can provide relatively accurate estimates of the number of fish within particular aggregations. For example, pair-wise comparisons (n = 14) of Cubera snapper counts by two independent teams of observers, diving at the same time within the same aggregation in Belize, April-May 2004, were not significantly different. Sample data from Belize collected using these techniques are provided in Figure 2. These data on two commercially important reef fish species at a single spawning site show the daily abundance and the year-round importance of the site as a spawning ground, and have helped managers and fishers alike to agree on year-round closures for several reef promontory spawning aggregation sites in Belize. Using UVS, Beets and Friedlander (1999) showed significant increases in abundance and sizes of red hind during six years following the closure of an aggregation site. The BSAWC considers UVS techniques as described in the Protocol to be sufficiently accurate for monitoring and for the basis of management decisions.

There are a few caveats when using UVS, however. The objectives of the monitoring program must be clear, particularly in a multi-species spawning aggregation. By timing observations to coincide with specific seasonal, lunar, and diel cycles, observers can dramatically increase their chances of documenting the aggregations accurately. Further, some species aggregate near the bottom and toward the shelf edge (e.g., groupers), while other species, (e.g. jacks) aggregate higher in the water column. Observers must define sampling strategies and divide efforts to get accurate and repeatable counts on target species. Natural variations in populations can also confound UVS results. Six years of monitoring a Cubera snapper aggregation at Gladden Spit, using UVS revealed significant seasonal and annual variations in the numbers of fish at this aggregation site (Heyman et al. In review). Therefore, drawing conclusions about population trends using census data will require at least eight to ten years for slower growing species such as large groupers, and we recommend the precautionary principle.

Table 1. Techniques used in the Protocol with references to studies that describe and use each.

Fishery Independent Techniques	References and Examples
Photography and Videography	Olsen & LaPlace 1979; Colin 1992; Shapiro et al. 1993; Tucker et al. 1993; Samoilys 1997a,b; Beets & Friedlander 1999; Sala et al. 2001; The Nature Conservancy 2003a, b; Whaylen et al. 2004; Heyman et al. in rev.
Underwater Visual Survey	Colin et al. 1987; Colin 1992; Tucker et al. 1993; Carter et al. 1994; Domeier & Colin 1997; Samoilys 1997a,b; Beets & Friedlander 1999; Sala et al. 2001; Colin et al. 2003; The Nature Conservancy 2003b; Medina-Quej et al. 2004; Heyman et al. in rev.
Fish Tagging Studies	Carter et al. 1994; Sadovy et al. 1994; Luckhurst 1998; Zeller 1998; Bolden 2000
Bathymetric and Site Mapping and Site Descriptions	Colin et al. 1987; Colin 1992; Shapiro et al. 1993; Sadovy et al. 1994; Aguilar-Perera & Aguilar-Dávila 1996; Samoilys 1997a,b; Beets & Friedlander 1999; Sala et al. 2001; Colin et al. 2003; Ecochard et al. 2003
Current Drogue Studies	Colin 1992
Physical Oceanographic Monitoring	Colin 1992; Carter et al 1994; Heyman et al. in rev.
Fishery Dependent Techniques	
Length:Frequency Distribution	Olsen & LaPlace 1979; Colin et al. 1987; Claro 1981; Crabtree & Bullock 1998; Colin 1992; Tucker et al. 1993; Aguilar-Perera 1994; Carter et al. 1994; Sadovy et al. 1994; Aguilar-Perera & Aguilar-Dávila 1996; Domeier et al. 1996; Sosa-Cordero & Cárdenas-Vidal 1996; Beets & Friedlander 1999; García-Cagide et al. 2001; Burton 2002; Medina-Quej et al. 2004
Catch per Unit Effort	Olsen & LaPlace 1979; Carter et al. 1994; Sadovy & Ecklund 1999; Sosa-Cordero & Cárdenas-Vidal 1996; Beets & Friedlander 1999; Sala et al. 2001
Gonosomatic Index	Munro et al. 1973; Olsen & LaPlace 1979; Claro 1981; Thresher 1984; Tucker et al. 1993; Carter et al. 1994; Sadovy & Ecklund 1999; Sadovy et al. 1994; Domeier et al. 1996; García-Cagide & García 1996; Beets & Friedlander 1999; García-Cagide et al. 1999; García-Cagide et al. 2001; Burton 2002; The Nature Conservancy 2003b

A.

B.

Figure 1. Photographs of spawning aggregations illustrating A. spawning coloration in Nassau grouper, and B. Dog snapper spawning event (photo by Douglas David Seifert).

Tagging studies — described in the Protocol use either simple identification tags, and/or sonic tags and stationary sonic receivers. While somewhat expensive, tagging studies can be very valuable, detailing both migration patterns and patterns of seasonality and site fidelity. Carter et al. (1994) found a Nassau grouper swam 150 km from Belize to Mexico; Bolden (2000) recorded one that swam 220 km to a spawning aggregation. Zeller (1998) provides an excellent example of the utility of sonic tags in studies of site fidelity, arrival and departure times of fish at an aggregation site, without having to dive. Managers are urged to use identification tags before investing in much more expensive sonic tags, and are urged to consider tags where diving would be too difficult.

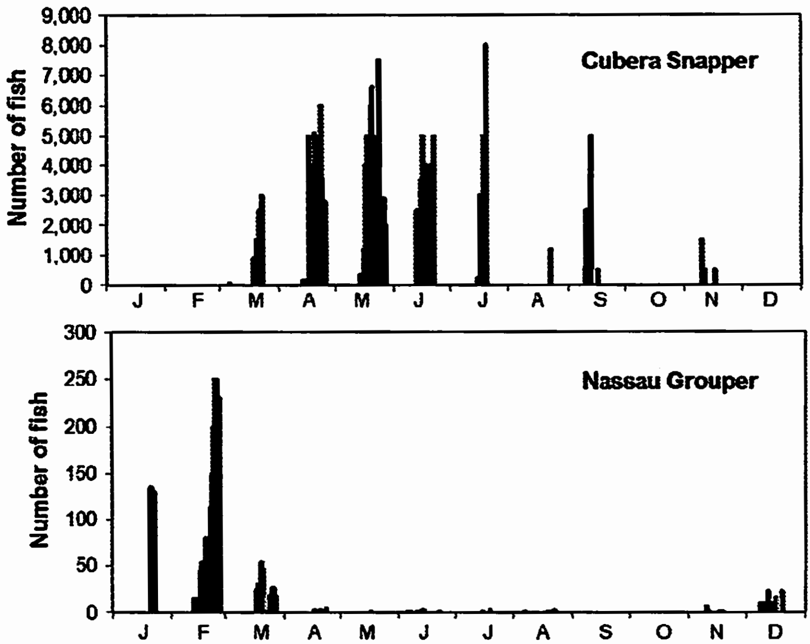


Figure 2. The timing and abundance of spawning aggregations from daily underwater visual surveys for A. Cubera Snapper and B. Nassau Grouper during 2003 at Gladden Spit in Belize. (Data kindly provided by Friends of Nature, Placencia, Belize).

Site maps and descriptions — are valuable for monitoring and assessment of spawning aggregations. A good base map is an essential tool if underwater visual assessments will be conducted regularly at a particular site. Maps of the spawning aggregation sites can also be helpful in the design and zoning of marine protected areas. Detailed methods for creating bathymetric maps that include spawning aggregation sites are described in Ecochard et al. (2003). Additional examples of maps and techniques are referenced in Table 1.

Database Design and Structure

Software was evaluated as a platform for the aggregation monitoring data. The software had to be scalable and flexible to handle the variety of data types and relationships. An automated database governed by a set of predefined rules and standards for the capture, update, and retrieval of data was needed. Microsoft Access 2000®, as a standalone application, offers all the basic features needed to manage the Database, and also has features that will allow for efficient data sharing and cost-effective upgrades. Access® is widely available and offers additional features that other platforms do not and was selected as the platform for the Database.

Access® has a built-in replication tool that can be used to distribute the Database to all participating organizations (see Data Sharing, below). Further, Access® can be used to create an easy-to-use interface to a more scalable and robust back-end database such as Microsoft SQL Server. Alternately, the entire Database can be upgraded to SQL Server.

Minimum hardware requirements for operating the database are:

i) Pentium II personal computer (PC),
ii) 233 Mhz processing speed,
iii) 128Mb of RAM,
iv) 200 Mb of hard disk space available,
v) VGA monitor,
vi) CD writer, and
vii) Internet connection and a reliable e-mail system

The Database stores data in a collection of related and linked tables. Data is entered into these tables through pre-made, automated, digital forms (e.g., Figure 3, the Underwater Visual Survey Data entry form). The four database entities are sites, survey types, organizations, and survey participants. Figure 4 shows the relationships among entities for the Visual Survey in an entity-relationship (ER) diagram. ER diagrams are popular high-level conceptual data models used in the design of database applications. In many cases, data entered for each entity is channeled into a data table for storage and retrieval. In some cases, however, complex entities are broken down into smaller, more stable tables for storage. Each table represents a group of relevant information captured and maintained together.

User Interface

The Database has been designed to be simple and easy to use, with heavy emphasis placed on the design of the user interface. The data entry screens (Figure 3) resemble the data sheets of the Protocol (Adrien 2003a). Whenever possible, data entry has been automated using look-up tables to minimize user entries of new species, new sites, or misspellings of existing entries.

Generating reports with the Database has also been designed to be simple (Figure 5) yet not compromise the functionality and flexibility for the user. The report section offers powerful ways to display survey data. Users can specify parameters of interest for specific comparisons. For example, within a single query, users can select to report either the count or the average of one or many species at one or many sites during any specific year or years (Figure 5).

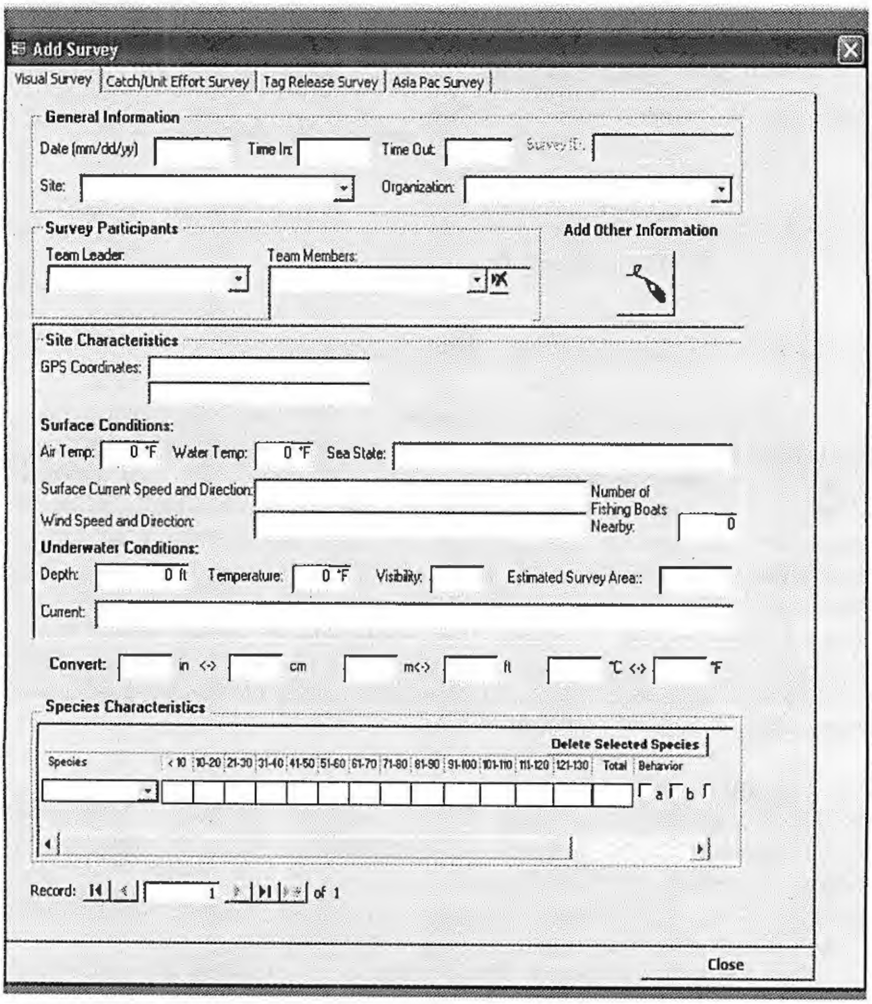


Figure 3. Spawning aggregation database digital entry form for visual underwater survey data.

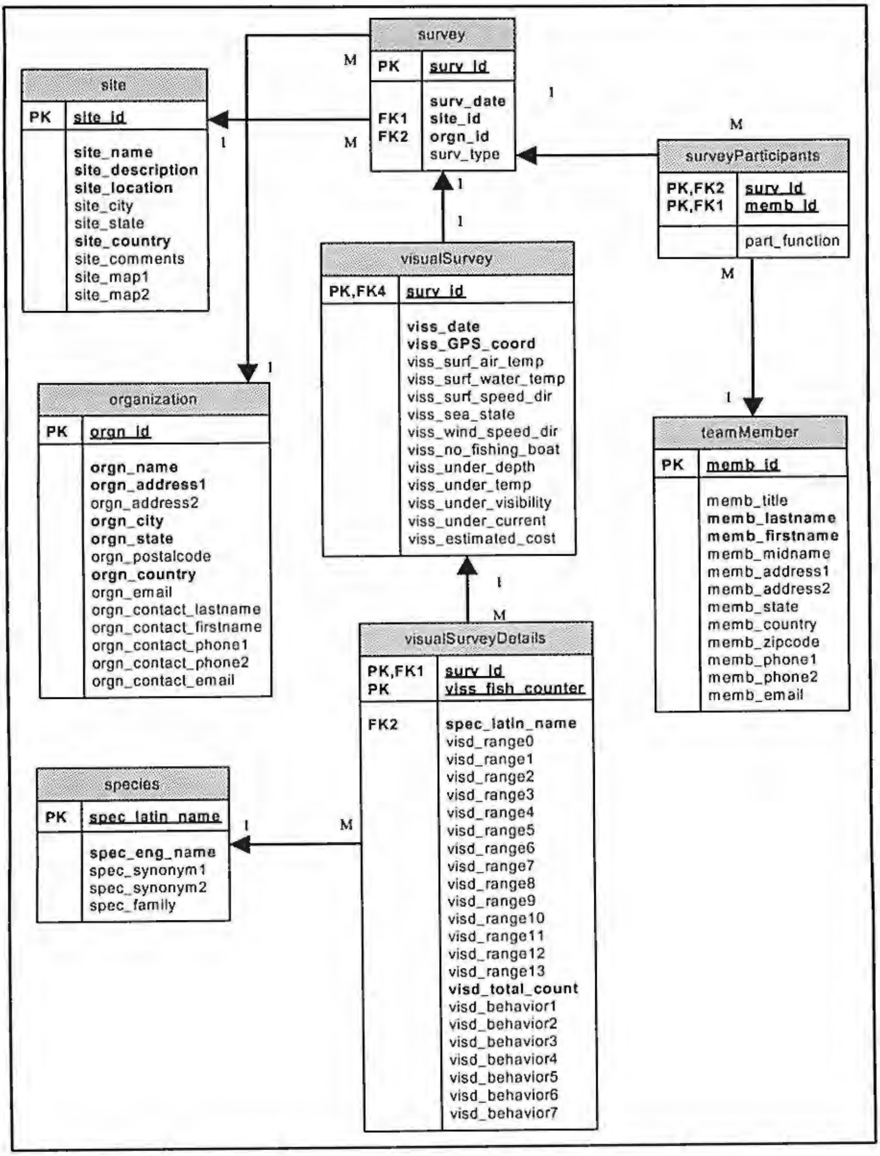


Figure 4. Entity-Relationship (ER) diagram for Visual Survey data from the Database illustrating the relationships between entities. Arrows indicate the type of relationship between entities with "1" (one) and "M" (many) at the end of each arrow.

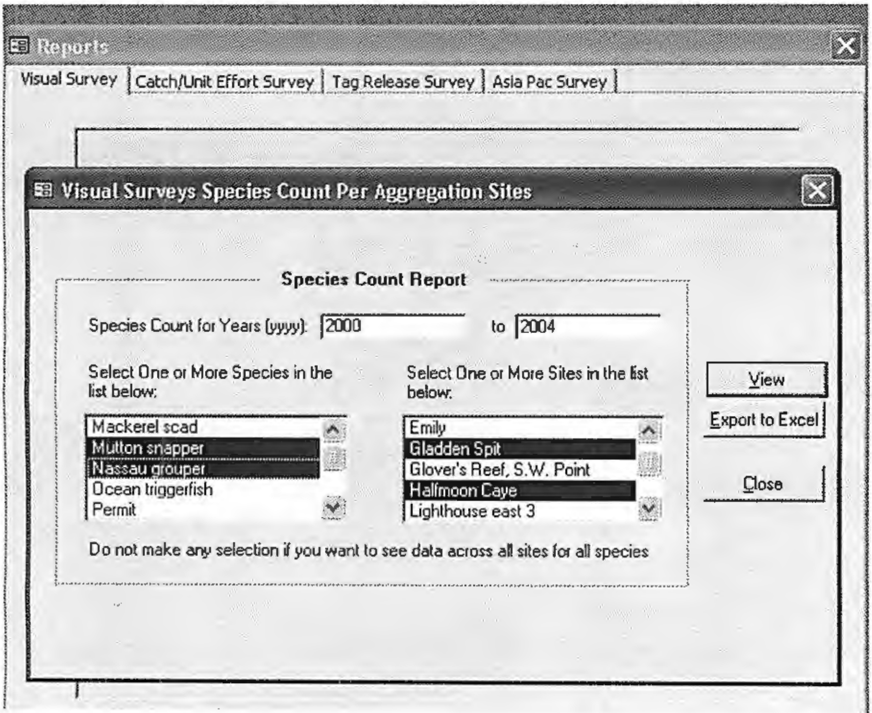


Figure 5. Visual survey report form from the Database illustrating an example of a user-defined query. In this case, a query is requested that will illustrate all entries of visual survey counts for two species (mutton snapper and Nassau grouper) at two sites (Gladden Spit and Halfmoon Caye) over a four-year period, 2000-2004. Users can also choose to see the data within Access, or have the data directly exported to an Excel spreadsheet, or choose another tab for queries using other data sets.

