



Proceedings of
**FISH HABITAT SYMPOSIUM:
GROWTH IMPACTS
ON
COASTAL N.E. FLORIDA
AND GEORGIA**

Edited by Carole L. DeMort
and
A. Quinton White

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**PROCEEDINGS OF HABITAT SYMPOSIUM: RECONSTRUCTION
GROWTH IMPACTS ON COASTAL N.E. FLORIDA AND GEORGIA
January 24-26, 1985**

Edited by:

Carole L. DeMort* and A. Quinton White**

*Department of Natural Sciences
University of North Florida
Jacksonville, FL 32216

**Department of Biology and Marine Science
Jacksonville University
Jacksonville, FL 32211

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FISH HABITAT SYMPOSIUM

1985

INTRODUCTION

Joseph G. Halusky

Welcome to this, the first, North East Florida and Coastal Georgia Fish Habitat Symposium. Why are we here and how did this event come to be? Very simply, we are here to fulfill a need to develop a better understanding of how rapid population growth is affecting our coastal fisheries habitats. It came to be, because people who depend on marine resources for their sport or their livelihood have recognized the need for wisely managing human activity affecting the coastal resources that support marine life. These "marine aware" citizens, through their sometimes daily contact with the coastal environment, have observed changes in wetlands thought to be associated with nearby "upland" activities. Many have expressed concern for wise coastal fish habitat management through Sea Grant Extension Advisory Committees, at public hearings, and through their industry, environmental, and civic associations. One issue they all seem to agree on is that decisionmakers, at all levels, need solidly founded scientific information about how people affect the environment and the marine life (especially the fisheries) it supports.

Ultimately, the decisions made by public officials and private developers will, in some way, affect the nearby wetlands. That almost any activity in upland areas will change the amount or quality of water before it reaches the estuary is as sure as the fact that water runs down hill. Ecologists recognize that an estuary is defined by the amount and quality of fresh water reaching it. Since the wetland dependent fishery is directly affected by upland changes that alter the water flowing through the system, it becomes a people and growth management problem. Fisheries management is people management!

The scope of wetland (fish habitat) changes can best be understood by looking at N.E. Florida's population trends and wetland acreages as an example. According to Florida Estimates of Population, published in April, 1981, seven counties (Nassau, Duval, St. Johns, Flagler, Volusia, Putnam and Clay) collectively, grew by 79% between 1970 and 1980. The 1980 census reported that 1,042,476 persons lived in N.E. Florida. By 1981, the

N.E. Florida Sea Grant Extension Agent, Route 1, Box 121A, St. Augustine, Florida 32086.

the population had grown by 22,126 persons. That is an increase of 426 new residents each week for the region. If growth continues at this same rate (approximately 500 per week), by the year 2000, we can expect over 375,000 new residents in an area just over 3000 square miles for a total population of 1.5 million, or 500 persons/sq. mile.

Keeping this in mind, and with a few more facts, we can surmise how this growth will affect fishery habitats. First, the majority of sport and commercially valuable marine fish and shellfish species are directly dependent on estuarine wetlands for their survival as a species. According to a recent report to the Florida Chapter of the American Fisheries Society, by the Florida Department of Natural Resources, 72% of the commercial and 74% of the sport species of fish and shellfish must spend all or part of their lives in or associated with the estuarine system. This includes many species commonly harvested offshore, such as Menhaden. The U.S. Geological Survey (personal communication) estimated that in the N.E. Florida seven county region, there are 227 square miles of non-forested wetlands, representing only 8% of the total land surface area. From this we can infer that over 70% of the sport and commercial fish produced in this area come from less than 8% of the surface area. The water draining from the rest, all 3000 sq. miles of the area that is used by the residents, eventually reaches the bottom of the hill, somewhere in these 227 sq. miles of wetland. In other words, their impact could be equivalent to 6,600 people living on each square mile on non-forested wetland. It is easy to see that without proper planning, the growing human population will undoubtedly alter the fish habitats.

Proper planning requires a holistic picture of the ecosystem, based on a solid foundation of scientifically acceptable information and research. A holistic picture includes studies of human needs and wants, as much as those of the marine life. Who has done this research? What does the scientific community know about this region's coastal fisheries habitats? What does it not know? Where are the gaps in information? What management strategies are needed to insure that the fisheries habitats will not be significantly changed by uncontrolled human activity nearby? How can people and fisheries co-exist? What do decisionmakers need to know about marine environments to make good decisions? These are just a few of the questions that are being explored by the speakers and guests of this symposium.

Solicited review papers will provide a broad overview of knowledge about the region, as presented by a variety of academic and agency experts. They will explore what work has already been done and give a synopsis of the present state of knowledge for their topic areas. These topics will include economics and trends in growth and fisheries; offshore fisheries; coastal fisheries habitat descriptions of Florida and Georgia; river basin contributions to fisheries; the governmental process affecting

fisheries habitats; and finally, a national overview of coastal fisheries habitat issues.

This symposium is intended for DECISIONMAKERS at all levels, businessmen; developers; local and state officials; sport and commercial fisherman, who depend on a healthy fisheries habitat; and the public, who enjoys and uses these natural resources. It is not pro- or anti-coastal growth. It is a factual approach aimed at solving perhaps one of N.E. Florida and Coastal Georgia's most important problems, that is, how can rapid human growth be managed so that a high quality of life can be assured for both people and marine life?

This symposium has three primary purposes:

- 1) identify existing scientific information regarding coastal marine fisheries habitat growth issues from Savannah, Georgia to Mosquito Lagoon, Florida, and the St. Johns River Basin.
- 2) summarize and distribute this information through a published proceedings.
- 3) promote further research and wise management of wetlands and adjacent areas by identifying relationships between growth issues, informational needs, decisionmaking, and the fish habitat system.

Ralph Waldo Emerson once said "The earth laughs in flowers". Marine life, like the flowers, grow only where there is a healthy environment to support it. How can we insure that the wetlands will continue to laugh in fish?

I hope that this event becomes a building block upon which a continuing relationship between the scientific community and the decisionmakers will develop. I hope that it becomes a platform from which sound decisions can be made for the benefit of all people who choose to live in these sensitive coastlands. Perhaps, more importantly, I hope that it becomes a platform from which sound decisions can be made for those who cannot choose for themselves - THE FISH!!!!

A BIRD'S EYE VIEW OF COASTAL GEORGIA: ITS GEOGRAPHY,
INFLUENCE OF MAN, AND FISHERY

Taylor Schoettle

Georgia and north Florida share a unique geographic setting being located together in the deep recess of the South Atlantic Bight. In spite of this fact, the differences between the two areas are surprising.

Geographic

Georgia harbors about a half a million acres of salt marsh along its 100 miles of coast. A four to eight mile wide strip of marsh separates the Georgia barrier islands from the mainland. Five major rivers bring water from all parts of our state, its mountains and piedmont, into our marshes. Ten major inlets allow 6.5 to 9 feet of tidal water to flood the marshes twice a day. Salt and brackish marshes extend as far as 20 miles inland. Comparing this description of Georgia's coastal wetlands with those of north Florida, one can fully appreciate their marked differences.

Population

Unlike Florida, only one-third of our 13 major barrier islands are inhabited and the other two-thirds are wildlife refuges, state parks, research stations and monuments under state and federal management. Less than 10% of the population of Georgia lives in our six coastal counties.

It is curious to see that, in spite of the relatively sparse development of the whole Georgia coast, two-thirds of the clam and oyster beds are condemned because of coliform pollution. Most of the older communities along our marshes have poor septic facilities, and are densely developed. Rapidly growing communities, like St. Simons, have overworked sewage treatment systems.

There are about 14 miles of beach on the public islands of Tybee, Jekyll, and St. Simons. About 70% of these beaches are sea walled. Except for Jekyll, a state owned island with restricted development, the beaches are being developed at an alarming rate. Unlike our well protected marsh lands, the laws protecting the beaches need serious revision.

The development of upper income cul-de-sac neighborhoods, condominiums, apartment complexes, restaurants and shopping centers is continuing at an accelerated rate in St. Simons, Sea

Island and Kings Bay. Accompanying the high density development, increased runoff with pesticides, fertilizers and organic pollutants adversely influence the estuaries and sounds. The mounting numbers of private boats and marinas also contribute to the increased pollution and disturbance of the estuary.