Data Sharing and Distribution

The database was designed with the understanding that many users, in different areas could use the system on a stand-alone PC, but that these data could be combined and shared. The eventual goal is to have the system operational on an SQL server that is accessible to all users over the Internet on a secure site. Web-based systems are more complex and costly to maintain and update, so in the interim, the system relies on desktop systems for individual organizations, each with a full copy of the database and all data. Data are shared and updated by manual replication and synchronization of the various databases (Figure 6). A detailed guide to Access® replication is freely available (Adrien 2003b). The drawback to the stand-alone system is synchronization. If synchronization does not occur regularly some organizations may end up with outdated data, leading to misinterpretation and incorrect reports.

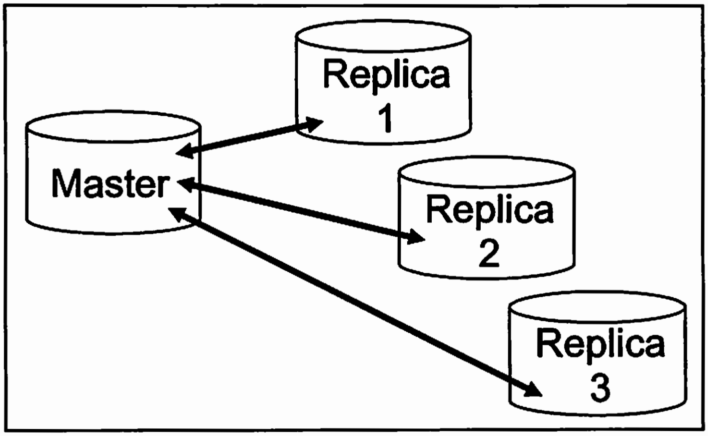


Figure 6. Database structure and replication: the database is designed to be able to be shared among multiple users. Using replication techniques, both the main database (master) and the copies (replicas) can update each other simultaneously.

CONCLUSIONS

As stated in the introduction to the Protocol:

"The purpose of the Protocol is to provide a standardized methodology for the evaluation and routine monitoring and conservation of transient multi-species spawning aggregations along the Meso-American Reef and the wider Caribbean. This document is intended for use by resource managers, conservationists, biologists, fishers, students and trained recreational divers." (Heyman et al. 2004).

The Database is an automated tool for data generated using the Protocol from anywhere in the Caribbean, and it should be noted that it also can serve the same purpose for the Asia-Pacific region. Despite the acceptance of the Protocol and Database by users, we consider both as works in progress. Users are encouraged to evaluate the systems critically, and to provide feedback to the authors such that later releases can benefit.

ACKNOWLEDGEMENTS

Thanks to Nicanor Requena for his extensive work on editing, testing, sharing, and training using this protocol. Thanks to Douglas David Seifert for providing use of Figure 1B. Thanks to the Fisheries Department, Government of Belize and the Belize Spawning Aggregations Working Committee for collaboration and support. Thanks to Friends of Nature for data used in Figure 2. Thanks to the Summit and Oak Foundations for financial support. This work was completed under the auspices of The Nature Conservancy.

LITERATURE CITED

Adrien, G.E. [2003a]. Academic report to The John Hopkins University on The Nature Conservancy's Spawning Aggregation Database. The Nature Conservancy, Arlington, Virginia USA. 41 pp. Unpubl. MS.

Adrien, G.E. [2003b]. User's Guide for The Nature Conservancy's Spawning Aggregation Database. The Nature Conservancy, Arlington, Virginia USA. 27 pp. Unpubl. MS.

Aguilar-Perera. A. 1994. Preliminary observations of the spawning aggregation of Nassau grouper, *Epinephelus striatus*, at Mahahual, Quintana Roo, Mexico. *Proceedings of the Gulf and Caribbean Fisheries Institute* **43**:112-122.

Aguilar-Perrera, A. and W. Aguilar-Dávila. 1996. A spawning aggregation of Nassau grouper, *Epinephelus striatus* (Pisces: Serranidae), in the Mexican Caribbean. *Proceedings of the Gulf and Caribbean Fisheries Institute* **45**:351-361.

Auil-Marshelleck, S. [1994]. A review of the occurrence of fish spawning aggregations in the Caribbean and the implications for fisheries management. Large Pelagics, Reef and Slope Fishes Assessment and Management Sub-Project Specification Workshop, CARICOM Fisheries Resource Assessment and Management Program (CFRAMP), St. Kitts and Nevis. LPRSF Assessment SSW/WP/24. 48 ppp. Unpubl. MS.

Belize Spawning Aggregations Working Committee (BSAWC) [2002]. Spawning Aggregation Data Sharing Agreement Between and Among Belize Audubon Society, Coastal Zone Management Authority & Institute, Fisheries Department, Friends of Nature, Green Reef, The Nature Conservancy, Toledo Institute for the Development and Environment, University of Belize, Wildlife Conservation Society, and World Wildlife Fund. 5 p. Unpubl. MS.

Beets, J. and A. Friedlander. 1999. Evaluation of a conservation strategy: a spawning aggregation closure for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands. *Environmental Biology of Fishes* **55**:91-98.

Bolden, S.K. 2000. Long-distance movement of a Nassau grouper (*Epinephelus striatus*) to a spawning aggregation in the central Bahamas. *Fishery Bulletin* **98**:642-645.

Burton, M.L. 2002. Age, growth and mortality of mutton snapper, *Lutjanus analis*, from the east coast of Florida, with a brief discussion of management implications. *Fisheries Research* **59**:31-41.

Carter, J., G.J. Marrow and V. Pryor. 1994. Aspects of the ecology and reproduction of Nassau grouper, *Epinephelus striatus*, off the coast of Belize, Central America. *Proceedings of the Gulf and Caribbean Fisheries Institute* **43**:64-111.

Claro, R. 1981. Ecología y ciclo de vida del pargo criollo, *Lutjanus analis* (Cuvier), en la plataforma Cubano. Academia de Ciencias de Cuba. Informe Científico-Técnico No. 186. Instituto de Oceanología. Havana, Cuba. 83 pp.

Colin, P.L. 1992. Reproduction of the Nassau grouper, *Epinephelus striatus* (Pisces: Serranidae), and its relationship to environmental conditions. *Environmental Biology of Fishes* **34**:357-377.

Colin, P.L., Y.J. Sadovy, and M.L. Domeier. 2003. Manual for the study and conservation of reef fish spawning aggregations. Society for the Conservation of Reef Fish Aggregations. Special publication No.1 (Version 1.0). (http://www.scrfa.org).

Colin, P.L., D.Y. Shapiro, and D. Weiler. 1987. Aspects of the reproduction of two groupers, *Epinephelus guttatus* and *Epinephelus striatus* in the West Indies. *Bulletin of Marine Science* **40**:220-230.

Crabtree, R.E. and L.H. Bullock. 1998. Age, growth, and reproduction of black grouper, *Mycteroperca bonaci*, in Florida waters. *Fishery Bulletin* **96**:735-753.

Craig, A.K. 1969. The Grouper Fishery of Cay Glory, British Honduras. *The Grouper Fishery* **59**:252-263.

Domeier, M.L. and P.L. Colin. 1997. Tropical reef fish spawning aggregations: defined and reviewed. *Bulletin of Marine Science* **60**(3):698-726.

Domeier, M.L., C. Koenig, and F. Coleman. 1996. Reproductive biology of Gray snapper (*Lutjanus griseus*), with notes on spawning for other Western Atlantic groupers. Pages 189-201 in: F. Arreguín-Sánchez, J.L. Munro, M.C. Balgos and D. Pauly, (eds). *Biology, Fisheries and Culture of Tropical Groupers and Snappers*. ICLARM Conference Proceedings 48, Manila, Philippines.

Ecochard, J.L.B., W.D. Heyman, E. Cuevas, N. Requena, and F.B. Biasi. [2003]. Adaptive Bathymetric System (ABS). The Nature Conservancy, Arlington, Virginia USA. 22 pp. Unpubl. MS.

Fine, J.C. 1990. Groupers in love: spawning aggregations of Nassau groupers in Honduras. *Sea Frontiers* **36**:42-45.

García-Cagide, A., R. Claro, and J.P. García-Arteaga. 1999. Biología del jocú *Lutjanus jocu* (Bloch y Schneider, 1801) (Pises:Lutjanidae) en las zonas NE y SW de la plataforma cubana, 1. Distribución, hábitat, reproducción y dinámica de los indicadores morfofisiológicos. *Revista de Investigaciones Marinas* **20**(1-3):22-29.

García-Cagide, A., R. Claro, and B.V. Koshelev. 2001. Reproductive patterns of fishes of the Cuban shelf. Pages 73-114 in: R. Claro, K.C. Lindeman and L.R. Parenti. *Ecology of the Marine Fishes of Cuba*. Smithsonian Institution Press, Washington, D.C. USA.

García-Cagide, A. and T. García. 1996. Reproducción de *Mycteroperca bonaci* and *Mycteroperca venenosa* (Pisces:Serranidae) en la plataforma Cubana. *Revista de Biología Tropical*.**44**(2):771-780.

Government of Belize. 2003a. Statutory Instrument No. 161 of 2003. Fisheries (Spawning Aggregation Site Reserves) Order, 2003 **161**:1-8.

Government of Belize. 2003b. Statutory Instrument No. 162 of 2003. Fisheries (Nassau Grouper Protection) Regulations, 2003. **162**:1-2.

Heyman, W.D. 1996. *Integrated Coastal Zone Management and Sustainable Development for Tropical Estuarine Ecosystems: A Case Study of Port Honduras, Belize*. Ph.D. Dissertation. University of South Carolina, Columbia, South Carolina USA. 247 pp.

Heyman, W.D. 2004. Conservation of multi-species spawning aggregation sites. *Proceedings of the Gulf and Caribbean Fisheries Institute* **55**:521-529.

Heyman, W., J. Azueta, O. F. Lara, I. Majil, D. Neal, B. Luckhurst, M. Paz, I. Morrison, K.L. Rhodes, B. Kjerfve, B. Wade, and N. Requena. [2004]. Spawning Aggregation Monitoring Protocol for the Meso-American Reef and the Wider Caribbean. Version 2.0. Meso-American Barrier Reef Systems Project, Belize City, Belize. 55 pp. Unpubl. MS.

Heyman, W.D., B. Kjerfve, R.T. Graham, K.L. Rhodes, and L. Garbutt. [In revision]. Spawning aggregations of Cubera snapper *Lutjanus cyanopterus* (Cuvier) on the Belize Barrier reef over a six-year period. *Journal of Fish Biology*.

Heyman, W.D. and N. Requena. [2002]. Status of multi-species spawning aggregations in Belize. The Nature Conservancy, Technical Report, Punta Gorda, Belize. 27 pp. Unpubl. MS.

Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J. A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner, and R.R. Warner. 2001. Historical overfishing and the recent collapse of coastal ecosystems. *Science* **293** (5530):629-637.

Johannes, R.E. 1978. Reproductive strategies of coastal marine fishes in the tropics. *Environmental Biology of Fishes* **3**:65-84.

Lindeman, K.C., P.A. Kramer, and J.S. Ault. 2001. Comparative approaches to reef monitoring and assessment: an overview. *Bulletin of Marine Science* **69**(2):335-338.

Luckhurst, B.E. 1998. Site fidelity and return migration of tagged red hind (*Epinephelus guttatus*) to a spawning aggregation site in Bermuda. *Proceedings of the Gulf and Caribbean Fisheries Institute* **50**:750-763.

Luckhurst, B.E. 2004. Current status of conservation and management of reef fish spawning aggregations in the wider Caribbean. *Proceedings of the Gulf and Caribbean Fisheries Institute* **55**:530-542.

Medina-Quej, A., R. Herrera-Pavón, G. Poot-López, E. Sosa-Cordero, K. Bolio-Moguel, and W. Hadad. 2004. Estudio preliminar de la agregación del Mero *Epinephelus striatus* en "El Blanquizal" en la costa sur del Quintana Roo, México. *Proceedings of the Gulf and Caribbean Fisheries Institute* **55**:557-569.

Munro, J.L., V.C. Gaut, R. Thompson, and P.H. Reeson. 1973. The spawning season of Caribbean reef fishes. *Journal of Fish Biology* **5**:69-84.

Nemeth, R.S., E. Kadison, S. Herzlieb, J. Blondeau, and E. Whiteman. 2004. Status of yellowfin and Nassau grouper spawning aggregations: Dynamics of a multi-species spawning aggregation site in the USVI. *Proceedings of the Gulf and Caribbean Fisheries Institute* **57**:73-74.

NRC (National Research Council). 1999. Sustaining Marine Fisheries. National Academy Press, Washington, D.C. USA.

Olsen, D.A. and J.A. LaPlace. 1979. A study of a Virgin Islands grouper fishery based on a breeding aggregation. *Proceedings of the Gulf and Caribbean Fisheries Institute* **131**:130-144.

Paz, M. and T. Grimshaw. [2001]. Status report on Nassau groupers for Belize, Central America. Report from the workshop: "Towards a sustainable management of Nassau groupers in Belize." Green Reef. Belize City, Belize. Unpubl. MS.

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**:43-65.

Sadovy, Y. and A. Ecklund. 1999. Synopsis of the biological information on *Epinephelus striatus* (Bloch, 1792), the Nassau grouper, and *E. itajara* (Lichtenstein, 1822), the jewfish. NOAA Tech. Rep. NMFS 146: 65 pp.

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.

Safina, C. 1995. The world's imperiled fish. *Scientific American* **November**:46-53.

Sala, E., R. Starr, and E. Ballesteros. 2001. Rapid decline of Nassau grouper spawning aggregations in Belize: fishery management and conservation needs. *Fisheries* **26**(10):23-30.

Samoilys, M., editor. [1997a]. Manual for assessing fish stocks on Pacific coral reefs. Queensland Department of Primary Industries, Training Series QE 97009, Brisbane, Australia. 78 pp. Unpubl. MS.

Samoilys, M.A. 1997b. Periodicity of spawning aggregations of coral trout *Plectropomus leopardus* (Pisces: Serranidae) on the northern Great Barrier Reef. *Marine Ecology Progress Series* **160**:149-159.

Shapiro, D. Y., Y. Sadovy, and M.A. Mcghee. 1993. Size, Composition, and Spatial Structure of the annual spawning aggregation of the red hind, *Epinephelus guttatus* (Pisces: Serranidae). *Copeia* **2**:399-406.

Smith, C.L. 1972. A spawning aggregation of Nassau grouper, *Epinephelus striatus* (Bloch). *Transactions of the American Fisheries Society* **101**:257-261.

Sosa-Cordero, E. and J.L. Cárdenas-Vidal. 1996. Estudio preliminar de la pesquería de mero *Epinephelus striatus* de Sur de Quintana Roo, México. *Proceedings of the Gulf and Caribbean Fisheries Institute* **44**:56-72.

The Nature Conservancy. [2003a]. R^2-Reef Resilience Toolkit. The Nature Conservancy, Arlington, Virginia USA. DVD.

The Nature Conservancy. [2003b]. Introduction to Monitoring and Management of Spawning Aggregations and Aggregation Sites for Three Indo-Pacific Pacific Grouper Species: A Manual for Field Practitioners. The Nature Conservancy, Bali, Indonesia. Unpubl. MS.

Thresher, R.E. 1984. *Reproduction in Reef Fishes*. TFH Publications, Neptune City, New Jersey USA.

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.

Tucker, J.W. Jr., P.T. Bush, and S.T. Slaybaugh. 1993. Reproductive patterns of Cayman Island Nassau Grouper (*Epinephelus striatus*) populations. *Bulletin of Marine Science* **52**:961-969.

Whaylen, L., C.V. Pattengill-Semmens, B.X Semmens, P.G. Bush, and M.R. Boardman. 2004. Observations of a Nassau grouper, *Epinephelus striatus*, spawning aggregation site in Little Cayman, Cayman Islands, including multi-species spawning information. *Environmental Biology of Fishes* **70** (3):305-313.

Zeller, D. 1998. Spawning aggregations: patterns of movement of the coral trout, *Plectropomus leopardus* (Serranidae), as determined by ultrasonic telemetry. *Marine Ecology Progress Series* **162**:253-263.

Spawning Locations for Atlantic Reef Fishes off the Southeastern U.S.

GEORGE R. SEDBERRY, O. PASHUK, D.M. WYANSKI,
J.A. STEPHEN, and P. WEINBACH
South Carolina Department of Natural Resources
P.O. Box 12559
Charleston, South Carolina 29422-2559 USA

ABSTRACT

Spawning condition was determined for 28 species of reef fish representing 11 families (Balistidae, Berycidae, Carangidae, Centrolophidae, Haemulidae, Lutjanidae, Malacanthidae, Polyprionidae, Scorpaenidae, Serranidae, Sparidae) collected off the Carolinas, Georgia and east coast of Florida (including the Keys) in depths from 1 - 686 m. The presence of migratory-nucleus oocytes, hydrated oocytes and/or postovulatory follicles was used to indicate imminent or very recent spawning, and locations of capture of fishes in spawning condition were mapped using GIS. Reproductive behavior was observed from submersible for a few species. Most fishes were collected from fishery-independent sampling, with time and location of collection accurately recorded. Some specimens were sampled from fishery landings, and time and location data were approximate. Samples came from all months and throughout the region, but sampling effort was not equally distributed and was concentrated from May through September and in the middle of the region (South Carolina and Georgia). In spite of some temporal and spatial sampling limitations, we determined that several species such as small serranids, haemulids, sparids and lutjanids spawn over protracted periods and throughout the region. Other species such as *Helicolenus dactylopterus, Caulolatilus microps, Epinephelus niveatus, Lopholatilus chamaeleonticeps, Hyperoglyphe perciformis* and *Polyprion americanus* have specific habitat requirements and live and spawn in very restricted areas. Several species (*Mycteroperca microlepis, M. phenax*) appear to spawn at specific shelf-edge reef sites (50 - 100 m depth), and tagging indicated they may undertake migrations to those specific sites during the spawning season. Some of the shelf-edge sites are utilized by several species, including some with moderately protracted spawning seasons that peak during winter or summer months. These sites may be in nearly continuous use by spawning fishes year-round, and should be considered as no-take MPAs to protect spawning adults.