Industry

North Florida and Georgia share a common feature which is rather rare. Water-dependent industries such as paper mills and sundry chemical plants play a major role in our communities. For many years, these industries have polluted our air and water and drawn heavily from our aquifer. Tightening of our pollution standards in the early 70's has helped the air and water pollution, but the continued wholesale drain on the aquifer is showing alarming signs of water depletion in both states. Coastal Georgia is continually bombarded with requests to acquire land by new chemical companies which want to take advantage of our water resource and cheaper operating costs. Their alluring promises of large scale employment and increased economic flow for our depressed coastal communities understandably find attentive audiences among municipal leaders.

Fisheries

Fisheries in Georgia at present are limited to shrimp and crab. Shrimping requires a large investment of money and can yield a highly valued product. As a result, the shrimp are under heavy fishing pressure. The increased number of boats and diminishing landings in the past five years are seriously hurting this fishery.

On the other hand, crabbing requires little investment but yields relatively little income. This fishery continues to yield a steady harvest. Soft crabs, with the high prices they bring and relatively inexpensive shedding facilities, offer great potential as a fishery, especially with our long warm season. With improved methods of peeler procurement and shedding technology, this fishery could grow rapidly and may have considerable impact on the crab population in the future.

Finfishing has not been a prominent industry in Georgia until recently. Our region with its extensive shallow, warm shelf waters and sandy bottoms offers a poor habitat for commercial finfishing. The 60 to 80 mile distance from our coast to the edge of the continental shelf has hampered offshore fishing. Improved technology and knowledge of offshore fish populations has increased our recent fish landings. But some of the valuable offshore species are rapidly declining in numbers under moderate fishing pressure.

Sport fishing is affected by the same factors as commercial fishing. Sport fishing for trout, croaker, sheepshead, bass,

whiting and flounder is enjoyed by Georgians. Local fish sold in coastal markets come mostly from sport fishing and from shrimp vessel by-catch. Shark, squid and eel are abundant, but as yet, consumers are few.

Oystering was a major fishery in Georgia at the turn of the century, but today it has virtually died out. There is an abundance of oysters and clams in our marshes and a growing interest in harvesting them. If our waters become cleaner, culturing procedures improve and depuration facilities are established, oystering and clamming may again become commercial fisheries here.

Fisheries Resources, Values and
Trends in Northeast Florida and
Georgia and Ties to Coastal Habitats

James C. Cato

Introduction

The coastal habitat of Northeast Florida and Georgia contributes heavily to the economic well being of both regions. The rivers, salt marshes, bays, oceans and watersheds all make a contribution in their own way. Some provide, through their use, economic benefits that are very difficult to measure. This paper will focus primarily on the measurable or identifiable products that result from the coastal systems--the fish and shellfish. This is the most visible part, is easily identifiable by the users and managers, and provides the common denominator for most discussions concerning the coastal systems. This overview includes a brief discussion of population pressures in the region and the fishing and boating public that impacts the estuaries, gives a few historical points of interest on certain fisheries within the region and concludes with a major review of important species trends of the past twenty years.

Fisheries are directly tied to the productivity of the estuaries. Most of the commercially and recreationally important species consist of estuarine dependent species as pointed out by McHugh (1976). No marsh or no coastal habitat means no fish, thus, most biologists estimate the value of the marsh to be very large. However, since most biological research results do not define quantitatively the relationship of fishing output response to marsh in terms of a physical production function that can be tied to economics using the concept of marginal productivity, it is difficult to put values on marsh productivity.

Sufficient marsh may still remain to maintain adequate fishing production. So, the real question may be the marginal values of the marsh in fish production. In other words, how much would fishermen pay to "not lose" one acre of marsh or how much could be paid to "gain" one acre. Lynne, et. al. (1981) reviews most attempts to determine the economic value of marsh estuarine systems.

At least four approaches have been tried to value the marsh, Depending on the method, the capitalized value per acre has ranged from \$7 dollars to \$82,940. It's easy to see the problem. All these methods and values can be seen as summarized in Cato (In Press).

James C. Cato is Professor of Food and Resource Economics, University of Florida and Director of the Florida Sea Grant College Program.

Has fishery production really declined in coastal Northeast Florida and coastal Georgia? Available data indicate that the answer is probably yes. The general public certainly perceives that to be the case. A 1981 survey as reported in Bell (1982) indicated that 21 to 50 percent of sportsfishermen in Florida thought there were declines in the stocks of snappers, seatrout, grouper, king mackerel, dolphin and catfish, depending on the species. When combined, water pollution and habitat destruction were perceived to be the primary reasons. It is interesting to note that residents perceived greater fish declines than did tourists.

Increasing numbers of people wanting to use a declining resource create the problem of political and/or economic allocation. Fisheries can be used without cost (for the resource itself) since they represent a common property resource. No user has the exclusive right to use the resource, nor can others be excluded from its use. When the resources become limited, and the users compete for the fish, no market exists to allocate them and the political system must solve the problem. Not only is this true between the fishermen themselves, but also between the fishermen and coastal development.

Users groups often want to use economic impact estimates as a tool in allocation. Extreme care must be taken in using these type estimates. Optimum allocation of resources should result in a position where the last unit allocated to each group brings identical benefits. Just because one group has a larger economic impact doesn't mean it should receive a larger allocation. For example, in a highly developed recreational fishery, a larger total economic impact resulting from a reallocation might occur by taking incremental amounts of the fishery from the recreational sector and giving it to the commercial sector. Recreational fishermen should still participate (assuming the incremental change is small) and the "new" fish in the commercial sector create value as they are traded in the market. Each fishery and combinations of fisheries must be examined on their own merits.

Developing any kind of aquatic habitat policy is difficult when the region has a large number of conflicting uses such as those described above and is already highly developed. Economic trade-offs must certainly be considered. Development is much more rational with an adequate policy in place to guide that development. There are a number of major policy issues that must be faced.

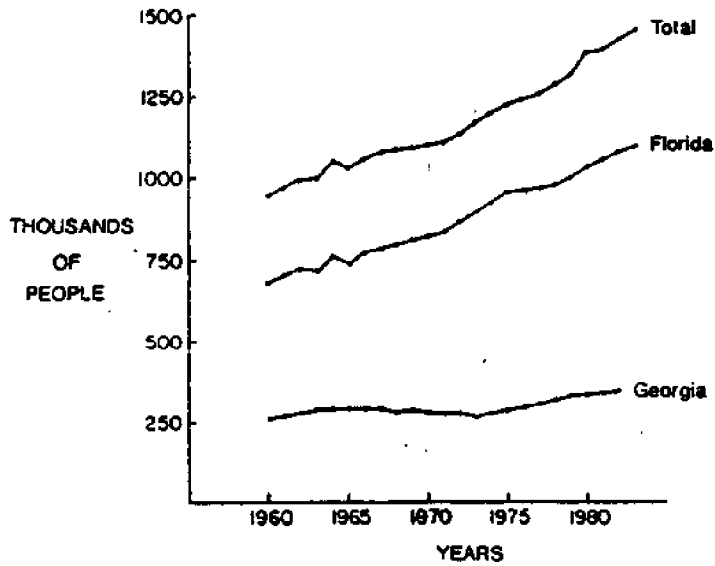
The demand on resources must be considered. Should aquatic habitat be used in any amount as suggested by demand? How far must demand for one use be reconciled with the demand for others when they compete for the use of natural resources? How far should government stimulate the free use of the commonly used aquatic areas? Should policies be developed to maximize the economic return from these habitats?

Maintaining environmental quality is also a major policy issue. Who sets the quality standards? Is the public prepared to pay the cost of quality maintenance? Who should enforce design criteria for environmental protection? Should cumulative impacts of using our aquatic habitat be considered?

Effective planning is a must. All agencies and groups will have to plan cooperatively to recognize both impacts of demand for the resources and environmental quality. This includes research planning. A recent meeting of economists from the Gulf and South Atlantic states defined a number of research needs for fisheries, wetlands and coastal resources as reported by Cato and Copeland (1983). Research needs in fisheries were grouped into those answering capital and financial questions and those with management implications. Those regarding wetlands and coastal resources were more general in nature. The interested reader is referred to that document for more detail.