KEY WORDS: Essential Fish Habitat, Geographic Information Systems, Marine Protected Areas

Sitios de Desove de Peces de Arrecife en el Atlántico Sudeste (USA)

Se determino la condición de desove de 28 especies de peces de arrecife representando a 11 familias (Balistidae, Berycidae, Carangidae, Centrolophidae, Haemulidae, Lutjanidae, Malacanthidae, Polyprionidae, Scorpaenidae, Serranidae, Sparidae). Los especímenes se obtuvieron en las aguas de las Carolinas, Georgia y de la costa este de la Florida (incluyendo los Cayos) en profundidades de 16 a 686 m. La presencia de ovocitos con núcleo migratorio, ovocitos hidratados y/o folículos postovulatorios se utilizo para acertar el desove inminente o muy reciente. Los sitios de captura de peces en condición de desove fueron trazados usando Sistemas de Información Geográfica (SIG). El comportamiento reproductivo de algunas especies fue observado desde un sumergible. La mayoría de los especímenes fueron obtenidos mediante muestreo independiente de la pesca, con el tiempo y el sitio de los muestreos registrados exactamente. Algunos de los especímenes se obtuvieron por medio de la industria pesquera, y la hora y los datos del sitio de captura son aproximados. Las muestras provinieron de todos los meses del año y de toda la región, pero el esfuerzo del muestreo no se distribuyo igualmente sino que se concentro de mayo a octubre y en el centro de la región (Carolina del Sur y Georgia). A pesar de los límites del muestreo, determinamos que varias especies tales como serranids pequeños, haemulids, sparids y lutjanids desovan durante períodos prolongados y por toda la región. Otras especies tales como *Helicolenus dactylopterus*, *Caulolatilus microps*, *Epinephelus niveatus*, *Lopholatilus chamaeleonticeps*, *Hyperoglyphe perciformis* y *Polyprion americanus* tienen requisitos específicos del habitat y viven y desovan en áreas muy restringidas. Aparentemente varias especies (*Mycteroperca microlepis*, *M. phenax*) desovan en sitios específicos de 50 a 100 m en el borde del continente, y de acuerdo con estudios de marqueo, estas especies emprenden migraciones a esos sitios específicos durante la estación de desove. Algunos de los sitios del borde del continente son utilizados por varias especies, incluyendo algunas con estaciones de desove moderadamente prolongadas que alcanzan su punto más alto durante los meses de invierno o verano. Los peces pueden utilizar estos sitios para el desove casi continuamente a lo largo del año, y por lo tanto estas áreas se deben considerar como Áreas de Conservacion Marinas donde no se permite la captura de ninguna especie para proteger el desove de peces adultos.

PALABRAS CLAVES: Áreas de Conservacion Marinas, hábitat esencial para peces, Sistemas de Información Geográficos

INTRODUCTION

In the re-authorization of the Magnuson-Stevens Fishery Conservation and Management Act, through the Sustainable Fisheries Act, the U.S. Congress included provisions that required fishery management councils to identify essential fish habitat (EFH). Such EFH should include "those waters and substrate necessary to fish for spawning, feeding or growth to maturity" (Schmitten 1999). The Magnuson Act re-authorization also provided for recognition of Habitat Areas of Particular Concern (HAPC) for various fish stocks or assemblages (e.g., Murawski et al. 2000). HAPC are areas where some user activities (e.g., trawling, bottom longlining) are banned because of particularly sensitive habitats or species assemblages such as ivory tree coral (*Oculina varicosa*) and associated organisms (Reed 2000). In order to manage fisheries under EFH and HAPC provisions, it is necessary to recognize and map EFH and HAPC, and to more clearly define them in relation to the fishery management unit (e.g., the Snapper-Grouper Complex of the U.S. South Atlantic Fishery Management Council). Spawning grounds, by definition, are EFH. Likewise, spawning areas must certainly qualify as HAPC, as spawning habitats are important in the life history of fishes and, for reef fishes in particular, often contain sensitive species assemblages such as corals and sponges.

In tropical and warm-temperate zones, many reef fishes undergo migrations to spawn at particular reef sites that probably possess hydrographic regimes or biological assemblages that enhance survival of offspring. Many species of coral reef fish spawn in large aggregations, wherein large portions of a dispersed population migrate to specific sites at specific times of the year to spawn (Domeier and Colin 1997). Because of the physical and biological conditions that are apparently favorable for survival of eggs and larvae, many different species use the same sites on tropical coral reefs (e.g., Carter and Perrine 1994). As a first step in mapping EFH and HAPC it is essential to determine where fishes spawn, where fishes that aggregate to spawn gather in spawning condition, and what sites are important spawning locations for multiple species, so that these areas can be given further considerations for management, such as area closures, that protect spawning fish. Determination of precise spawning times is essential for establishing time closures that might protect spawners and enhance recruitment. For species with protracted spawning periods, or for areas used as spawning grounds by many species that spawn at different times of the year, permanent closure of the grounds may be needed to protect spawning assemblages of fishes. Of greatest priority is determining spawning grounds for exploited reef fishes, especially those that are exploited during the spawning season when they are aggregated at specific locations and times. Off the southeastern United States, such priority species and habitats include at least some of the 73 species of the Snapper-Grouper Complex (e.g., snappers, groupers, porgies, grunts, tilefishes) that are managed by the South Atlantic Fishery Management Council (SAFMC), and their hard-bottom and sponge-coral habitats.

The South Carolina Department of Natural Resources (SCDNR) has conducted research since 1973 on the continental shelf and slope off the southeastern U.S., in an area often referred to as the South Atlantic Bight (SAB), from Cape Hatteras to Cape Canaveral. Some surveys have extended south to the Florida Keys, and offshore to the Charleston Bump area of the Blake Plateau. Through cooperative programs with federal resource management agencies, the SCDNR has conducted basic descriptive faunal surveys, fishery assessment surveys, monitoring surveys, and studies directed at specific resource management problems. Surveys have included sampling of demersal fishes with a variety of fishing gear; and hydrographic, benthic and ichthyoplankton sampling (e.g., Wenner 1983, Mathews and Pashuk 1986, Collins and Stender 1987, McGovern, Sedberry and Harris 1998, Harris et al. 2001). Various cooperative state-federal projects at SCDNR have conducted detailed life history studies of many reef fishes. These have included descriptions of age and growth, reproduction, feeding habits, early life history, movements determined by tagging, and population genetics (e.g., Collins and Stender 1987, Sedberry and Cuellar 1993, Van Sant et al. 1994, Sedberry et al. 1999, McGovern et al. 1998). Ichthyoplankton (1973-1984), trawl (1973-1987) and trap (1978-2004) surveys have included region-wide annual sampling cruises. Studies of reproductive biology of reef fishes have included determination of spawning times and frequencies (e.g., Cuellar et al. 1996). Tagging studies have indicated movements to locations suspected to be spawning grounds (Van Sant et al. 1994).

Data from the published studies cited above, from monitoring and sampling that has continued since those publications, and a substantial database on other species of the region are available for additional analyses. Of particular interest in a re-analysis of the historical data is the goal of using recently developed spatial and geographic analysis tools unavailable or not considered when many of the original data analyses were performed. Spatial analysis tools such as Geographic Information Systems (GIS) can be used on these databases to determine areas that support greater abundance, biomass and/or diversity of fishes. The databases can also be examined to describe distribution of individual species in relation to bottom and hydrographic features. Importantly, the databases can be queried for locations of fish in spawning condition, locations where large numbers of juveniles are found (recruitment areas) and locations where early larvae of priority species are found (spawning areas). Mapping of EFH and HAPC for reef fishes off the southeastern U.S. Atlantic coast is of particular importance at this time, as increasing demands are placed on the resource (see Coleman et al. 2000 for review). The consumption of fishes by humans has increased dramatically in the last several decades because of increases in human population, per-capita consumption of seafood, and advances in fishing technology. Reef fishes such as those of the warm-temperate hard-bottom reefs in the SAB appear to be particularly at risk, and many species are undergoing overfishing, are overfished, or are in danger of being so (Coleman et al. 2000, NMFS 2004). Severe restrictions, including size limits, bag limits, closed seasons and limited entry have been imposed on a species-by-species basis by the SAFMC. More restrictions might be needed; for example, the fishery for red porgy in the U.S. Atlantic was closed in 1999 because of extremely low spawning potential. The economic value of the reef species complex makes protecting the sustainability of the fishery a critical consideration for this region. Commercial reef fish landings in the SAB from 1980-1996 were roughly 147 million lbs, with an ex-vessel value near $186 million (www.st.nmfs.gov/st1/commercial/landings/annual_landings.html).

Many economically important reef fish species share a suite of life history and behavioral characteristics that make them particularly susceptible to overexploitation. These characteristics include long life, large adult size, late maturity, protogyny, and spawning in aggregations or at sites that are predictable in time and space (Coleman et al. 2000). Predictable spawning aggregations are particularly well-documented in tropical reef fishes, and the negative impacts of fishing these aggregations are well-known (Craig 1969, Carter et al. 1994, Domeier and Colin 1997, Sala et al. 2001). Although some studies have presented evidence for spawning aggregations of gag (*Mycteroperca microlepis*) on temperate reefs of the Gulf of Mexico (Coleman et al. 1996), it is uncertain if such aggregations represent a major regional spawning ground, as has been documented for some tropical groupers (Carter et al. 1994), and what the effects might be of fishing such aggregations if they do represent the major reproductive output for a large region. There are few data available on spawning locations, times and behavior of reef fishes of the SAB, but there is some circumstantial evidence for aggregations of some species such as gag. Circumstantial evidence includes long-distance migrations that sometimes coincide with the spawning season, and are thought to be movements toward pre-spawning aggregations or movements to actual spawning sites (Van Sant et al. 1994, McGovern et al. in press). Additional circumstantial evidence for spawning aggregations of gag in the SAB includes capture of fish in spawning condition (presence of migratory-nucleus oocytes, hydrated oocytes or post-ovulatory follicles) at specific depths such as deep shelf edge reefs (MARMAP unpublished data). Such capture might represent spawning aggregations that should certainly be classified as EFH. If fishermen target these aggregations, additional HAPC consideration should be given to current management plans, so that such spawning sites can be protected during the spawning season. If such spawning sites are used by many species for much of the year, additional protection should be provided in the form of no-take MPA designation.

Spawning aggregations in reef fishes are believed to correspond spatially and temporally with hydrographic features that insure greatest survival of early life history stages. For this reason, many species utilize the same locations for spawning, often at different times of the year (e.g., Carter et al. 1994, Carter and Perrine 1994). These hydrographic features are often associated with prominent bottom features that influence circulation near (and downstream from) the spawning banks (Carter et al. 1994, Sedberry et al. 2001, Govoni and Hare 2001). Many reef fishes with pelagic eggs and larvae spawn in the vicinity of gyres near the shelf edge (Johannes 1978). Such topographically-produced gyres are implicated in removal of pelagic eggs from the spawning site, thus reducing predation, while retaining fish eggs and larvae for the ultimate return of larvae to the shelf at later developmental stages that can avoid some predation. Such gyres may carry eggs and larvae toward ideal post-larval settlement habitat, or toward areas of high larval fish food production. Along the continental shelf edge of the SAB, there are areas of gyres and upwelling that are associated with high nutrients and plankton productivity (Paffenhöffer et al. 1984, Mathews and Pashuk 1986). Small occasional frontal eddies and meanders that propagate northward along the western edge of the Gulf Stream provide small-scale upwellings of nutrients along the shelf break in the SAB (Miller 1994). Such intermittent upwellings might coincide with reef fish spawning times and locations. In addition to these intermittent upwellings, there are two more permanent upwelling areas in the SAB. One is located just to the north of Cape Canaveral and is caused by diverging isobaths (Paffenhöfer et al. 1984). The other much larger and stronger upwelling occurs mainly between 32°N and 33°N (Atkinson 1985, Mathews and Pashuk 1986) and results from a deflection of the Gulf Stream offshore by the topographic irregularity known as the Charleston Bump (Bane et al. 2001). Off of South Carolina and North Carolina, the large meander set up by the Charleston Bump forms the Charleston Gyre, an eddy with upwelled water at its core, and which moves shoreward across the edge of the shelf and may be important in reef fish recruitment.

The presence of high nutrients at the shelf edge, and a gyre mechanism to transport larvae from shelf-edge spawning to estuarine nursery habitats influences recruitment success in gag (Sedberry et al. 2001). Recruitment in gag and some other fishes is correlated with the location, strength, and persistence of the Charleston Gyre (Sedberry et al. 2001, Govoni and Hare 2001). It is likely that spawning of gag and other reef fishes off the Carolinas is timed and located to take maximum advantage of the hydrographic conditions created by the Charleston Bump complex from 32°N and 33°30'N (Sedberry et al. 2001, Govoni and Hare 2001). Other intermittent upwelling sites along the shelf edge of the SAB, and the more permanent upwelling north of Cape Canaveral might also be important spawning grounds. Life history and spawning strategies of reef fishes might be timed to coincide with different upwelling types, times and locations. For example, fishes that spawn in a few large aggregations might utilize areas of more permanent gyres, while fishes with protracted seasons (spawning many times) might use more intermittent upwelling areas. Such areas might be considered EFH or HAPC, and it is important to map prominent and persistent hydrographic features in relation to distribution of fish larvae, juveniles and adults to determine the spatial relationships among life history stages and hydrographic features.

As a result of overfishing and the apparent inability of traditional methods to reverse declines in abundance of deep reef fishes, the SAFMC has proposed a series of Marine Protected Areas (MPAs) that could include no-take marine reserves (SAFMC 2004). The SAFMC has recently gone through an exercise in siting MPAs that included obtaining input from user groups, interested parties, and the general public, along with some review of existing biological and habitat data. Of prime concern is protecting those spawning habitats and locations that are essential to completing the life cycles of overfished species. Also of concern is placement of MPA networks to maximize spawning potential and recruitment of larvae from protected areas to harvest areas and to other protected areas in order to provide fishing opportunities while conserving spawning stock biomass. Additional study of distribution of individual reef fish species and spawning sites in relation to bottom habitats and faunas, and the relationship of bottom features to hydrographic features and proposed MPA sites, is needed. These data are needed to maximize the effectiveness of severe management measures, such as no-take reserves, that are perceived to be an extreme burden on commercial and recreational reef fish fishermen. By strategic placement of MPAs in networks based on biological and oceanographic data, it is hoped that the maximum positive effect can be achieved with the minimum impact on fishermen. It is imperative to collect and summarize such biological and oceanographic data, particularly data on spawning locations and recruitment pathways.

We have utilized a 30-year fishery-independent database to build a GIS that has mapped distributions of species, and their abundance, biomass and diversity. We have also mapped data on gonad condition for several fishery species using this database and some fishery-dependent sampling. In this paper we will describe some of the results aimed at locating spawning grounds for reef fishes. We hypothesize that species that appear to form large aggregations do so at specific sites and times that are related to cyclical yet permanent hydrographic features. We also hypothesize that species that appear to have protracted spawning in small widely-distributed groups may use ephemeral features such as those that form intermittently during summer and fall. The purpose of this paper is to report on the results of a temporal and spatial analysis of the data available on reproduction in several species of reef fish, in order to determine locations of EFH and HAPC for spawning reef fishes, and sensitive areas that might need intensive management in the form of temporal, spatial or some combination of no-take Marine Protected Areas (MPAs).

METHODS

Study Area, Field Methods and Databases

The MARMAP (Marine Resources Monitoring, Assessment and Prediction) fishery-independent database that went into this analysis consisted of a variety of demersal fish surveys conducted from several research vessels (Figure 1, Table 1). Details of sampling can be obtained from the senior author. Briefly, fish surveys generally covered the region from Cape Fear, North Carolina to Cape Canaveral, Florida, with some stations outside that range. Surveys were conducted with bottom trawls (e.g., Wenner et al. 1979, Wenner 1983), baited fish traps (Collins 1990), bottom longlines and hook-and-line (Harris et al. 2004). MARMAP trawling was conducted from 1973 to 1987, in depths from 9 - 366 m. Trawl stations were established randomly within depth and latitude strata; along transects perpendicular to the coast; or at index monitoring sites in reef habitat. Those index stations were also sampled with fish traps from 1978 to the present; however, since 1987 the trap survey has been conducted at randomly chosen reef points (e.g., McGovern, Sedberry and Harris 1998), many of which are at or near the trap index stations sampled from 1978 - 1986.

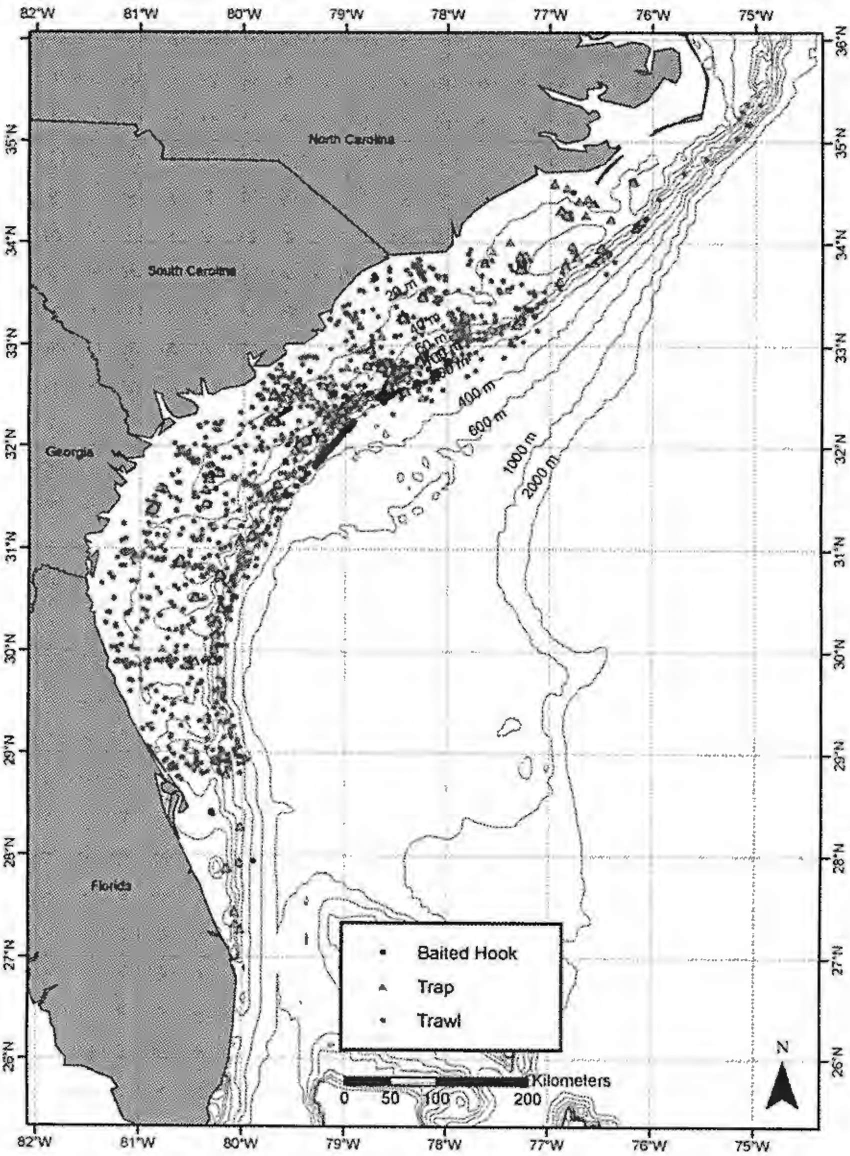


Figure 1. Sampling locations, by fishery-independent gear type, for specimens used in the spatial and temporal analysis of reef fish spawning.

Table 1. Summary of primary sampling gear used in collection of specimens; and months, years, latitude and depths of collections. Ind = fishery-independent samples; Dep = fishery-dependent samples.

Gear	Number of Collections	Month Range	Year Range	Latitude Range (°N)	Depth (m) Range	Ind	Dep
Conductivity-temperature-Depth (CTD) cast	1393	Mar - Oct	1987 - 2003	27.2 - 34.6	15 - 789	X	X
Blackfish trap	3298	Jan - Dec	1977 - 1999	30.7 - 34.3	15 - 65	X	X
Chevron fish trap	6185	Mar - Dec	1987 - 2003	27.2 - 34.6	13 - 218	X	X
Florida snapper trap	1710	Feb - Sep	1980 - 1989	30.4 - 34.3	15 - 196	X	
Mini-Antillean S-trap	157	Jan - Feb May - Sep	1977 - 1980	30.7 - 33.7	19 - 75	X	
Bottom longline	502	Jan - Dec	1982 - 2003	27.9 - 38.7	15 - 500	X	X
Kali pole bottom longline	199	May - Sep	1982 - 1986	32.0 - 32.8	44 - 229	X	
Vertical longline	305	Feb - Mar May - Sep	1979 - 2003	28.2 - 34.2	49 - 220	X	X
Hook and line (rod & reel)	369	Jan - Dec	1983 - 2003	26.0 - 34.4	1 - 234	X	X
Snapper reel	3226	Jan - Dec	1974 - 2003	18.2 - 34.7	11 - 256	X	X
Wreckfish reel	452	Jan - Dec	1989 - 2003	25.8 - 32.0	396 - 838	X	X
Falcon net (23-m otter trawl)	232	Apr Aug - Oct	1986 - 1989	29.1 - 33.9	3 - 13	X	X
Fly net (16-m bottom trawl)	145	Feb Apr - Sep	1980 - 1987	31.6 - 34.3	15 - 35	X	X
Otter trawl (18-m semi-balloon)	1071	Jan - Dec	1980 - 1987	28.7 - 34.9	4 - 20	X	X
Yankee trawl (3/4 scale)	1214	Jan - Dec	1973 - 2001	28.7 - 40.6	9 - 686	X	
Spear gun	38	Feb - Aug Oct, Dec	1988 - 2002	26.0 - 32.5	17 - 52		X

In order to sample deeper habitats, we employed experimental longline gear, directed at two habitat types: upper continental slope reefs (100 - 250 m) and mud-bottom tilefish grounds (175 - 225 m).

Data collected from each sampling gear included location, hydrographic parameters (measured with CTD), species composition, abundance, biomass, and length frequency of all fish species caught. Stations were located using LORAN-A, LORAN-C, or GPS, and the best available navigation technology was used at the time of fishery-independent sampling. All fish samples from fishery-independent sampling that were processed for reproductive studies were obtained using LORAN-C or differential GPS navigation.

Subsamples of certain priority species in the catches (Table 2) were dissected to obtain otoliths and gonad tissues. For those fishes, all appropriate lengths and weights were measured and the otoliths and gonads removed. Gonads were fixed in the field in 10% seawater formalin solution.

In addition to samples collected during the fishery-independent surveys, we sampled commercial catches to obtain a full size range of specimens or to obtain samples outside of the months (generally May through September) that fishery-independent sampling occurred. Samples were processed in the field and lab in the same manner as those collected during fishery-independent surveys; however, precise catch time and location were not always available. Catch location was often reported as a National Marine Fisheries Service (NMFS) Reef Fish Logbook statistical grid cell number. Those cells are one degree of latitude by one degree of longitude or about 10,440 km^2 for this region. Deficiencies in time and location data were noted in the data analysis.

Laboratory Processing of Gonad Samples

Reproductive tissues were vacuum infiltrated and blocked in paraffin, and then sectioned (7 mm thickness) on a rotary microtome. Three sections from each sample were placed on a glass slide, stained with double-strength Gill's hematoxylin and counter-stained with eosin Y. Sections were viewed under a compound microscope at 40 - 400X and for most species two readers independently assigned sex and reproductive state with criteria from Harris et al. (2004) for gonochorists and from Wenner et al. (1986), Harris and McGovern (1997) and McGovern et al. (1998) for hermaphrodites. Date of capture, specimen length, and specimen age were unknown to the readers. If the assessments differed, both readers viewed the slide simultaneously and agreement was reached. Spawning females of all species had at least one of the following structures in histological sections:

i) Migratory-nucleus oocytes,
ii) Hydrated oocytes, or
iii) Postovulatory follicles.

Table 2. Species on which SCDNR has collected life history samples from which data on sex and reproductive state were obtained for spatial and temporal analysis.

Family / Scientific Name	Common Name
Berycidae	
Beryx decadactylus	red bream
Scorpaenidae	
Helicolenus dactylopterus	blackbelly rosefish
Polyprionidae	
Polyprion americanus	wreckfish
Serranidae	
Centropristis ocyurus	bank sea bass
Centropristis striata	black sea bass
Cephalopholis cruentata	graysby
Cephalopholis fulva	coney
Diplectrum formosum	sand perch
Epinephelus adscensionis	rock hind
Epinephelus drummondhayi	speckled hind
Epinephelus flavolimbatus	yellowedge grouper
Epinephelus morio	red grouper
Epinephelus nigritus	warsaw grouper
Epinephelus niveatus	snowy grouper
Mycteroperca interstitialis	yellowmouth grouper
Mycteroperca microlepis	gag
Mycteroperca phenax	scamp
Malacanthidae	
Caulolatilus microps	blueline tilefish
Lopholatilus chamaeleonticeps	tilefish
Carangidae	
Seriola dumerili	greater amberjack
Lutjanidae	
Lutjanus campechanus	red snapper
Rhomboplites aurorubens	vermilion snapper
Haemulidae	
Haemulon aurolineatum	tomtate
Haemulon plumieri	white grunt
Sparidae	
Calamus nodosus	knobbed porgy
Pagrus pagrus	red porgy
Centrolophidae	
Hyperoglyphe perciformis	barrelfish
Balistidae	
Balistes capriscus	gray triggerfish

Data Manipulation, Standardization and GIS Analysis

Data from the surveys (fishery-independent and -dependent) and laboratory analysis were incorporated into a database that could be queried for species identification, collection data, sex and reproductive state. The database also included hydrographic measurements taken by CTD deployed at the same time as the fish collections (± 2 h), and within one kilometer of the fish collection sites. We queried the database for the priority species for which we had reproductive data (Table 2) and exported the data to ESRI ArcInfo ArcMap 9.0 for spatial analysis. We plotted location of capture of all specimens of each species, and overlaid location of capture of spawning females (as defined above) on the same map. Where relevant, we included on each map the location of proposed no-take (no bottom fishing) MPAs that are currently under consideration by the SAFMC (SAFMC 2004). We also analyzed occurrence of spawning females by month to define spawning season and temporal peaks in spawning activity. We calculated mean (± one standard deviation) and range of bottom temperatures recorded when spawning females of each species were collected. Data reported in tables were from fishery-independent sampling only, and depth, location, time and temperature data are accurate. Maps generated from the GIS analysis included approximate locations from some fishery-dependent samples, and those are differentiated on the maps.

RESULTS AND DISCUSSION

Fishery-independent sampling effort was not equally distributed, either spatially or temporally (Figure 1, Table 1), and was concentrated from May through September and in the middle of the region (South Carolina and Georgia). Fishery-dependent samples provided accurate temporal information (± 5 days) on spawning times for those months not sampled during fishery-independent surveys, but location data, particularly those collected by NMFS, were often "rounded" to the nearest degree of latitude and longitude.

In spite of some temporal and spatial sampling limitations, we found that fish species examined exhibited a variety of spatial patterns of spawning activity, with respect to their general distribution, habitat features and in relation to other species. Several species such as small serranids, haemulids, sparids and lutjanids spawned over protracted periods and throughout the region (Table 3).

Black sea bass (*C. striata*), a small serranid, were distributed across the continental shelf throughout the region, generally in depths less than 60 m (range: 2 - 130 m). Of 30,170 examined to determine sex and reproductive state, 2251 were spawning females (Table 3). Spawning sites were located throughout the region in depths of 15 - 56 m (Figure 2), although most were found mainly in the middle of the SAB. Spawning females were collected during most months of the year (Table 4), with a major spawning period of February through April. In contrast, black sea bass north of Cape Hatteras spawn mainly from June through September (Able et al. 1995); however, spawning times here were similar to those found in the Gulf of Mexico

[December to April (Hood et al. 1994)]. Bottom water temperatures where spawning females were collected ranged from 11.45 to 26.57°C (Table 3, N = 898 independent measurements).

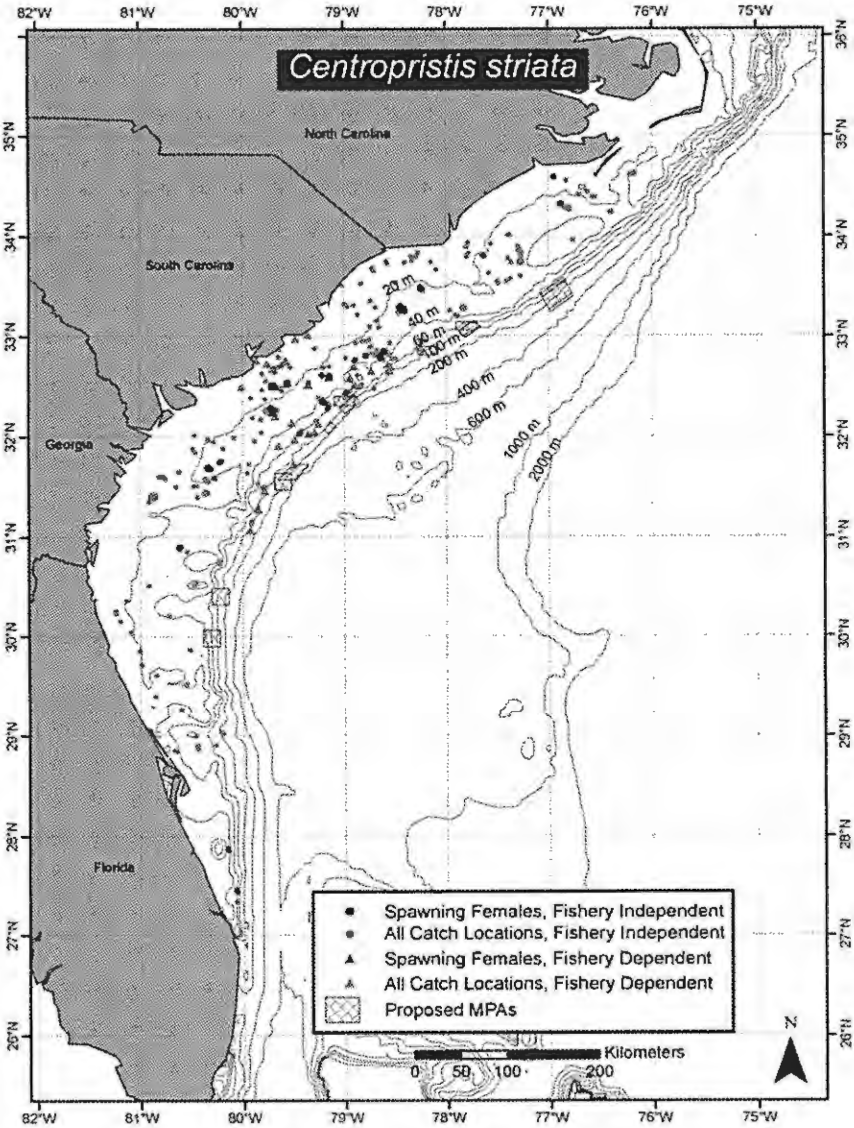


Figure 2. Locations of capture of black sea bass, including all captures and capture of spawning females, by survey type (fishery-independent vs. fishery-dependent). Sites proposed as MPAs that would prohibit bottom fishing are also shown.

Table 3. Collection data for species examined for spawning activity. Data include total number of specimens collected, number examined to determine sex and reproductive state, and number found to be spawning females; depth of capture of all specimens and of spawning females; latitude range (°N) of collections of spawning females; and bottom temperatures (mean, standard deviation and range) where spawning females were collected. Depth, latitude, and temperature data were from fishery-independent sampling. In some cases (-), data were not available.

Species	Total Specimens			Capture Depth	Spawning Depth	Spawning Latitude	Spawning Temperatures (°C)		
	Collected	Exam	Spawning (m)	(m)	(°N)	Mean	sd	Range	
B. capriscus	7582	4349	141	13 - 128	20 - 75	27 - 33	22.41	1.96	18.87 - 27.42
B. decadactylus	17	16	8	-	-	-	-	-	-
C. nodosus	3210	1181	88	21 - 155	45 - 60	31 - 32	21.92	0.68	20.10 - 22.67
C. microps	1344	1112	514	46 - 256	48 - 234	32 - 32	14.91	2.12	8.87 - 16.28
C. ocyurus	20754	2402	52	1 - 146	27 - 57	32 - 32	16.81	0.63	16.24 - 18.63
C. striata	118059	30170	2251	2 - 130	15 - 56	27 - 34	18.88	2.68	11.45 - 26.57
C. cruentata	11	7	0	30 - 50	-	-	-	-	-
C. fulva	24	18	1	39 - 58	39	33	23.80	-	23.80 - 23.80
D. formosum	12830	780	634	9 - 84	17 - 47	27 - 34	23.55	3.09	14.03 - 28.50
E. adscensionis	43	34	5	33 - 83	37 - 53	32 - 32	21.75	1.51	20.05 - 23.96
E. drummondhayi	427	274	5	28 - 114	-	32 - 32	-	-	-
E. flavolimbatus	1000	73	6	31 - 205	160 - 194	32 - 32	14.47	-	14.47 - 14.47
E. morio	2390	2223	46	22 - 95	30 - 90	32 - 34	21.01	2.09	16.97 - 24.08
E. nigritus	21	12	1	48 - 168	168				

Table 3. Continued.

Species	Total Specimens			Capture Depth (m)	Spawning Depth (m)	Spawning Latitude (°N)	Spawning Temperatures (°C)		
	Collected	Exam	Spawning				Mean	sd	Range
H. dactylopterus	4280	1381	138	38 - 686	229 - 238	32 - 32	-	-	-
H. perciformis	353	102	12	181 - 520	-	-	-	-	-
L. chamaeleonticeps	3552	2431	324	62 - 311	190 - 300	31 - 32	13.02	1.96	10.16 - 14.90
L. campechanus	1225	778	80	7 - 240	24 - 67	27 - 33	23.16	2.02	18.05 - 27.59
M. interstitialis	29	18	9	27 - 84	49 - 51	32 - 32	-	-	-
M. microlepis	7329	5363	1848	15 - 117	24 - 117	26 - 33	17.26	-	17.26 - 17.26
M. phenax	3759	2467	351	17 - 113	33 - 93	29 - 32	21.18	1.84	15.60 - 24.08
P. pagrus	22732	15687	457	9 - 307	26 - 57	30 - 32	16.88	0.89	16.24 - 18.99
P. americanus	2067	1466	55	44 - 653	433 - 595	31 - 31	-	-	-
R. aurorubens	41455	11798	3280	14 - 163	18 - 97	27 - 34	23.37	2.01	16.01 - 28.09
S. dumerili	2797	2498	250	15 - 216	45 - 122	24 - 33	23.71	0.00	23.71 - 23.71

Table 4. Spawning periods for fishes examined. Spawning percentage = percent of female specimens in spawning condition. Dark gray indicates major spawning period. Light gray indicates months of spawning activity.