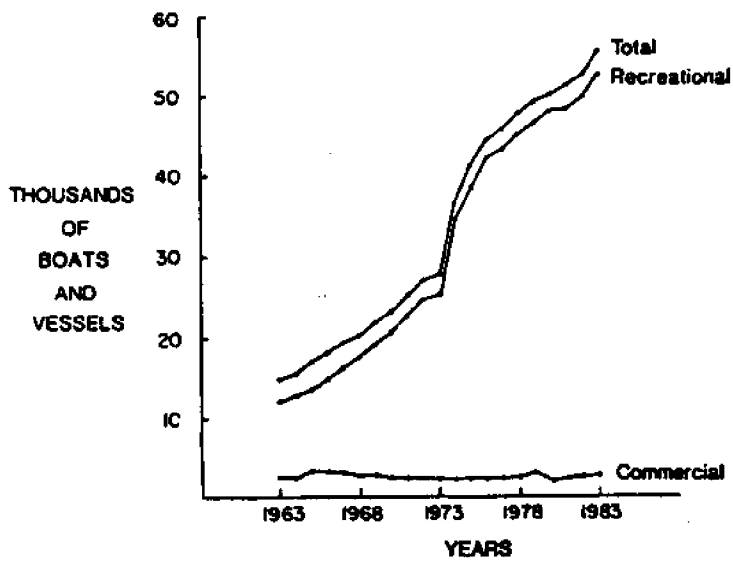
Population

From 1960 to 1983, total population in seven Northeast Florida and six coastal Georgia counties increased 53 percent from 952 thousand people to 1.456 million in 1983 (Figure 1). Florida population increased 62 percent while Georgia coastal population increased 29 percent. Population in 1983 and percent growth by county is shown in Table 1.



Population in Seven Northeast Coastal Florida and Six Coastal Georgia Counties, 1960-82

Figure 1



Commercial and Recreational Boat and Vessel Registrations in Nassau, Duval, Putnam, St. Johns and Volusia Counties, Florida, 1963-1983 (1983 Commercial Data Estimated)

Figure 2

Table 1. --Population in 1983 and Percent Growth Since 1960
by County for Coastal Northeast Florida and Georgia.

County	1983 Population (Thousands)	1960 - 1983 Growth	
		(Thousands)	(Percent)
Georgia			
Bryan	12.0	5.8	93.6
Camden	16.4	6.4	64.0
Chatham	206.3	18.0	9.6
Glynn	56.1	14.1	33.6
Liberty	45.8	31.3	215.9
McIntosh	9.0	2.6	40.6
Total	345.6	78.2	29.2
Florida			
Nassau	36.3	19.1	111.1
Duval	587.1	131.7	28.9
Clay	74.5	55.0	282.1
Putnam	54.2	22.0	68.3
St. Johns	60.1	30.1	100.3
Flager	13.8	9.2	200.0
Volusia	284.6	159.3	127.1
Total	1,110.6	426.4	62.3
Grand Total	1,456.2	504.6	91.5

Boating

Growth in the total number of boats and vessels in Northeast Florida has been 242 percent (from 15,660 to 53,634) over the past 21 year period (see Figure 2). Recreational boats have caused this growth (320 percent) while commercial vessels have actually declined 21 percent (3,556 to 2,795). Change in registration laws (1973 - 74) had some impact but the growth has still been tremendous.

Historical data on Georgia boats and vessels are not as readily available. Georgia does not have an annual renewal of boat registrations and an owner purchases a three year license. Consequently, all license registration figures are for those licenses currently valid and would include licenses purchased up to three years ago. The number of recreational boats registered in 1983 in the six coastal counties was 22,347 (Andre Kvaternik, Georgia Department of Natural Resources, personal communication). A grand total of 1,046 commercial fishing boat (trawler) licenses were issued in Georgia in 1983. This included boats (547) and vessels (499) and 214 non-resident licenses. A total of 93 of these are probably included in Florida registrations. In addition 729 non-trawler licenses were sold in Georgia in 1983.

These data total 73,186 recreational boats and 4,570 commercial boats and vessels combined for the same time period. The intensity of recreational boat use can also be demonstrated by the fact that across the coastal region an average of one boat is registered for every 18 people or 7 households (Table 2).

Sport Fishing

Data on sports fishing are not nearly as abundant as those for commercial fishing. However, the earliest reports highlight the same commercial and sport conflict that exists today. Gregg (1902) reports that the fish in Florida had declined since the advent of "the steamboat", the railway and last but not least the ice factory, which were followed by the "man with the net". Gregg added that in some areas the "man with the net" had been restricted and fishing in those parts was still good today. Sounds like today.

Gregg (1902) reported beginning trips to Florida in 1885, spending most of his time at various angling resorts on both the Eastern and Western coasts. His first stop was at St. Augustine where he fished the Mantanzas and Sebastian Rivers many times. Fishing "tourists" were not numerous in the late 1800's. Parties visting the West coast were obliged to go by steamer up the St. Johns River and then by stage or wagon to the coast, or by rail to Cedar Key and then along the coast by small steamers or sailing craft. Parties bound for the East coast could go from Jacksonville to New Smyrna by steamer or sailboat, then up or

Table 2. --Recreational Boats in Coastal Northeast Florida and Georgia and Persons and Households Per Boat for the Approximate 1983 Time Period.

State and County	Recreational Boats Registered ^a	Persons Per Boat ^b	Households Per Boat ^b
<u>Georgia</u>			
Chatham	12,698	16.2	5.9
Bryan	1,335	8.5	2.7
Liberty	1,445	31.1	8.3
McIntosh	963	8.5	3.0
Glynn	4,343	12.9	4.8
Camden	1,563	9.1	3.0
Total	22,347	15.2	5.3
<u>Florida</u>			
Nassau	2,174	16.9	5.8
Duval	26,066	22.2	8.4
Putnam	4,990	10.9	4.1
St. Johns	2,759	20.6	7.8
Volusia	14,850	19.0	8.0
Total	50,839	19.9	7.7
Grand Total	73,186	18.4	7.0

^a As of August, 1984 For Georgia, 1983-84 for Florida

^b Based on 1982 Population data from Sales Marketing Management Magazine, 1983.

down the inside or outside waters to their destinations on sailboats, or could take a steamer up the St. Johns to Sanford, and a stage or wagon to New Smyrna, and then a sailboat up or down the coast. According to Gregg, the leading fishing resorts on the East coast during the late 1800's were located at Oak Hill, New Smyrna and Ponce Park.

Specific locations mentioned by Gregg with some detail are Mayport, Atlantic Beach, San Pablo, and St. Augustine. Regarding Mayport, Gregg mentioned many species of fish, but mentions that the best of all fishing occurred standing at the jetties on the rocks or near them in a small rowboat. Channel Bass seemed to be of interest. Atlantic Beach also produced Channel Bass and sportmen staying at a new hotel there in 1901 could take the train to Mayport at several different hours during the day, "fish the tide" and return to the hotel for dinner. At San Pablo that same year, the hotel was supplied with Pompano caught from the surf with nets. Lastly, Gregg reports the following about St. Augustine:

"A very pleasant way of spending the day at St. Augustine is to provide yourself with a cheap cooking outfit, consisting of a wire gridiron, frying pan, coffee pot, and cups and saucers, plates, knives and forks, spoons, etc. Go to Corbett's and buy some Oysters, or you can depend upon picking up all the "Coon" Oysters you will need. Take one of the sailboats, go to the North River, or other place recommended by the boatman. Catch your fish, land and cook them with such other edibles as you choose, and roast your Oysters in their shells over a wood fire. Oysters cooked in this way suit me better than in any other style, but, as I have before said, "tastes differ". Try it once and see what your judgment is. Oyster roasts are quite a feature at St. Augustine from November to March or April".

Sportfishing in Northeast Florida has changed dramatically since the writing of Gregg and those who fished before him. For example, the 1981 three-day Greater Jacksonville King Mackerel fishing tournament generated an estimated \$700 to \$800 thousand in economic activity from just the participants alone as reported in Milon et.al. (1982). Bell et.al. (1982) provides characteristics of the typical modern Northeast Florida angler in Tables 3 and 4. The average resident angler spent 19 days and the average tourist almost 3 days sportfishing for a 1980-81 twelve month period.

Table 3. -- Demographic Profile of Resident and Tourist Saltwater Recreational Fisherman by the Northeast Florida State Planning Region, 1980-81.

Characteristic	Resident	Tourist
male	73.2%	93.4%
female	26.8%	6.6%
Caucasian	96.0%	90.0%
Black	3.6%	9.8%
Professional	11.6%	10.3%
Management	29.5%	21.4%
Blue Collar	27.7%	32.7%
Retired/Semi-Retired	10.7%	23.5%
Other	20.5%	12.1%
Median Age		
Age	35.6	50.3
Median		
Yrs. fished in Fla.	11.6	5.0
Mean		
Household income	\$18,950	\$24,470

Source: Bell, et. al. 1982.