Species	# Females	Spawning Percentage	Percentage in spawning condition by month											
			Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
B. capriscus	2259	6.24	0.0	0.0	0.0	0.0	2.7	10.0	13.0	2.4	0.0	0.0	0.0	0.0
B. decadactylus	11	72.73	-	-	-	0.0	0.0	100.0	100.0	100.0	100.0	-	0.0	0.0
C. nodosus	752	11.70	0.0	0.0	2.6	55.4	76.5	2.2	2.8	0.0	0.0	0.0	-	0.0
C. microps	619	83.04	0.0	100.0	66.7	68.8	89.4	84.2	92.7	75.7	91.1	86.4	-	-
C. ocyurus	1267	4.10	13.6	45.0	26.1	29.6	0.2	0.0	0.0	0.0	0.0	15.4	14.8	0.0
C. striata	19740	11.40	0.0	31.5	79.9	35.6	20.5	0.6	6.4	0.2	2.9	0.0	15.1	0.0
C. cruentata	4	0.00	-	-	0.0	-	-	-	0.0	-	-	-	-	-
C. fulva	8	12.50	-	-	-	-	-	100.0	0.0	0.0	-	-	-	-
D. formosum	779	81.39	-	-	-	-	100.0	95.8	78.4	77.0	64.1	-	-	-
E. adscensionis	12	41.67	-	-	100.0	-	100.0	20.0	0.0	-	-	-	-	-
E. drummondhayi	169	2.96	-	0.0	0.0	0.0	2.5	6.8	0.0	2.9	0.0	-	-	0.0
E. flavolimbatus	52	11.54	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	27.8	-	-	-
E. morio	2058	2.24	0.0	2.8	3.5	13.3	2.3	3.6	0.0	0.0	0.0	0.0	0.0	0.0
E. nigritus	9	11.11	-	0.0	-	-	50.0	0.0	0.0	-	-	-	-	0.0
E. niveatus	533	18.01	0.0	0.0	0.0	3.1	28.7	7.1	19.0	31.3	15.0	-	-	0.0
H. aurolineatum	925	25.73	-	0.0	-	0.0	58.1	31.3	31.1	0.0	0.0	-	-	-
H. plumieri	1227	12.31	0.0	0.0	2.4	10.8	23.4	26.4	1.1	0.9	3.9	0.0	0.0	0.0
H. dactylopterus	548	25.18	38.5	57.8	77.1	37.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
H. perciformis	68	17.65	14.3	-	-	-	50.0	-	0.0	-	-	0.0	21.4	22.2
L. chamaeleonticeps	1161	27.91	1.4	1.3	40.0	76.2	85.6	66.1	18.8	1.7	0.7	0.0	1.3	0.0
L. campechanus	402	19.90	8.7	0.0	0.0	0.0	15.2	27.3	56.0	28.1	41.2	18.2	0.0	0.0
M. interstitialis	12	75.00	-	50.0	100.0	0.0	-	0.0	-	100.0	-	-	-	-
M. microlepis	4872	37.93	11.8	39.6	57.3	50.2	3.6	0.0	0.0	0.0	0.0	0.0	0.0	1.2
M. phenax	1988	17.66	0.0	1.1	39.2	53.0	64.1	8.8	3.6	0.4	0.0	0.0	0.0	0.0
P. pagrus	10870	4.20	88.5	64.0	33.3	3.5	0.1	0.0	0.0	0.0	0.1	0.0	48.0	43.5
P. americanus	793	6.94	14.7	77.8	92.9	16.4	1.7	0.0	0.0	0.0	0.0	0.0	1.0	3.1
R. aurorubens	8666	37.85	0.0	0.0	0.0	8.6	24.0	41.9	59.7	40.2	34.6	0.0	0.0	0.0
S. dumerili	1363	18.34	1.9	5.7	14.1	49.1	53.5	4.4	0.0	0.0	0.0	0.0	0.0	0.0

Bank sea bass (*C. ocyurus*) were also broadly distributed across the shelf throughout the region (Figure 3), but appeared to prefer deeper waters than black sea bass (range 1 - 146 m). Of 2402 examined for sex and reproductive state, only 52 were spawning females, and all of those were collected in depths of 27-57 m off South Carolina in October through May (Tables 3-4). The major spawning period was February through April. Spawning females were collected in water temperatures that ranged from 16.24 to 18.63°C (n = 21).

Sand perch (*D. formosum*) were also widely distributed across the shelf (Figure 4), generally in depths less than 60 m (range 9 - 84 m). The sand perch appears to be much less dependent on reef habitat, and was often taken in trawl collections over sandy bottom (e.g., Wenner et al. 1979, Darcy 1985). More than 80% of the female sand perch examined were in spawning condition. Spawning females (n = 634) were collected throughout the region from May through September at depths of 17 - 47 m (Tables 3-4). Bottom temperatures at spawning sites ranged from 14.03 to 28.50°C (n = 596). A similar spawning season (April-October) was reported from the southern Caribbean (Obando and Leon 1989) and Bortone (1971) reported peak ovary maturation in May in the northern Gulf of Mexico.

Like sand perch, tomtate (*H. aurolineatum*) were found across the shelf throughout the region. Spawning females (n = 238 of 2412 examined) occurred on middle and outer-shelf reefs (Figure 5) and were collected from May through July in depths from 15-54 m (Tables 3-4). Bottom temperatures at spawning sites ranged from 20.16 to 28.04°C (n = 232).

Red snapper (*L. campechanus*) were also widely distributed across the shelf (Figure 6, Table 3), but appeared to spawn at mid- to outer-shelf depths (24 - 67 m). Of 778 red snapper examined for sex and reproductive state, 80 were spawning females. Spawning females were collected in January and May through October in the waters off South Carolina to Florida (Table 4). The major spawning period was June through September. Red snapper spawned at temperatures ranging from 18.05 to 27.59°C (Table 3; n = 41). Red snapper were reported to spawn in the northeastern Gulf of Mexico from April through October (Collins et al. 2001).

Vermilion snapper (*R. aurorubens*) were ubiquitous in collections on the middle and outer shelf, and were found in depths from 14 - 163 m (Figure 7, Table 3). Spawning females (n = 3280 of 11,798 fish examined) were found at nearly all depths and latitudes where vermilion snapper occurred. Vermilion snapper spawned in depths from 18 to 97 m and at temperatures from 16.01 to 28.09°C (n = 2511). Spawning occurred from April through September, with a major spawning period of May through September (Table 4). Spawning appears to be slightly more protracted than in the Gulf of Mexico [May to September (Hood and Johnson 1999)].

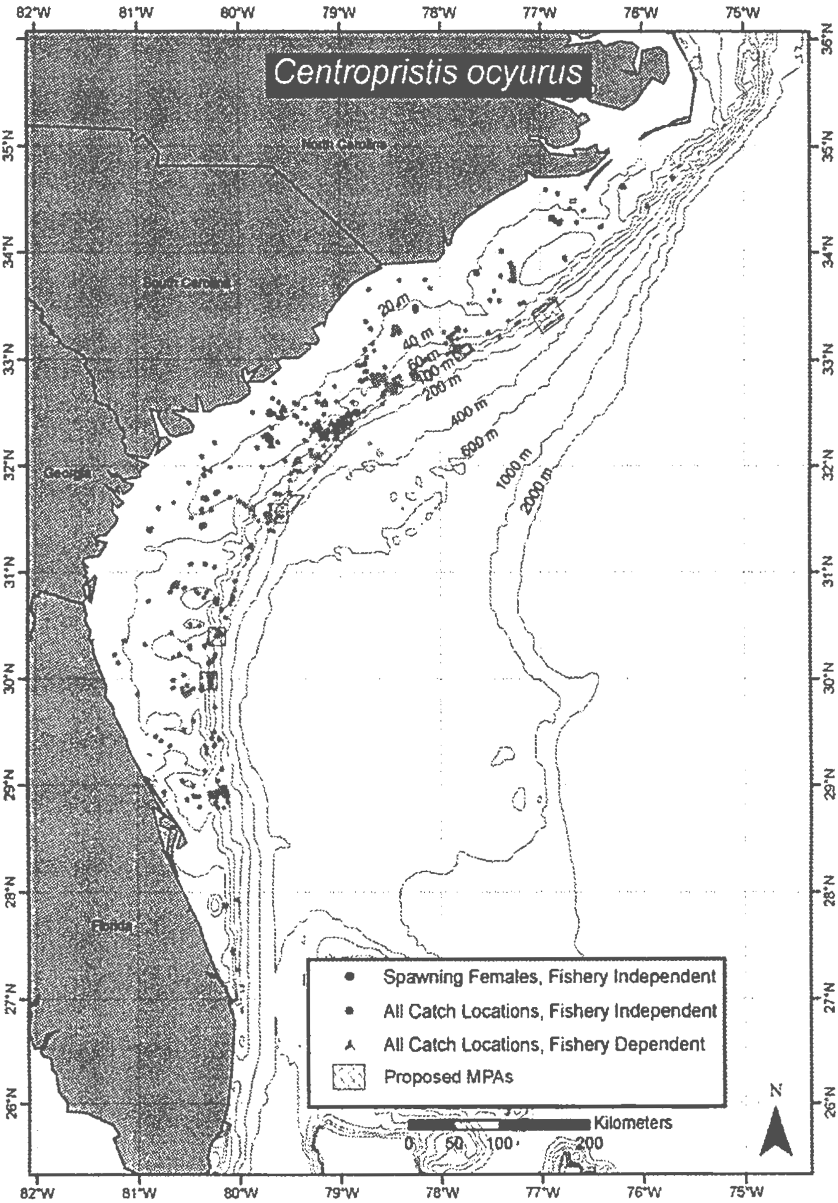


Figure 3. Locations of capture of bank sea bass. See Figure 2 for additional explanation.

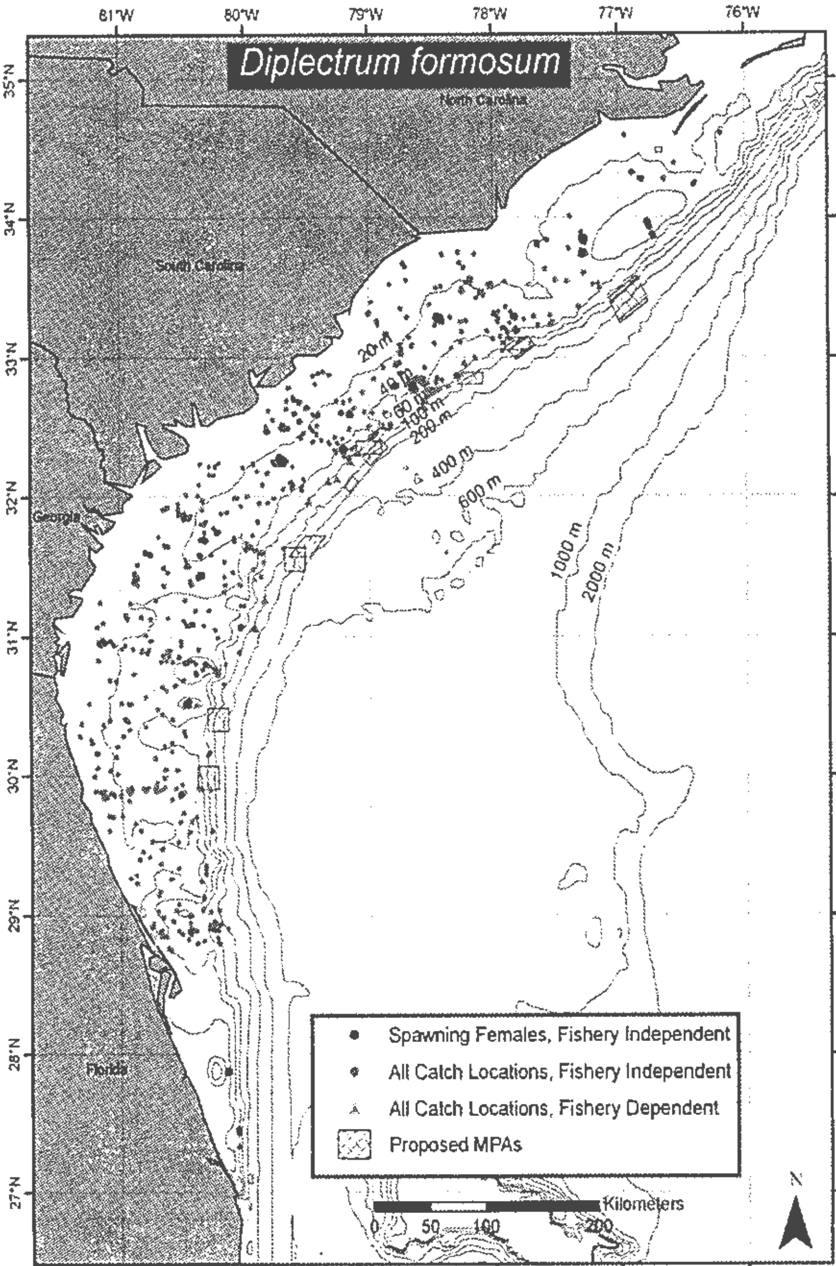


Figure 4. Locations of capture of sand perch. See Figure 2 for additional explanation.

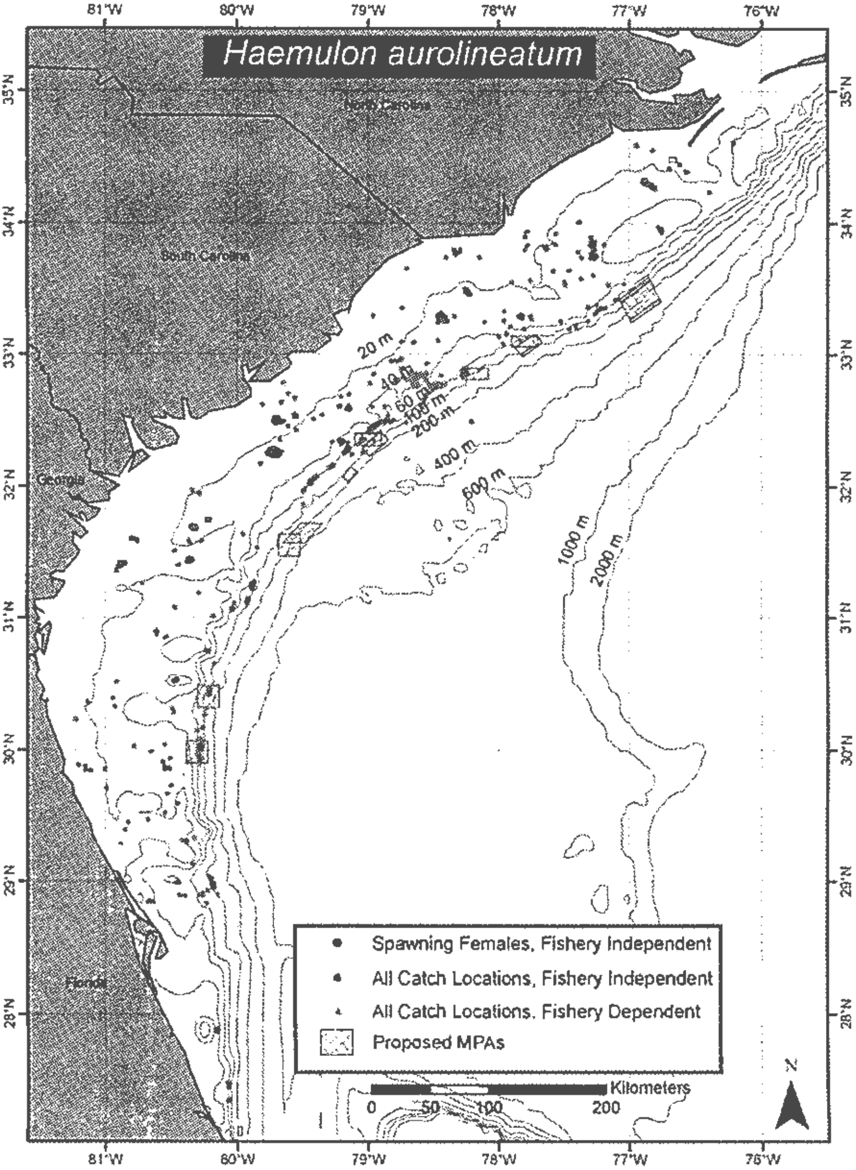


Figure 5. Locations of capture of tomtate. See Figure 2 for additional explanation.

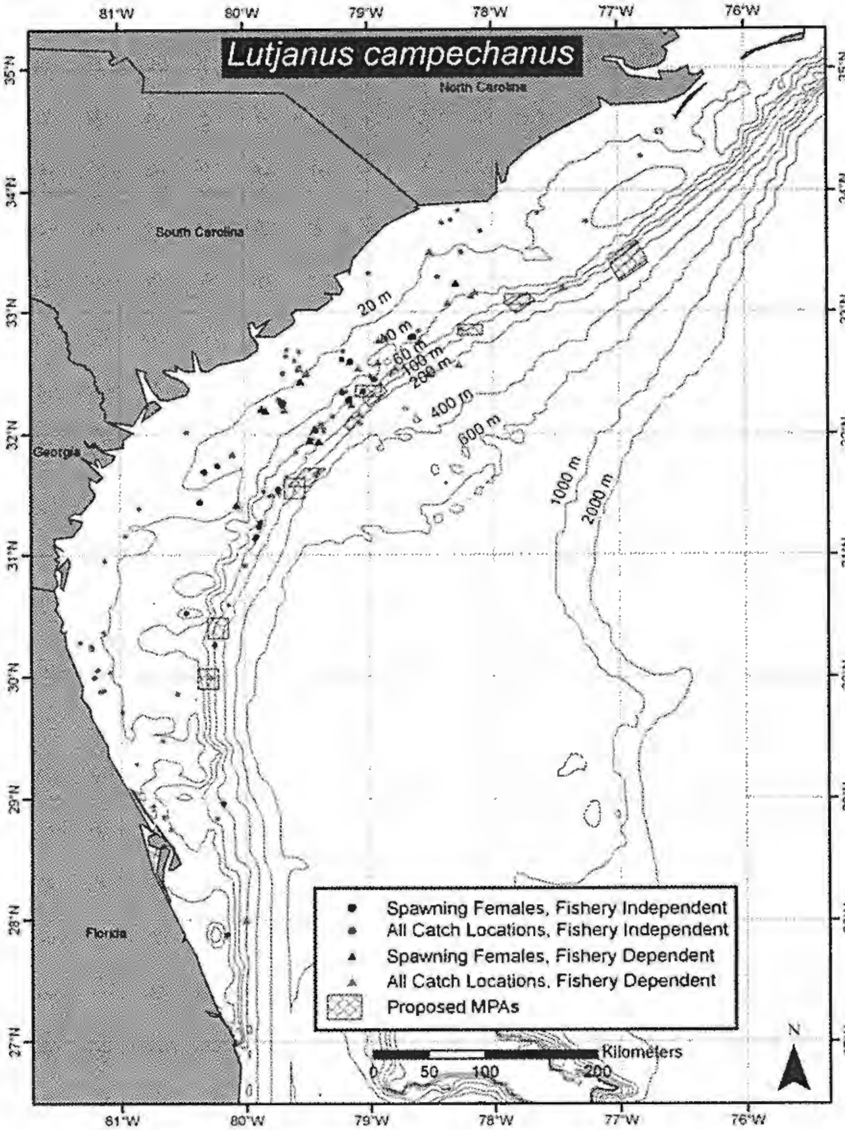


Figure 6. Locations of capture of red snapper. See Figure 2 for additional explanation