Table 4. --Estimated Percentage of Time Spent in Various Fishing Modes by Resident and Tourist Saltwater Recreational Fishermen by the Northeast Florida State Planning Region, 1980-81.

Fishing Mode	Resident	Tourist
Pier, Jetty Bridge	25.0%	40.1%
Surf and Shore	24.1%	30.2%
Charter Boat	2.0%	less than 1.0%
Party Boat	1.0%	3.9%
Private	47.9%	25.3%
Boat Modes		
Charter	4.0%	1.6%
Party	2.0%	13.2%
Private	94.0%	85.2%
Brackish, Rivers & Marshes	36.9%	14.8%
Bay Sound & Along Coast	24.5%	61.0%
Deep Sea (beyond 3 mi)	38.6%	24.1%
Days inside Fla. waters	80.4%	92.8%
Days outside Fla. waters	19.6%	7.2%

The Seafood Industry

As pointed out by O'Conner (1980), every school child knows Florida was discovered by Ponce De Leon in 1513 and that the first permanent European settlement on the peninsula was at St. Augustine. After settlement, not much happened for 250 years. Records do show that in 1771 66,677 pounds of goods were imported into St. Augustine and 22,335 pounds were exported. During 1781, a total of 69 vessels entered and cleared the port of St. Augustine. Ships in the trade were about 30 tons burden and about 30 feet in length.

Jacksonville was laid out as a city in 1822 and received its charter in 1830. Its position on the St. Johns River assured its growth and importance as a seaport. In the late 1800's deep draft steamers began to arrive at the port of Jacksonville to unload passengers and freight from New York, Philadelphia and Boston. Railroads from the interior fed the port with oranges, kegs of oysters, honey, vension, turtles and pineapples to be shipped North.

Shrimping

Fishing is often called the first industry. Northeast Florida and Georgia lay claim to some of those firsts as pointed out in Cato and Sweat (1980). A doctoral dissertation by Overbey (1982) contains a colorful history of the early seafood industry in the region. Many of the following sections are taken from that dissertation. In St. Mary's residents used cast nets to procure shrimp for home consumption and for sale. One elderly resident as quoted by Overbey (1982) recalled catching shrimp from river banks as a boy in the 1880's and early 1890's:

"When I was a boy we used to make (cast) nets by hand. I made many a one by hand....Four foot nets and we'd go at night and catch these, what they called "prawn" then. They called the shrimp "prawn", the big shrimpsWhen we was casting into them they'd just go "shooooo," you know. Just like sand. And at night you can see the reflection in the water. You could just see them shrimp, big shrimp....And we'd sell them shrimp \$.10 for a quart, or three quarts for a quarter."

Commercial shrimping activity is first recorded in 1880 in Savannah, Georgia, and Fernandina, Florida. The shrimp were boiled and dried and then either sold in a local market or shipped to northern markets. Earll (1887a) reports:

....During the height of the season, twenty to twenty-five men go to Saint Catherine and Osabaw Sounds, where they camp for several weeks for the purpose of engaging

in the fishery. They carry a complete outfit, including seines, cast-nets, boats, and kettles for cooking the shrimp. After cooking and drying the catch of the day, one boat is detailed to carry it to market. The price paid by the Savannah dealers varies from \$5 to \$1.50 per bushel according to circumstances, \$2.50 being a fair average. During the summer of 1879 about 1,400 bushels, valued at \$2,500, were landed....Of those taken, part are sold locally, others go to the interior cities, and the remainder are packed in crates and sent to the Northern markets.

In Fernandina, the shrimping was on a much smaller scale; however, the beginnings of commercial export were evident. Again, from Earll (1887b).

According to Capt. T.E. Fisher, shrimp and prawn are abundant in the harbor directly opposite the city during the entire year, and a man can readily secure 3 or 4 bushels with a small cast-net on any pleasant night. The catch, which is not less than 450 bushels, is boiled and dried for shipment to New York, Philadelphia and Savannah.

Overbey (1982) continues by quoting many sources, to describe the beginnings of commercial shrimping in Fernandina as well as St. Marys as generally attributed to Sollecito Salvador. A Sicilian immigrant, Salvador used seines to catch shrimp and probably started as a buyer who processed the shrimp he caught as well as the shrimp that others caught to sell for export. One St. Marys resident recalled Salvador's entry into St. Mary's to buy shrimp from community fishermen, an act which catalyzed the development of commercial shrimping in St. Marys:

We.....,we'd catch them shrimp and there was a fella, I don't know if he was a Portuguese or Italian or what, but his name was Salvador....[and another] Mitchell. Well, they'd buy these shrimp by the bushel and they'd boil 'em and dry them. Then they'd ship 'em in boxes little boxes, all over the country. That was the first of these shrimp....They caught 'em by seines and cast-nets-....They shipped them all over the country by express. Boiled shrimp....They'd get orders all over the country. They'd ship them a lot....And they get rich at it.

By 1902, Salvador had instituted the power driven boat to pull a haul seine in deeper waters for shrimp. In 1906, Salvador founded his own company in Fernandina. An elderly St. Marys resident remembers these first shrimp boats in the area:

....They took small boats and they didn't have but a five-horse engine. [They were] what they call "yawl" boats [with] an engine in it. A fella done that and

made a little net and he went out there....Right off of Cumberland, he just loaded that boat with so many shrimp. Plenty of shrimp. Let me see if I can get about the year that was. I imagine that was about 1906 or 1907.

This became the nucleus of the shrimping industry as it is recognized today. Around 1912, two brother-in-law of Salvador, S. Versaggi and Anthony Poli, came to Fernandina from Sicily to start their own shrimping operations. Between 1912 and 1915 the first otter trawl was designed by Capt. Billy Corkum and first used by S. Versaggi.

In 1922 Mr. Salvador moved his firm to St. Augustine, which was located nearer to rich shrimp beds and where transportation facilities were more accessible than in Fernandina. Production climbed rapidly until 1929, when the depression hit the industry. The low price of shrimp during the years which followed furnished little incentive to the fishermen; as a result, production in the South dropped off by about 25 million pounds and Florida's production dropped from 25,000,000 to 17,000,000 pounds.

By 1934, the catch was restored to its former high level and continued to increase until 1940. Around 1949, another decline in production was one reason for the exploration of new grounds which resulted in the development of Key West as the chief shrimp port of Florida. John Salvador (the son of Sollecito) discovered the Key West grounds in 1950 when, while examining a daylight trawl at about dusk, he found many more shrimp than normal in his catch, prompting him to put the nets back overboard. This second trawl was filled with shrimp and "pink gold" had been discovered. Some 300 boats quickly came to Key West, and the first full season, 1950-1951, produced 15 million pounds. Before the Key West discoveries, Apalachicola was the main shrimp-producing center on the Florida Gulf Coast.

Hamilton's (1951) prognosis was correct. At the time of his writing, St. Augustine, the oldest port in the U.S., was still the best equipped port of Florida, but Hamilton felt St. Augustine was in a position to lose its significance as the shrimping center of the State to the rapidly developing ports of Key West and Ft. Myers.

Fernandina, the birthplace of Florida shrimping, declined in importance because of overfishing and pollution. Another reason was due to its isolated location and limited transportation facilities. Mayport had similar problems and supplied mainly the local markets in Jacksonville.

Developments in commercial shrimping in Fernandina spurred advances in St. Marys. By the time the menhaden plant was built in St. Marys, commercial shrimping was well established as shrimp

canneries developed to handle the market of shrimp. Campbell's Soup Company operated a canning factory nearby and bought shrimp from local fishermen to put in soup. One resident explained:

"Well, now, the Campbell Soup Company, they had a canning factory on St. Simons Island. They bought these small shrimp for soup, to put in soup. They'd buy from here (St. Marys) and all around."

Canneries were developed in St. Marys to accommodate the shrimp catches. One of these canneries was started by the Hardee Brothers of Fernandina. Another one was built by Brandon and Davis. Probably the largest shrimping operation and cannery was the St. Mary's Canning Company, owned by C.A. Taylor. In 1930, Taylor owned 25 to 30 shrimp boats and employed 50 to 60 men on the boats. In the cannery, Taylor employed almost 100 black and white men and women. The business was situated on the St. Marys Rivers at the end of town. The canning process included heading the shrimp and peeling the hull; cooking the shrimp; and canning the shrimp.

Shrimping was initially pursued in inshore waters--in the sounds, rivers and nearby beaches. Lengthy shrimping trips were impractical in the small boats. Shrimp caught in the sounds and rivers were small because they were the post-larval, juvenile shrimp developing to adult size in the protected and productive waters of the estuary. One resident felt that the canneries "destroyed the shrimp" because they canned only small shrimp, thus depleting future populations.

Menhaden

The development of the menhaden fishery accompanied the development of a Savannah based fertilizer and chemical plant on the North River in St. Marys in 1917. The plant processed menhaden for oil which was used for manufacture of soap. The scrap was used to make fertilizer. The plant was a major development in St. Marys economy, employing 300 people in the processing plant on the fishing vessels. Today, the only menhaden plant in the region is located in Fernandina. It is interesting to note that the menhaden crews come to St. Marys from Nova Scotia and Virginia. In 1928 alone, over 30 million pounds of menhaden were landed and processed in St. Marys.

The growth of commercial shrimping in Camden County probably produced competition for labor between it and the menhaden fishery. The menhaden fishery which employed mostly blacks began to lose fishermen to commercial shrimping as they began to be hired as captains of shrimp boats. This along with the seasonal nature of menhaden fishing and declining catches probably resulted in

the closing of the Southern Fertilizer and Chemical Plant in St. Marys in 1937. As Overbey (1982) reports, one shrimper spoke of the reasons for the decline of the menhaden fishery:

"It wasn't bringing much [money]. And....the pogies were gone...It was something like farming, some seasons would be real good and some would be bad. So there had been a couple of bad seasons so they thought they'd phase it out."

Oysters

Oysters once were a very important component of Georgia fisheries. Numerous historical sources report the early dependence of both the Indians and early colonists on the oyster resource. It appears that oysters were intensively gathered by Indians as far back as 4,000 years ago.

Oyster canneries were located in several locations on the Georgia coast during the late 1800's according to Harris and Quarteman, (1978). There are no known publications which document the proportion of the early catch handled by the canneries nor any records of distribution patterns. In 1902 it was reported that thousands of bushels of Brunswick oysters were shipped to interior markets each season and that two canneries packed and shipped 30,000 cases of oysters annually.

Churchill (1920) writes that in 1920 oyster beds were found along the entire coastline of Georgia, especially the St. Catherine, Sapelo, DoBoy, Altamaha, St. Simons, St. Andrews, and Cumberland Sounds. there were 18 canneries in the state. Four were at Savannah and the rest were scattered along the coast. there were five wholesale dealers in raw oysters, besides several retailers at Savannah, Brunswick, and other points. There were a few oysters canned at Fernandina.

The oyster industry has gradually declined in Georgia since the early 1900's. Harris and Quarterman (1978) note the production data are suspect in the early 1900's, but indicate a substantial decline from 330,000 pounds in 1936 to a low of 38,000 pounds in 1978. Landings were reported as high as eight million pounds in 1908. The last cannery closed in 1960.

Harris and Quarteman (1978) also suggest disease may have been at least part of the cause for the decline in the fishery. However, reports by Ingersall, (1881), Oemler, (1984), East Georgia Planning Council, (1937) and Harris and Quarteman, (1978) for the past 80 years have been warning of overfishing and a lack of cultivation. The 1937 report by the East Georgia Planning Council specifically recommended a return of shells by oyster shuckers to natural beds, planting of seed or adult oysters on natural beds and establishment of beds and oyster culture.

Since oysters are primarily sold locally, there is a limited demand which has been concluded to limit production such that all beds are not harvested each year. Furthermore, conscientious replanting by shuckers has not been pursued for the most part according to Carley and Frisbie, (1968).

The tentative conclusion with respect to a lack of market demand causing a decline in oyster production and marketings may be applicable in the short run. However, longer run considerations suggest other possibilities. Historical accounts of overfishing may suggest the Georgia oyster resource was fished down to such low levels that a significant quantity is not available on which to develop extended markets. Oyster markets are strong in the surrounding states.

Wholesale Trade

Fiedler (1928) reported on wholesale trade in fishery products in Jacksonville, which was a major fisheries trade center. It was noted that Jacksonville's waters supported no extensive commercial fisheries and the wholesale fish dealers were considered essentially as assemblers and distributors, rather than producers. Characteristics of the industry during 1928 were:

1. The fisheries of 11 states and 1 Canadian province supply Jacksonville with fresh and frozen fishery products.
2. During 1926, 502,000 pounds of fish were landed at Jacksonville; 8,965,000 pounds were received overland, of which 5,724,000 pounds were reshipped, leaving 3,743,000 pounds consumed in Jacksonville.
3. Less-than-carload shipments from Florida producers are assembled by wholesalers and forwarded in car-lot shipments.
4. Wholesale dealers in Jacksonville distribute fresh and frozen fishery products to 25 states, the District of Columbia, and 1 Canadian province.
5. The states of New York, Georgia, Florida, Pennsylvania, and Missouri receive 60 percent of the fish distributed from Jacksonville.
6. Mullet, Spanish mackerel, sea trout, fresh-water bream, and shrimp constitute about 60 percent of the fish distributed from Jacksonville.
7. Wholesale stores are located on the waterfront, on railroad spur tracks, and near local consumer trade.
8. Cold-storage facilities are available for freezing and storing about 1,800,000 pounds of fish. This can be expanded.

9. Ten varieties of fish constitute 75 percent of the retail trade.
10. Fish retailers show apathy toward making window displays of fishery products.
11. Of the 24 retail stores handling fishery products every day in the week, 12 catered to the black population, 4 to the white population, and 8 to trade of both races.
12. Sales in retail stores show that 68 percent of the week's trading is done on Friday and Saturday.
13. Only a small number of grocery and meat stores handle fishery products.
14. Hawkers operate in the city streets from motor trucks and horse or hand drawn vehicles.
15. Barrels predominate as shipping containers.
16. Per capita consumption of fish in the round is 25 pounds and of the edible portion about 18 pounds.

Only five percent of the fishery products handled by this local industry were produced in the immediate vicinity and over 60 percent of the products received were sent outside the city. Jacksonville's fishery trade was considered in its infancy because at that time no other city in Florida was as favorably situated regarding production centers, transportation and warehouse facilities. The studies results are interesting.

Current Trends

Shellfish constitute the primary source of value for commercial fisheries in both Georgia and Florida. For the three year period of 1980-82, average dockside values in Georgia were almost 97 percent shellfish in Georgia and 71 percent shellfish in Florida (Table 5). Average value of all landings was \$18.9 million in Georgia and \$13.7 million in Florida for a combined total of \$32.6 million in the region.

In the region only one landing area ranks in the top 60 ports in the U.S. The Darien-Bellville, Georgia area ranked 55th in pounds landed and 39th in value of landings in 1983. For the three year period 1960-62, average landings in Georgia and north-east Florida declined from 69.6 million pounds to 46.7 million pounds (Table 6). Most of this decline was menhaden since removal of menhaden from the statistics leaves a decline of from 39.4 million pounds to 31.6 million pounds. These same data for important species in the region are shown in Table 6. Commercial fish and shellfish products are also harvested from the St. Johns River in Florida. Average landings from this area for 1980-83 were 5.4 million pounds valued at \$2.0 million (Table 7).

The general trends in landings of individual species and groups of species are given in Table 8 and Figures 3 through 25. It should be noted that some of the trends could have been influenced by regulatory changes (shad, for example). These trends are shown without cause/effect analysis, but rather to illustrate landed commercial catches over the last decade.

Summary

As the population of the region continues to increase, the demand for goods, services and leisure time activities will increase. This will clearly impact the coastal habitat. Unfortunately, the limited supply of waterfront areas and our coastal habitat will face the many development demands. competition among water dependent users--ranging from fishing to marinas to urban development--necessitates the formation of policies for managing growth and demand. All sectors must be afforded a fair and equitable chance to utilize our coastal resources--as long as the public interest and the future maintenance of our resources are not compromised.

The demands on our coastal habitats can be grouped into financial and environmental concerns. Pressure for development of coastal areas is great. Foremost in everyone's mind is the preservation of certain areas of high environmental integrity. Beyond that, the competition for the remaining fixed amount of habitat becomes one of financial competition. Those holding control over those resources desire to maximize the economic return from using them. Many times this is not in the best interest of minimizing the impact on the resources.