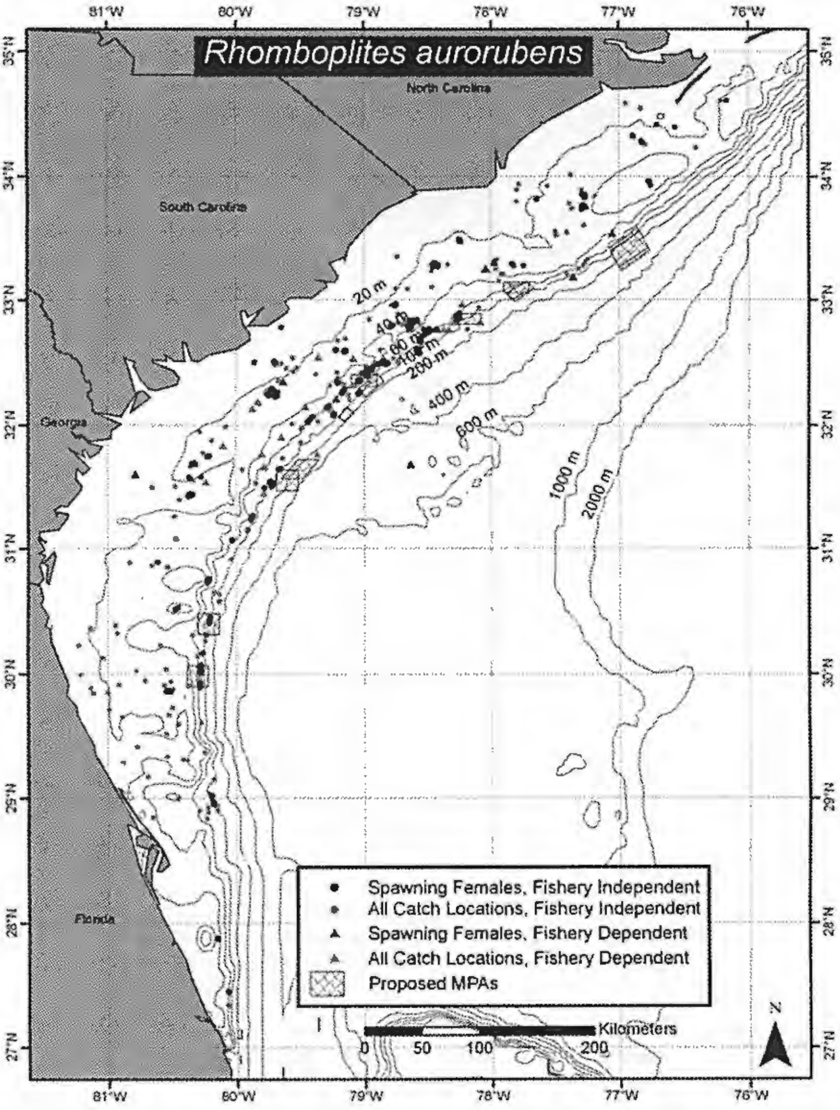


Figure 7. Locations of capture of vermilion snapper. See Figure 2 for additional explanation.

Several species (*Mycteroperca microlepis, M. phenax, Balistes capriscus, Calamus nodosus, Pagrus pagrus and Seriola dumerili*) appeared to spawn at specific shelf-edge reef sites (50 - 100 m depth) in spite of being generally distributed across the shelf. Gag (*M. microlepis*) were caught throughout the region (15 - 117 m) during fishery-independent sampling (Table 3, Figure 8).

Because gag are winter-early spring spawners (from December through May), few were collected during research cruises that sampled mainly from May through September. However, fishery-dependent sampling yielded many female gag in spawning condition from throughout the region. Of 5,363 gag obtained from all sampling, 1,848 were spawning females. Most fishery-dependent samples were landed under an emergency rule that required fishermen to land gag with the gonads intact so that researchers could determine sex ratios and other aspects of reproduction (McGovern et al. 1998). Unfortunately, the emergency rule did not require accurate location data and catch locations were often reported in NMFS sampling grid cells (Figure 8). In spite of the inaccuracy in location, it appears that gag spawn at shelf-edge reefs, in depths from 24 - 117 m, primarily from February through April (Table 4), at a bottom temperature of 17.26°C (only one measurement). Gag in the Gulf of Mexico spawn slightly earlier than we found here [December to May, with peak activity occurring during February and March (Hood and Schlieder 1992)].

Scamp (*M. phenax*) were found mainly on middle- and outer-shelf reefs throughout the region (Table 3, Figure 9). Spawning females (n = 351 of 2,467 examined) were found at shelf-edge reefs from northern Florida to South Carolina from February to August (Table 4), with a major spawning period of March through May. In the Gulf of Mexico, scamp spawning peaks from late February to early June (Coleman et al. 1996). Spawning females were collected at depths of 33 - 93 m and water temperatures from 15.60 - 24.08°C (Table 3; n = 131). We observed scamp engaged in courtship behavior like that described by Gilmore and Jones (1992) at shelf-edge reefs off northern Florida and South Carolina in summer of 2002 and 2004 (off St. Augustine, 28 July 2002, 29.9°N, 80.3°W, 60 - 61 m depth, 1000 EDT, 19.46 - 19.49°C; off St. Augustine, 29 August 2004, 30.0°N, 80.3°W, 59 m, 0912 EDT, 17.8°C; off Jacksonville, 30 July 2002, 30.4°N, 80.2°W, 56 - 85 m depth, 1923 - 1929 EDT, 20.90 - 20.94°C; ESE of Charleston, 1 August 2002, 32.3°N, 79.0°W, 56 - 61 m depth, 1818-1829 EDT, 20.47 - 22.03°C). These observations involved one gray-head (apparent) male scamp and one to a few apparent females. Courtship behavior was observed, but not any spawning. As described by Gilmore and Jones (1992), scamp occurred in various color phases; individual fish were constantly in motion, and changed rapidly between different color morphs. Apparent females (usually one or two, but up to five, courted by single apparent males) tended to remain in the "brown phase", whereas the apparent males switched between "gray-head" phase when pursuing females, and "cat's paw" phase when turning away from apparent females. These behaviors were observed in the morning and late afternoon. Spawning was not observed, but as in other groupers (Carter et al. 1994) that may occur after sunset (Harris et al. 2002), when we were not making observations. Bottom temperatures during our observations were similar to those observed by Gilmore and Jones (1992) during spawning activity in scamp.

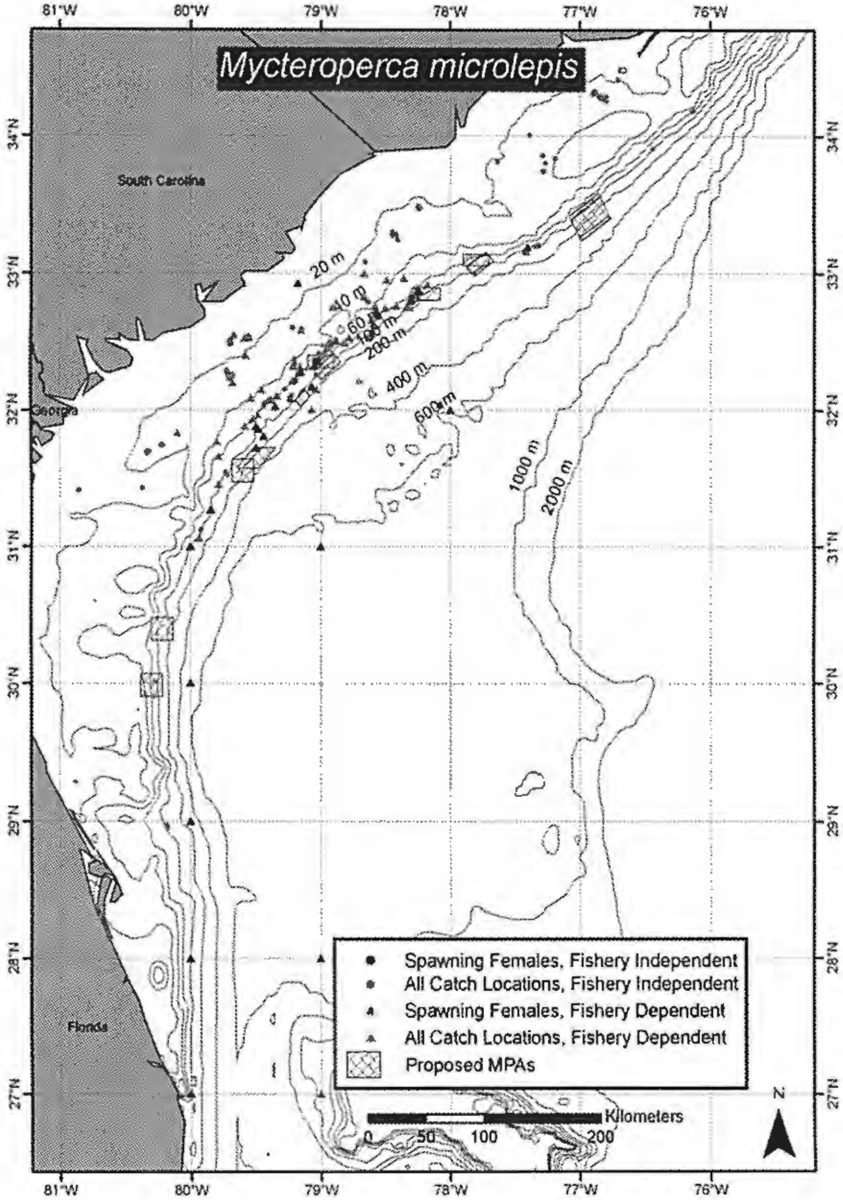


Figure 8. Locations of capture of gag. See Figure 2 for additional explanation. Note that all spawning locations deeper than 175 m are from fishery-dependent collections, reported from NMFS statistical areas (see Methods).

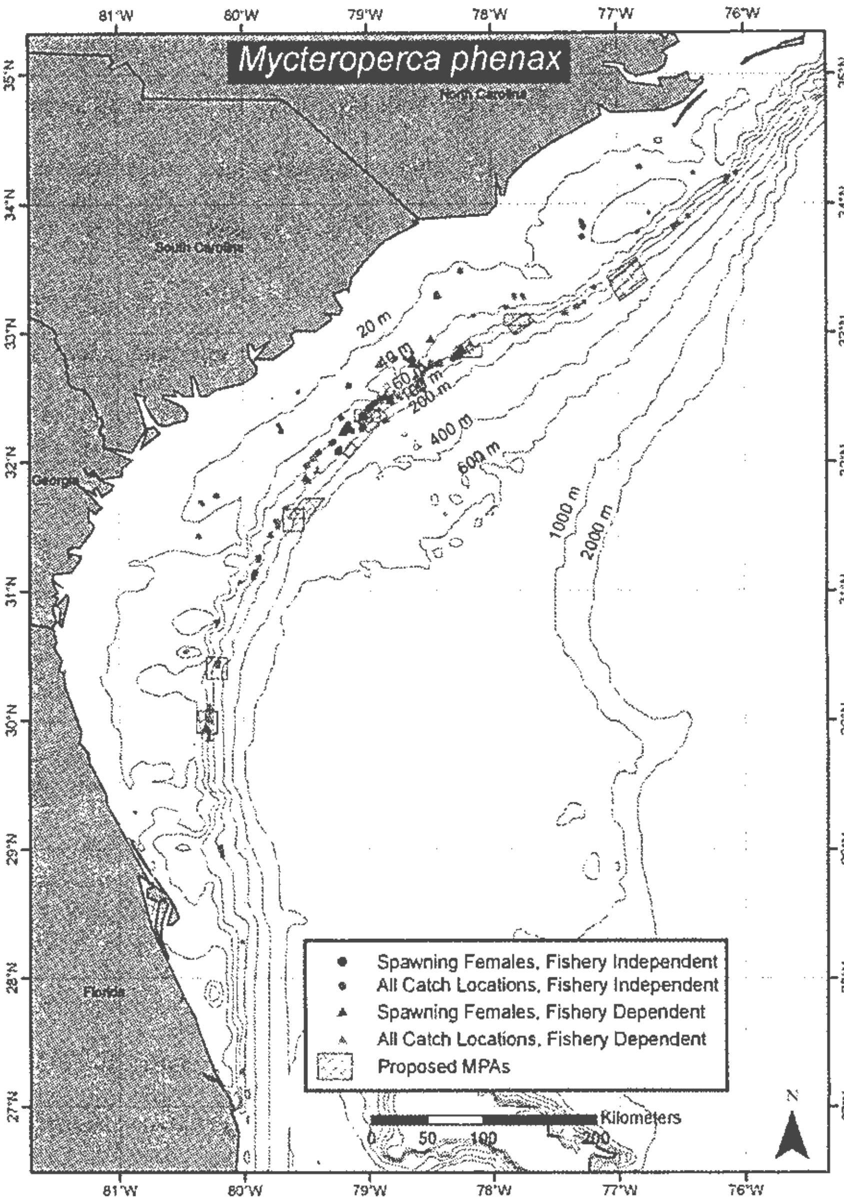


Figure 9. Locations of capture of scamp. See Figure 2 for additional explanation.

Greater amberjack (*S. dumerili*) occurred on middle- and outer-shelf and upper-slope reefs throughout the region and were captured at depths of 15 - 216 m (Table 3; Figure 10). We examined 2,498 gonads, 250 of which were from spawning females. Spawning females were collected from depths of 45 to 122 m. Only two spawning specimens were obtained from research cruises, and they were collected at a water temperature of 23.71°C. Spawning females were collected from January through June, with a major spawning period in April and May (Table 4). Most (88%) spawning greater amberjack were collected by commercial fishermen in the Florida Keys during a special effort aimed at obtaining gonads for determining fecundity, sex ratios and spawning season. Most (95%) spawning females were collected from waters south of 30°N latitude, although there is evidence for spawning off the Carolinas and Georgia too.

Knobbed porgy (*C. nodosus*) were more restricted to mid- and outer-shelf reefs off the Carolinas and Georgia (21 - 155 m, Figure 11). Spawning females were found almost exclusively at outer-shelf reefs and occurred at depths of 45 to 60 m (Table 3). Of 1181 specimens examined for sex and reproductive state, 88 were spawning females (Table 3). Knobbed porgy spawned over a narrow temperature range (49 measurements; range = 20.10 - 22.67°C). Spawning occurred from February through July, with a major spawning period of April through May (Table 4).

Red porgy (*P. pagrus*) were also distributed across the middle and outer shelf throughout the region, and spawning females were collected in depths from 26 - 57 m (Table 3, Figure 12). Of 15,687 examined for sex and reproductive state, 457 were spawning females. Females in spawning condition were found from September through May at bottom temperatures of 16.24 to 18.99°C (n = 18); however, the major spawning period was November through March (Table 4). In the Gulf of Mexico, red porgy spawn from January to April (Hood and Johnson 2000).

Gray triggerfish (*B. capriscus*) were broadly distributed across the shelf (13 - 128 m) throughout the region (Figure 13), but appear to concentrate spawning on middle-shelf to shelf-edge reefs (20 - 75 m). Of 4,349 examined for sex and reproductive state, 141 gray triggerfish were spawning females (Table 3). Gray triggerfish and other balistids construct nests by moving debris and fanning sediments on the bottom, creating a shallow cleared depression. These nests are guarded by either parent for 24 - 48 hours after spawning (Fricke 1980, Lobel and Johannes 1980). On 4 August 2002 (32.8° N, 78.3°W; 54 m; 20.58°C) we observed a large (~30 cm TL) gray triggerfish hovering over a cleared depression about 75 cm in diameter. An apparent egg mass could be observed in the bottom of the depression. Gray triggerfish spawned from May through August, with a major spawning period of June and July (Table 4), at temperatures of 18.87 - 27.42°C (N = 148; Tables 3. Gray triggerfish also spawn in warmer months (peak in November and December) in the southeastern North Atlantic [Ghana (Ofori-Danson 1990)].

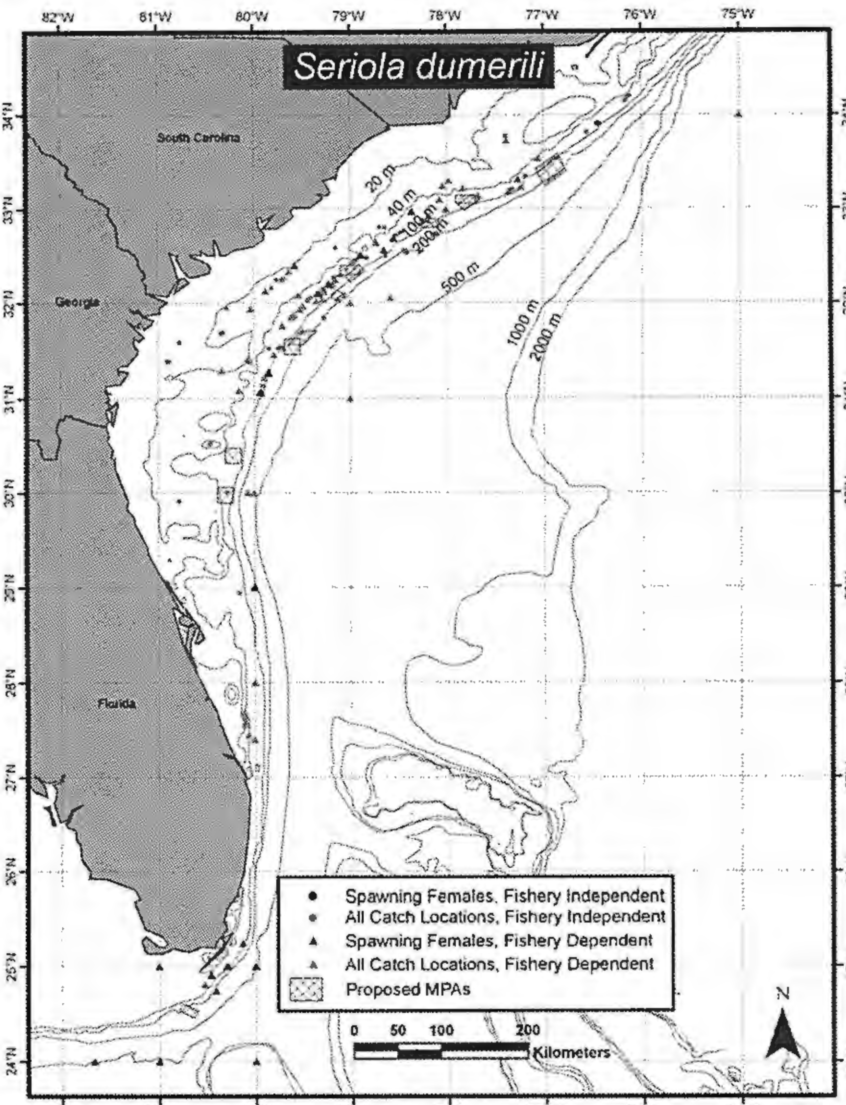


Figure 10. Locations of capture of greater amberjack. See Figure 2 for additional explanation. Note that some fishery-dependent collections in south Florida are as reported from NMFS statistical areas (see Methods).