As the region began its early development, draining lowlands and dredging and filling the coastlands was done to build good water access and an economic base. Today, this trend has been reversed hopefully, and environmental laws have been enacted which regulate coastal development. Policies exist which should grant preemptive uses fairly and equitably, consider riparian rights of upland owners, preserve certain estuarine areas, minimize water degradation and hopefully, recognize that each body of water is different in natural quality and permit uses based on these qualities. Together, we can manage our coastal habitat for future enjoyment and use of all the citizens of coastal Georgia and Northeast Florida.

Table 5. -- Average Value of Finfish and Shellfish at Dockside in Georgia and Northeast Florida, 1980 - 82

	Georgia		N.E. Florida		Total		
	Thousand Dollars	Percent	Thousand Dollars	Percent	Thousand Dollars	Percent	
			With Menhaden	Without Menhaden	With Menhaden	Without Menhaden	
Finfish without menhaden	623.4	3.3	4,012.	29.4	-	4,635.4	14.2
Shellfish	18,302.6	96.7	9,638.8	70.6	73.9	27,941.4	85.8
Total	18,926.0	100.0	13,650.7	100.0	-	32,576.8	100.0
Total without menhaden	-	-	13,034.4	-	100.0	31,960.3	-
							100.0

Source: Derived from statistics of the U.S. National Marine Fisheries Service.

Table 6. -- Average Landings of Important Fish and Shellfish Species in Georgia and Northeast Florida, 1960-62 and 1980-82.

Species	1960-62			1980-82		
	Thousand Pounds	Percent		Thousand Pounds	Percent	
		With Menhaden	Without Menhaden		With Menhaden	Without Menhaden
Black Mullet	1,084.5	1.6	2.8	1,222.2	2.6	3.9
Catfish	2,714.1	3.9	6.9	859.6	1.8	2.7
Flourders	187.6	.3	.5	348.5	.8	1.1
Groupers and Scamp	94.2	.1	.2	467.7	1.0	1.5
King Mackerel	10.9	a	a	270.8	.6	.9
King Whiting	973.7	1.4	2.5	1,033.1	2.2	3.3
Menhaden	30,185.1	43.4	-	15,014.2	32.2	47.4
Red Drum	89.4	.1	.2	170.3	.4	.5
Shad	1,039.1	1.5	2.6	244.7	.5	.8
Scup	0	0	-	263.8	.6	.8
Spotted Sea Trout	258.7	.4	.7	390.0	.8	1.2
All others	1,539.0	2.2	3.9	1,622.1	3.5	5.1
Total Finfish	38,176.3	54.9	-	21,907.0	46.9	69.1
Total Finfish (without menhaden)	7,991.2	-	20.3	6,892.8	-	21.7
Blue Crabs	17,489.5	25.1	44.4	14,470.1	31.0	45.7
Rock Shrimp	0	0	0	1,708.2	3.4	5.4
Shrimp	13,657.4	19.6	34.7	7,115.0	15.3	22.5
All others	253.0	.4	.6	1,499.6	3.2	4.7
Total Shellfish	31,399.9	45.1	79.7	24,792.9	53.9	78.3
Grand Total	69,576.2	100.0	-	46,699.9	100.0	-
Grand Total (without menhaden)	39,391.1	-	100.0	31,685.7	-	100.0

^a Less than .05

Source: Derived from statistics of the U.S. National Marine Fisheries Service.

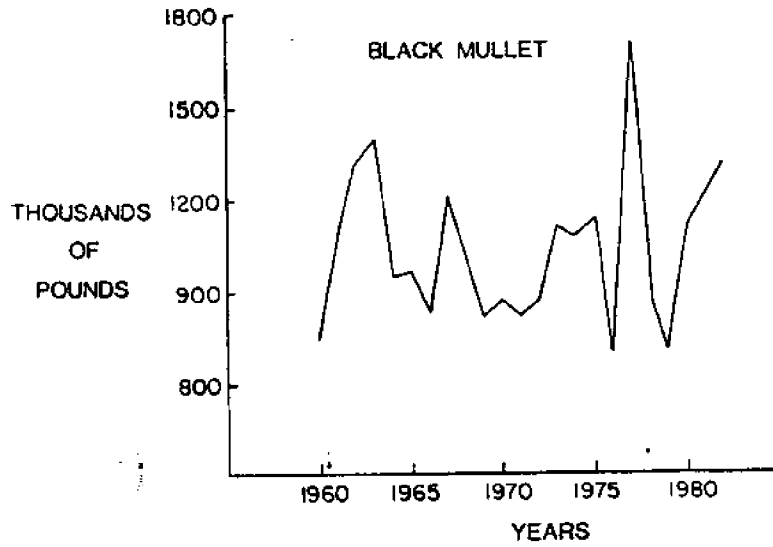
Table 7. -- Average Catch Statistics and Values for the
St. Johns River, 1980-83.

Species	Thousand	Thousand	
		Pounds	Dollars
American Shad		62.5	27.1
Blue crab		2,877.5	744.
Catfish		2,281.5	1,088.6
Eels		113.1	116.5
Gizzard Shad		97.5	7.6
Tilapia		3.1	1.1
Turtle (dressed)		2.2	2.6
Total		5,437.4	1,988.4
Shiners (dozen)		1,702.5	11.6
Grand Total		-	2,000.0

Source: Florida Game and Fresh Water Fish Commission.

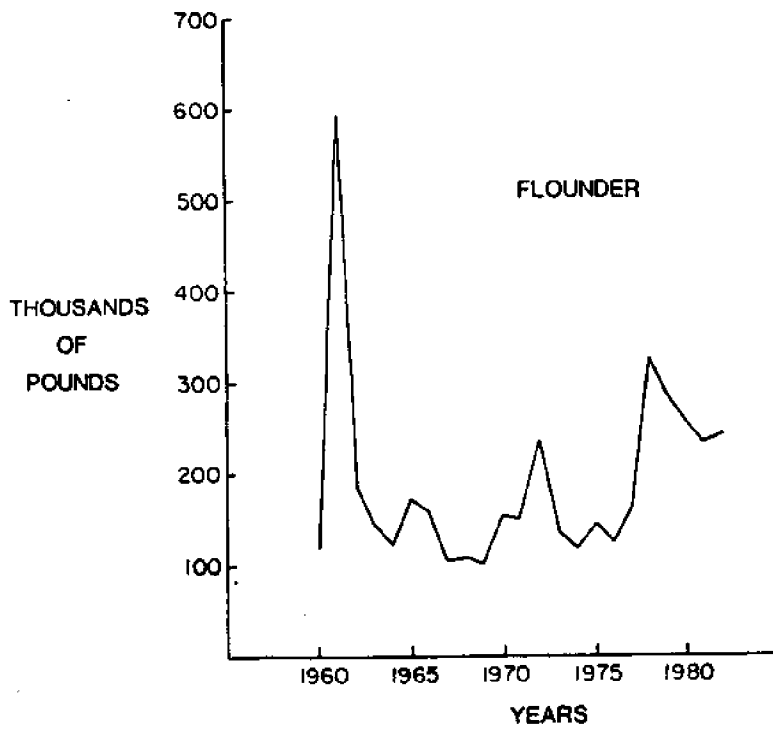
Table 8. -- General Trends in Landings of Fish and Shellfish for
Northeast Florida and Georgia
the Periods of 1960-63 and 1980-83.