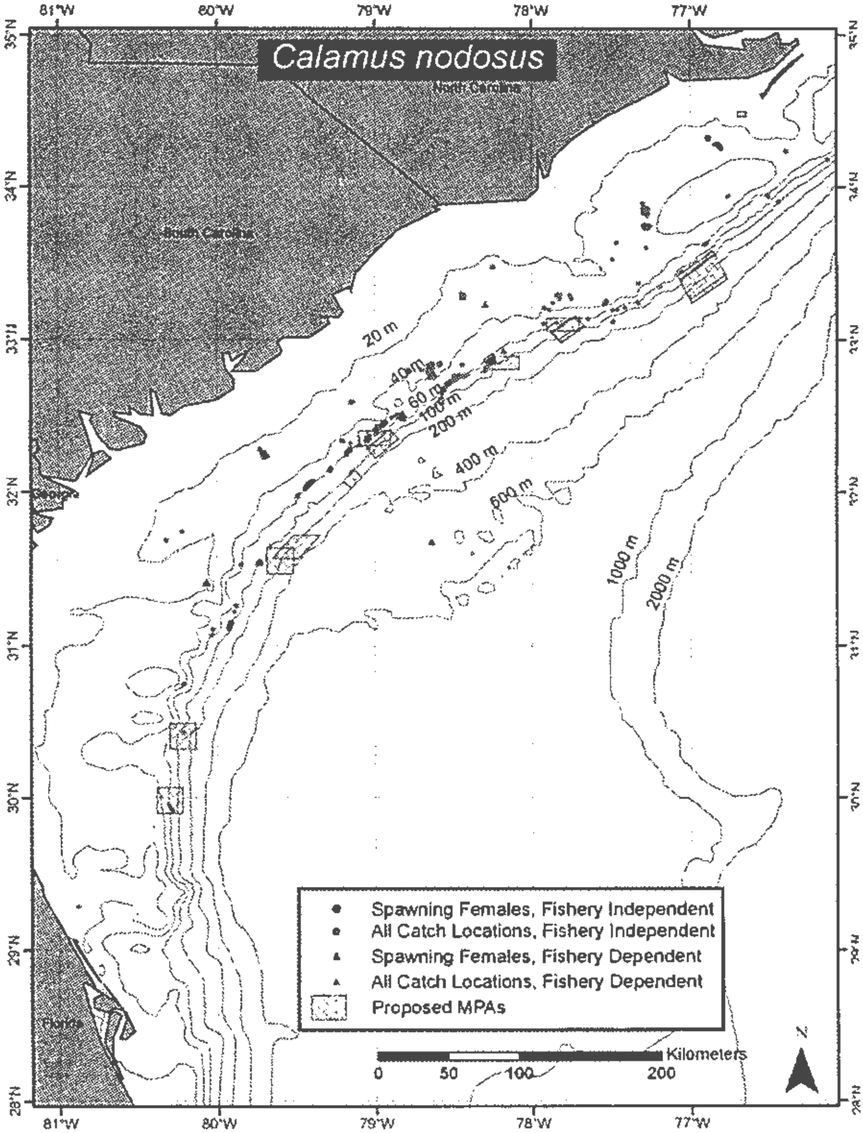


Figure 11. Locations of capture of knobbed porgy. See Figure 2 for additional explanation.

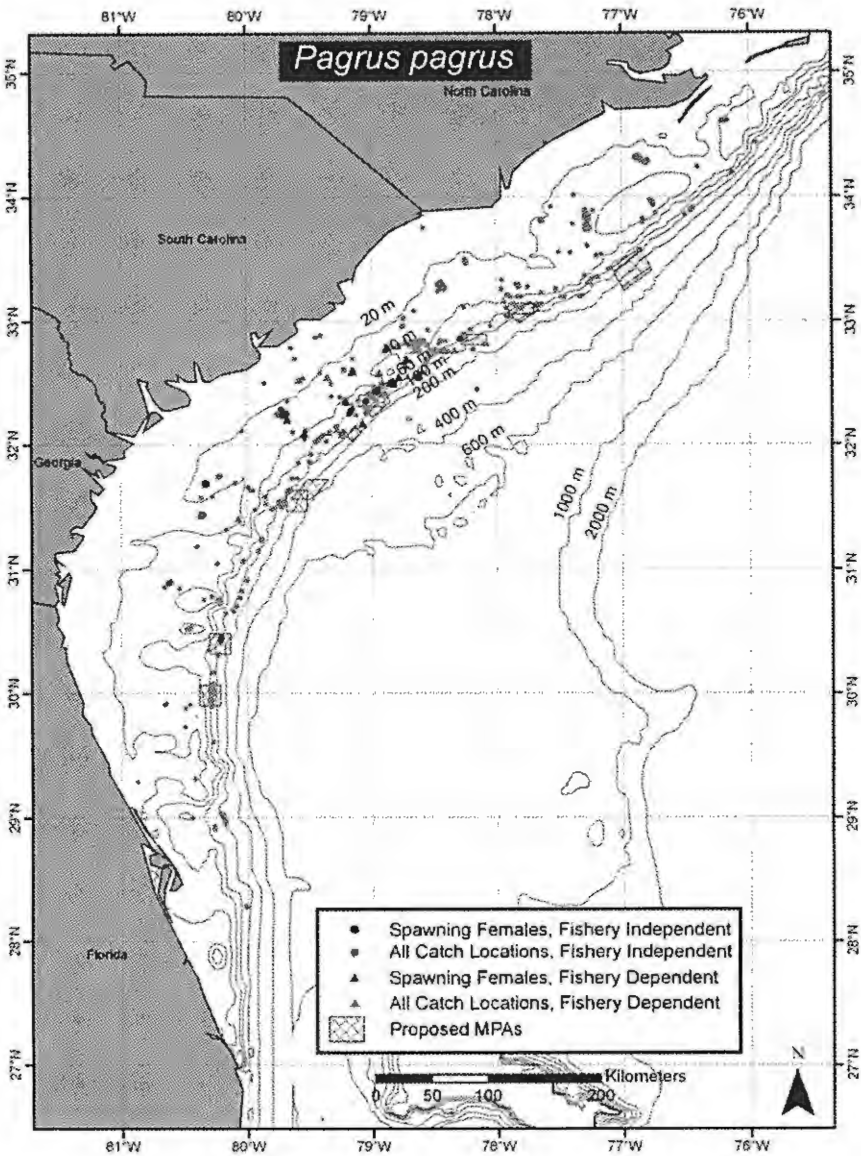


Figure 12. Locations of capture of red porgy. See Figure 2 for additional explanation.

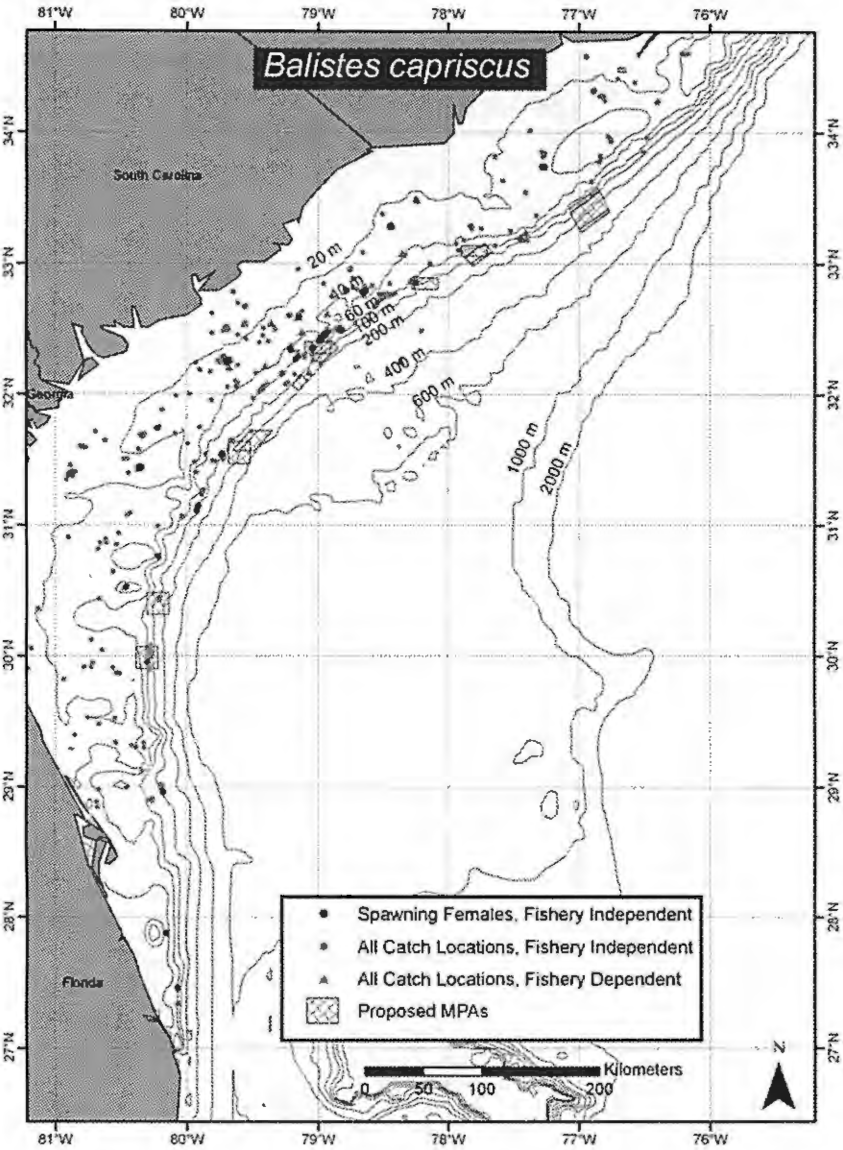


Figure 13. Locations of capture of gray triggerfish. See Figure 2 for additional explanation.

White grunt (*H. plumieri*) and red grouper (*E. morio*) had distributions that differed from most shelf species (Figures 14 - 15). Both species were caught on the middle and outer shelf, mainly in the northern part of the SAB, and apparently have a disjunct distribution (Zatcoff et al. 2004, Chapman et al. in prep.). They are abundant in the Caribbean and southern Florida, but are not common off northern Florida or Georgia. They appear to be more tropical species that are found only in the waters of the northern SAB, which are under the influence of the Charleston Gyre (see additional discussion below).

Of the 2,256 white grunt examined, 151 were spawning females. Spawning females were collected from March through September at most locations where white grunt occurred, with a major spawning period of April through June (Table 4). Spawning occurred in depths from 22 to 51 m (Table 3). White grunt spawned in warmer waters (20.23 - 27.42°C; n = 123) than other species examined, reflecting its preference for warmer waters.

Red grouper (*E. morio*) have a distribution similar to that of white grunt, although spawning is generally restricted to depths greater than 40 m (Figure 15). Spawning females (n = 46) represented 2.1% of the 2223 red grouper examined for sex and reproductive state (Table 3). Red grouper spawn in late winter and spring (February through June with a peak in April; Table 4) in depths from 30 to 90 m. In the Gulf of Mexico, peak spawning occurs in April (Coleman et al. 1996). Red grouper spawned in generally cooler waters than white grunt (range 16.97 - 24.08°C; n = 7).

Several species such as *Caulolatilus microps, Lopholatilus chamaeleonticeps, Epinephelus flavolimbatus, E. niveatus, Helicolenus dactylopterus, Polyprion americanus, Hyperoglyphe perciformis* and *Beryx decadactylus* have specific habitat requirements and were therefore collected and found in spawning condition in very restricted areas. They generally exhibited protracted spawning periods. Blueline tilefish (*C. microps*) were collected only off of South Carolina on shelf-edge and upper slope reefs between 46 and 256 m (Figure 16). Blueline tilefish (n = 1112 examined for sex and reproductive state) were found associated with hard bottom that occurs in that area (Sedberry et al. 2004). Females in spawning condition (n = 514) were collected from February through October, with a major spawning period of March through September (Table 4). Spawning females were collected at a temperature range of 8.87 - 16.28°C (n = 32).

Tilefish (*L. chamaeleonticeps*) also had a restricted depth and latitude range (Table 3, Figure 17); however, tilefish are found on soft-bottom habitat on the upper slope, where they construct burrows (Harris et al. 2001). Most tilefish were collected off South Carolina and Georgia, and spawning females were found in those areas. Spawning females (324 of 2431 fish examined) were collected in all months except October and December (Table 4), in depths from 190 to 300 m, at temperatures from 10.16 to 14.90°C (n = 9). The major spawning period was March through July. North of Cape Hatteras, most tilefish spawn from May to September (Grimes et al. 1988).

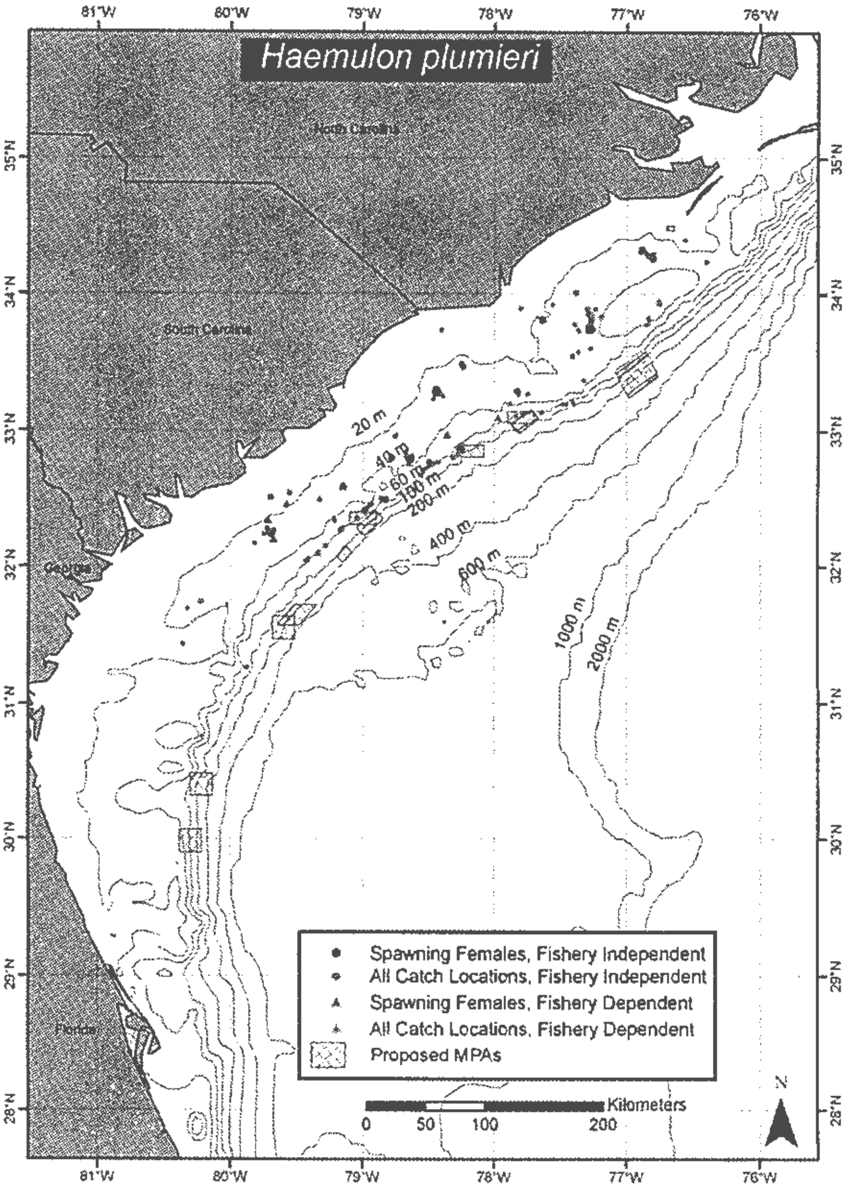


Figure 14. Locations of capture of white grunt. See Figure 2 for additional explanation.