Category	Northeast		
	Georgia	Florida	Total
Black Mullet	-	Stable	Stable
Flounders	-	Increase	Increase
Groupers and Scamp	Stable	Increase	Increase
King Mackerel	-	Increase	Increase
King Whiting	Increase	Decrease	Stable
Menhaden	-	Decrease	Decrease
Red Drum	-	Increase	Increase
Shad	Decrease	Decrease	Decrease
Spotted Sea Trout	Stable	Increase	Increase
Total Finfish	Stable	Decrease	Decrease
Total Finfish (without menhaden)	-	Decrease	Decrease
Blue Crabs	Decrease	Decrease	Decrease
Rock Shrimp	Increase	Increase	Increase
Shrimp	Decrease	Decrease	Decrease
Total Shellfish	Decrease	Decrease	Decrease
Grand Total	Decrease	Decrease	Decrease
Grand Total (without menhaden)	-	Decrease	Decrease



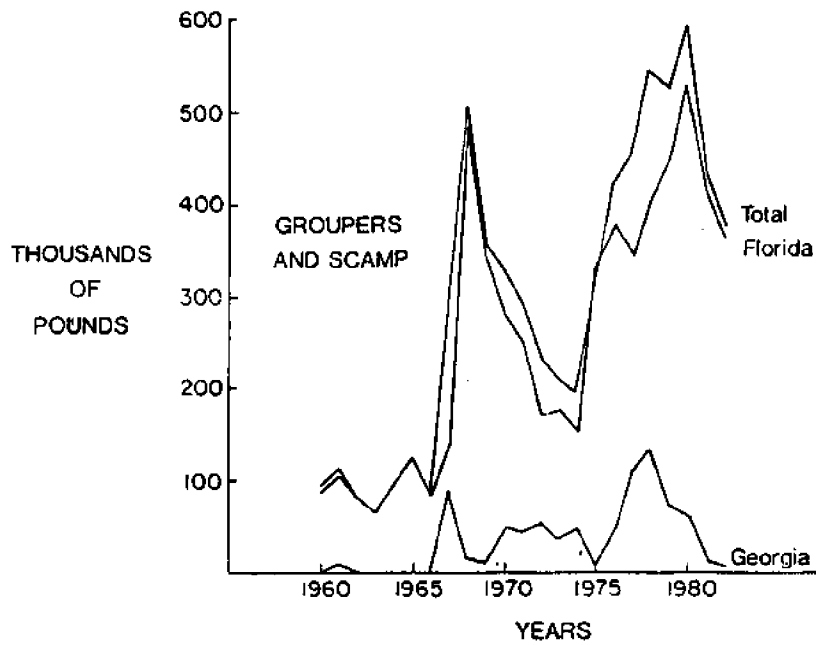
Landings of Black Mullet
in Northeast Florida, 1960-82

Figure 3



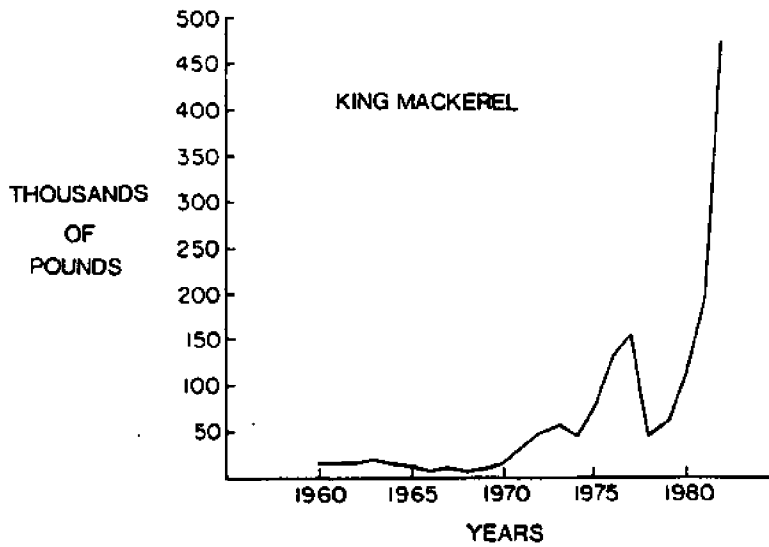
Landings of Flounder
in Northeast Florida, 1960-82

Figure 4



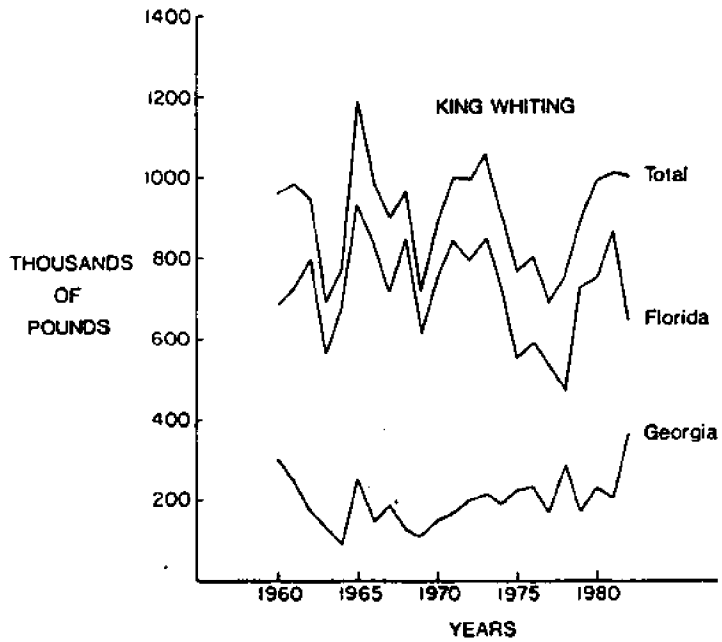
Landings of Grouper and Scamp in Northeast Florida and Georgia, 1960-82

Figure 5



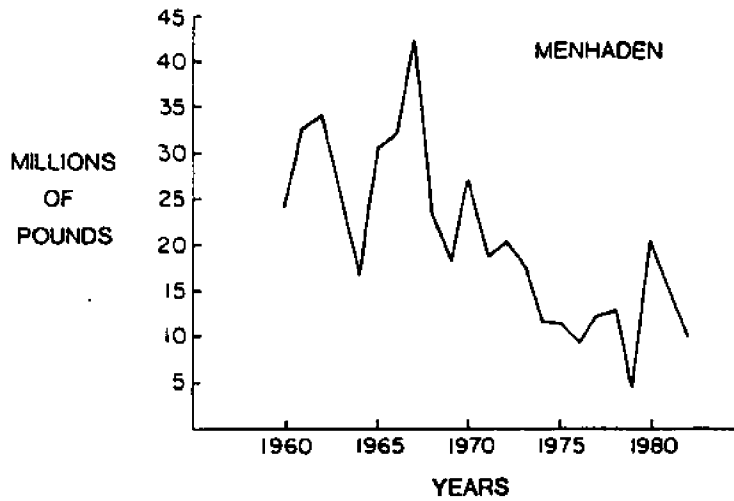
Landings of King Mackerel in Northeast Florida, 1960-82

Figure 6



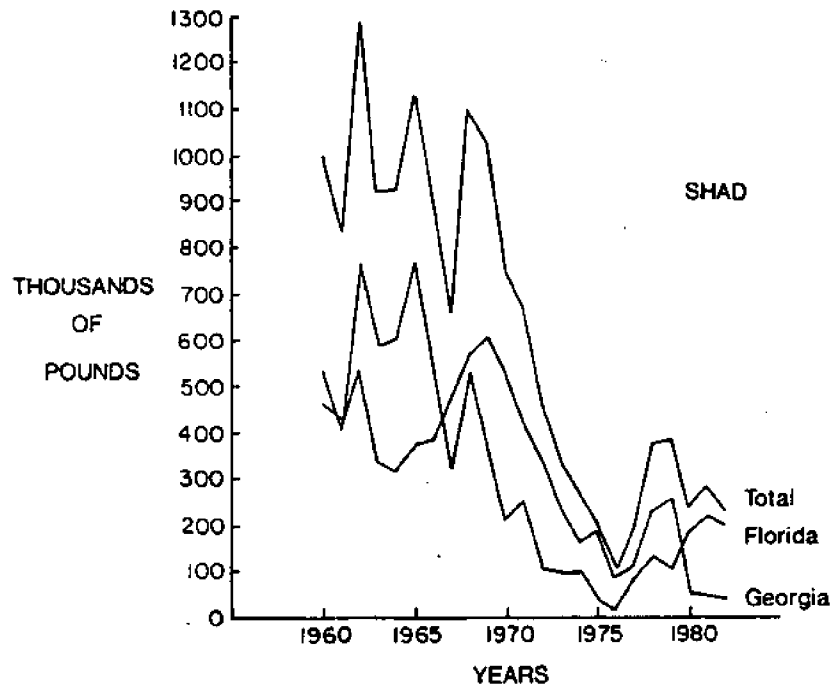
Landings of King Whiting
in Northeast Florida and Georgia, 1960-82