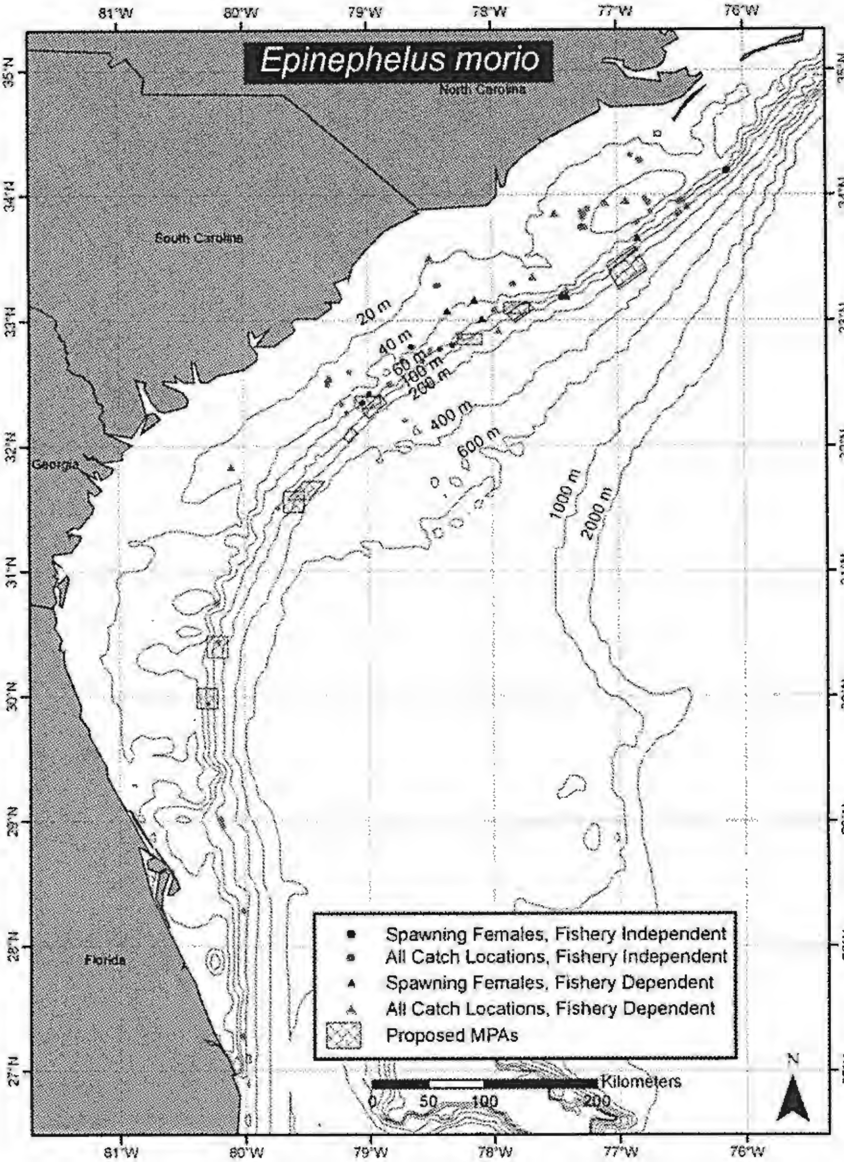


Figure 15. Locations of capture of red grouper. See Figure 2 for additional explanation.

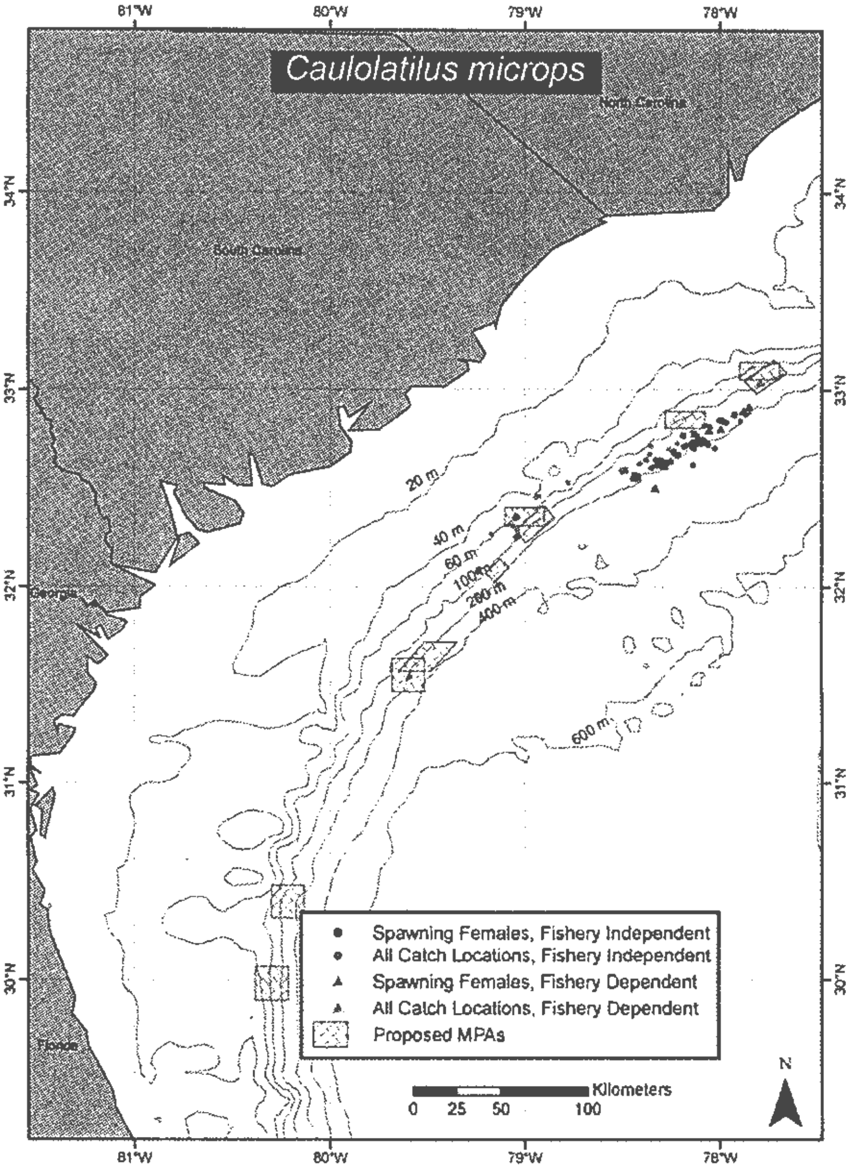


Figure 16. Locations of capture of blueline tilefish. See Figure 2 for additional explanation.

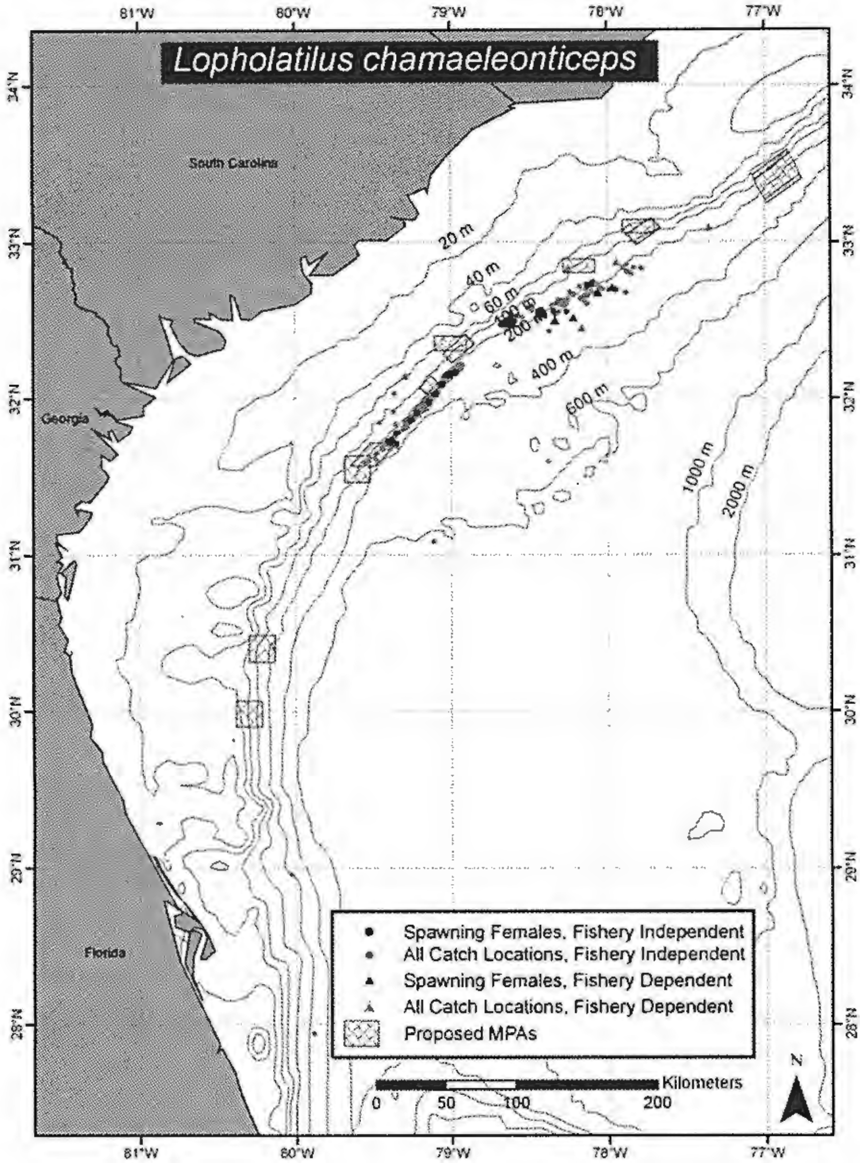


Figure 17. Locations of capture of tilefish. See Figure 2 for additional explanation.

Yellowedge grouper (*E. flavolimbatus*), like blueline tilefish, had a restricted depth distribution (Figure 18) and were also found mainly on shelf-edge and upper-slope reefs off of the Carolinas at depths of 31 to 205 m. Spawning females (six of 73 fish examined) were collected in August and September in depths from 160 to 194 m, at a temperature of 14.47°C (one measurement) (Tables 3-4). Yellowedge grouper spawn earlier (April to July) in the southern Caribbean (Manickchand-Heileman and Phillip 2000).

Snowy grouper (*E. niveatus*) were collected on shelf-edge and upper-slope reefs, mainly off the Carolinas (Figure 19). Spawning females (96 of 649 fish examined) were collected from April through September, in depths from 187 to 302 m (Tables 3 - 4). The major spawning period was May through August. No bottom temperature data were available for collections of spawning snowy grouper. During a submersible dive on snowy grouper habitat in August (2002) off South Carolina, a bottom temperature of 13.27°C was measured, although no spawning snowy grouper were observed during that dive (Sedberry et al. 2004).

Blackbelly rosefish (*H. dactylopterus*) were also found over a relatively restricted depth range over hard bottom, and were often caught along with snowy grouper (Figure 20). Blackbelly rosefish were collected between 38 and 686 m and spawning females were caught in depths from 229 to 238 m (Table 3). Of 1,381 specimens examined, 138 were spawning females. Females were in spawning condition from December through April, with a major spawning period of January through April (Table 4). In the western Mediterranean Sea, blackbelly rosefish spawn in January and February (Munoz et al. 1999). No bottom temperature data were available for collections of spawning blackbelly rosefish, and only one collection off South Carolina had location data (Figure 20).

Wreckfish (*P. americanus*) occurred only on the continental slope, on a feature known as the Charleston Bump (Sedberry et al. 2001). Of 1,466 wreckfish examined for sex and reproductive state, 55 were spawning females. Wreckfish were caught in depths from 44 to 653 m, and spawning females were caught in depths from 433 to 595 m (Table 3, Figure 20). Wreckfish on the Charleston Bump have been collected at temperatures ranging from 6.2 to 16.3°C (Sedberry et al. 1999), and observed from submersibles (September 2001; August-September 2003) at temperatures of 8.4 - 16.7°C in depths from 430 to 570 m. Females in spawning condition were collected from November to May and were most prevalent in samples from February and March (Table 4). The Charleston Bump is the only known spawning area for wreckfish in the western North Atlantic (Sedberry et al. 1999); wreckfish in the South Atlantic (Brazil) spawn in the austral winter [July to October (Peres and Klippel 2003)].

We obtained 325 barrelfish (*H. perciformis*) from commercial fishermen and conducted histological examination of 102 specimens. All samples, including spawning females, came from wreckfish fishermen fishing on the Charleston Bump (Sedberry et al. 2001). The distribution of adult barrelfish is similar to that of adult wreckfish and spawning locations and times are about the same. Of the 102 specimens examined, 12 were females in spawning condition (Table 3). Females in spawning condition were found from November through January and in May (Table 4).

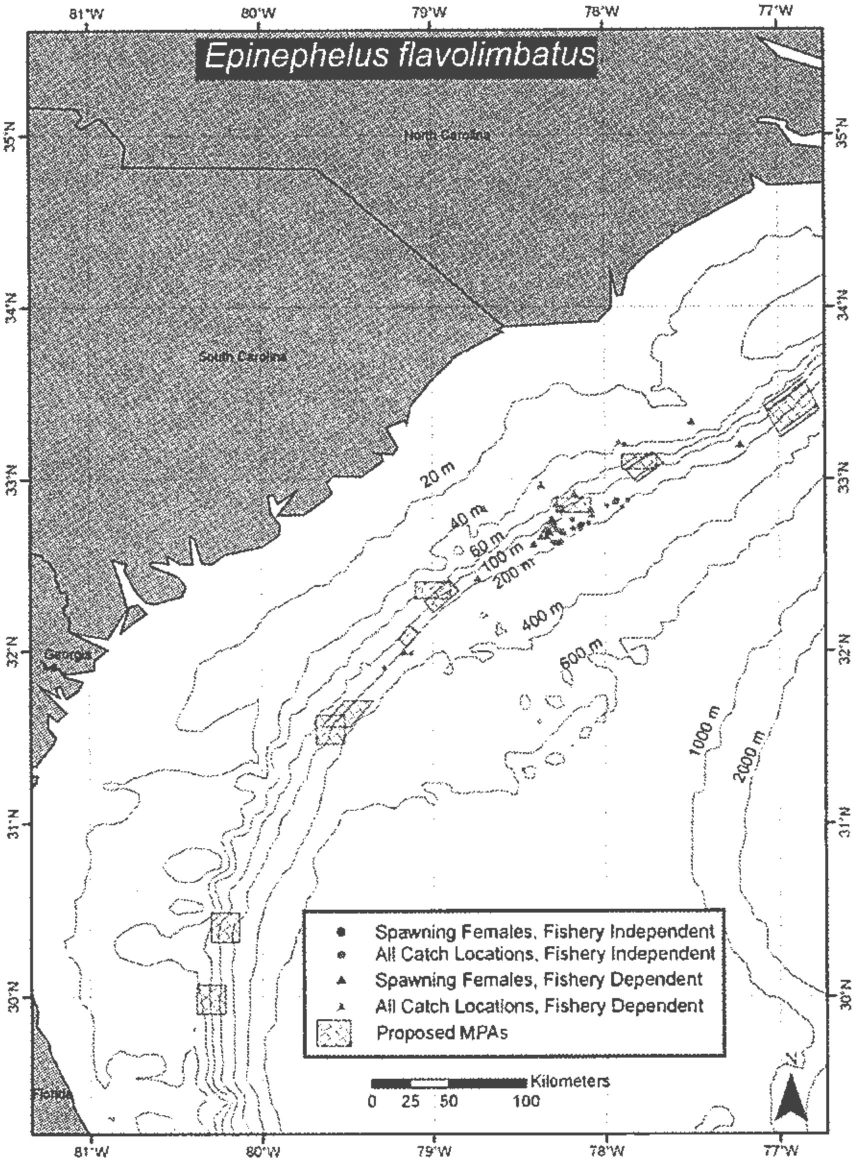


Figure 18. Locations of capture of yellowedge grouper. See Figure 2 for additional explanation.

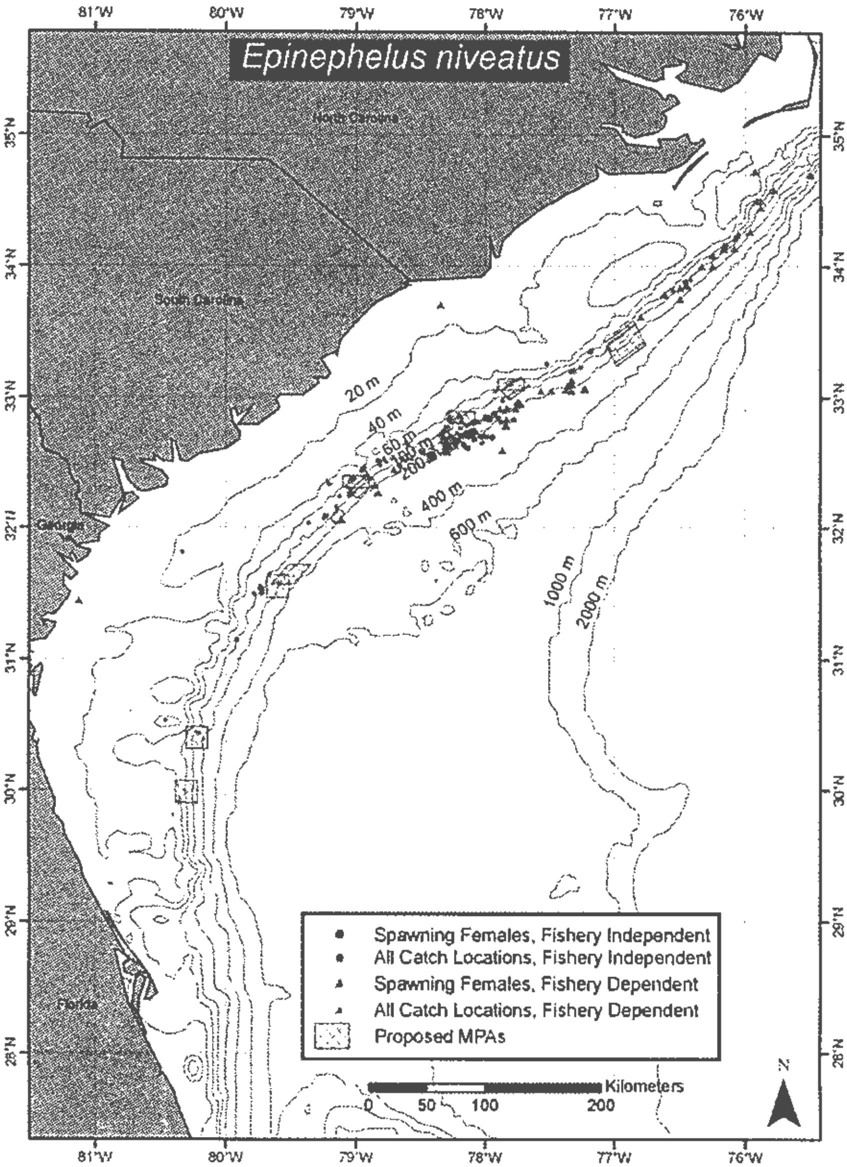


Figure 19. Locations of capture of snowy grouper. See Figure 2 for additional explanation.