Figure 7



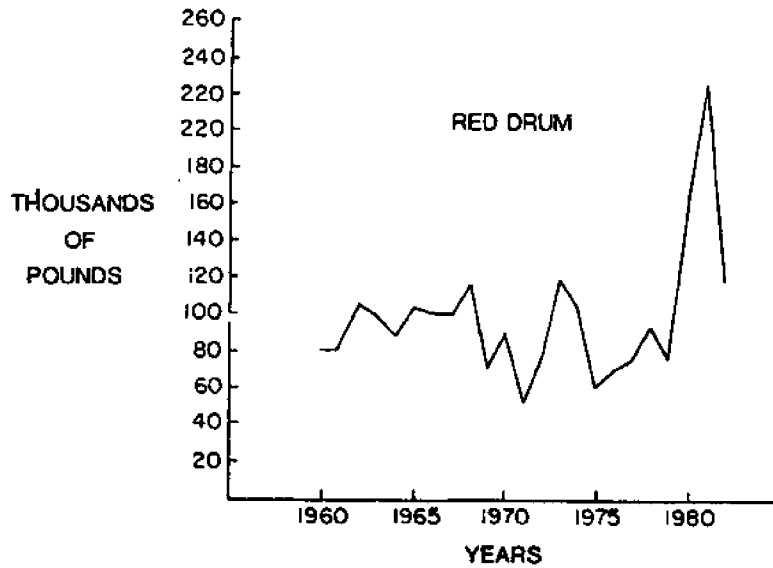
Landings of Menhaden
in Northeast Florida, 1960-82

Figure 8



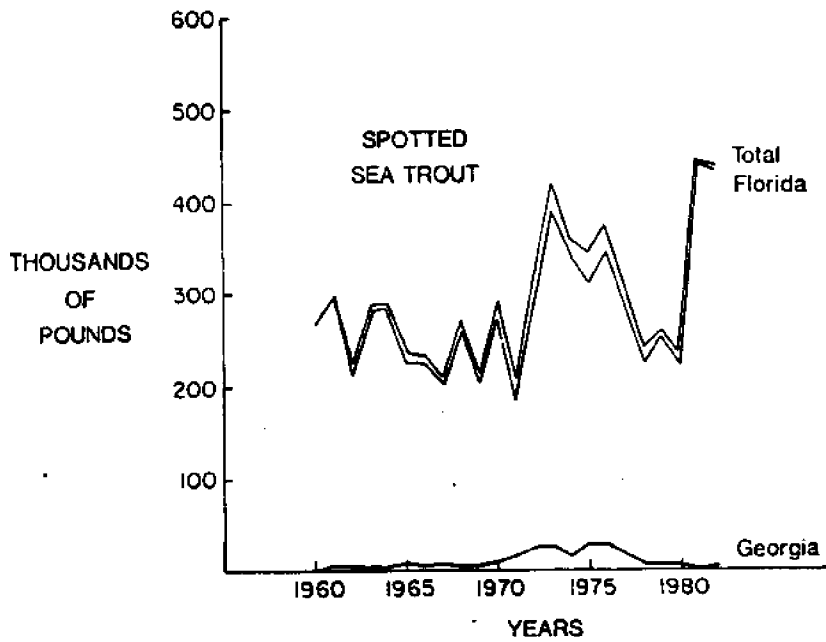
Landing of Shad in Northeast Florida, and Georgia, 1960-82

Figure 9



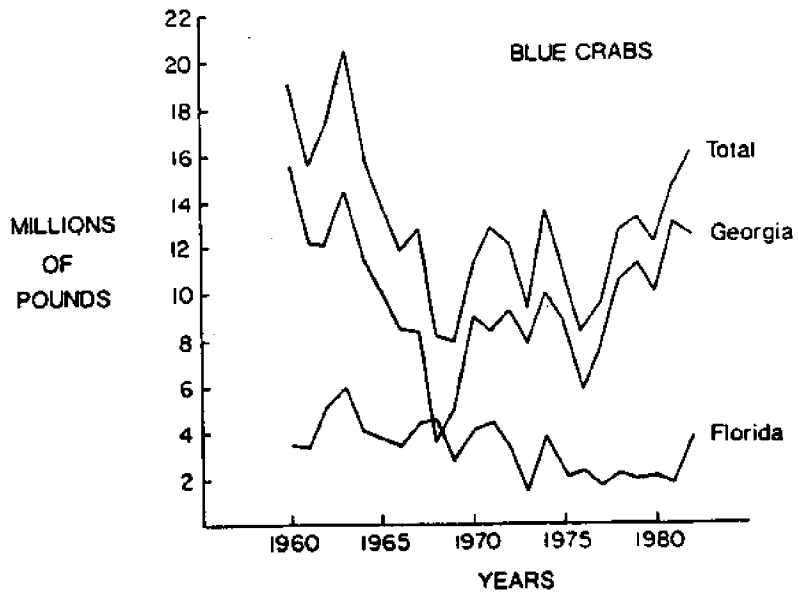
Landings of Red Drum in Northeast Florida, 1960-82

Figure 10



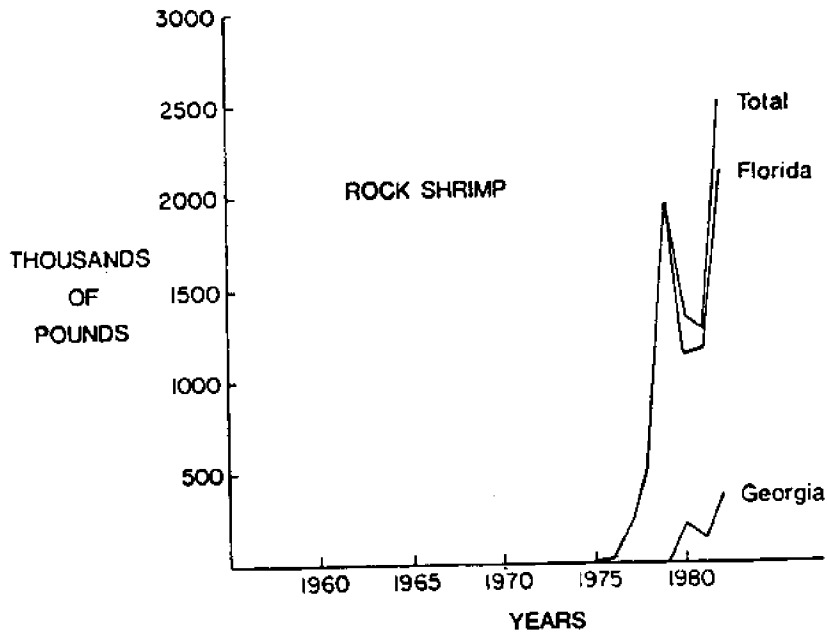
Landings of Spotted Sea Trout
in Northeast Florida and Georgia, 1960-82

Figure 11

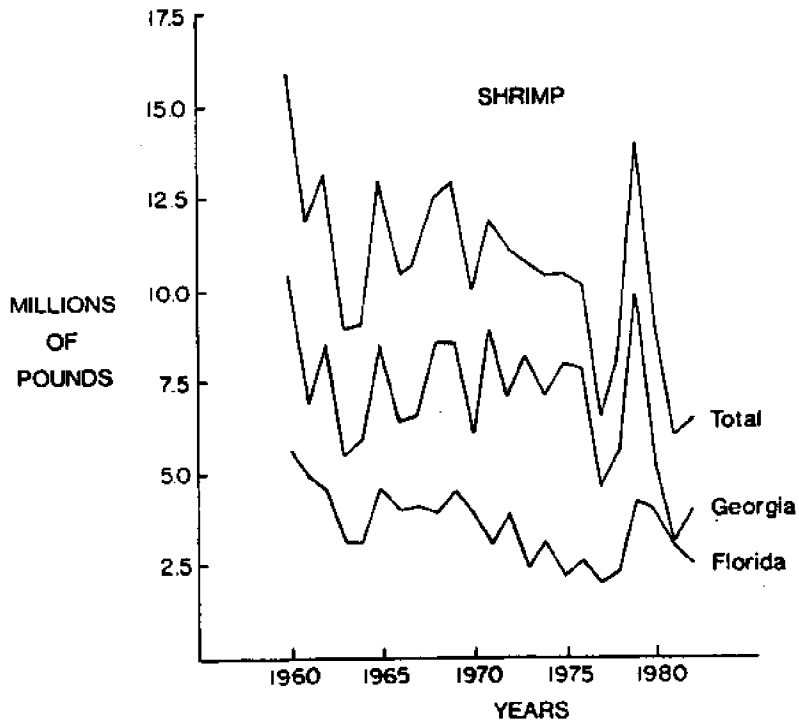


Landings of Blue Crabs
in Northeast Florida and Georgia, 1960-82

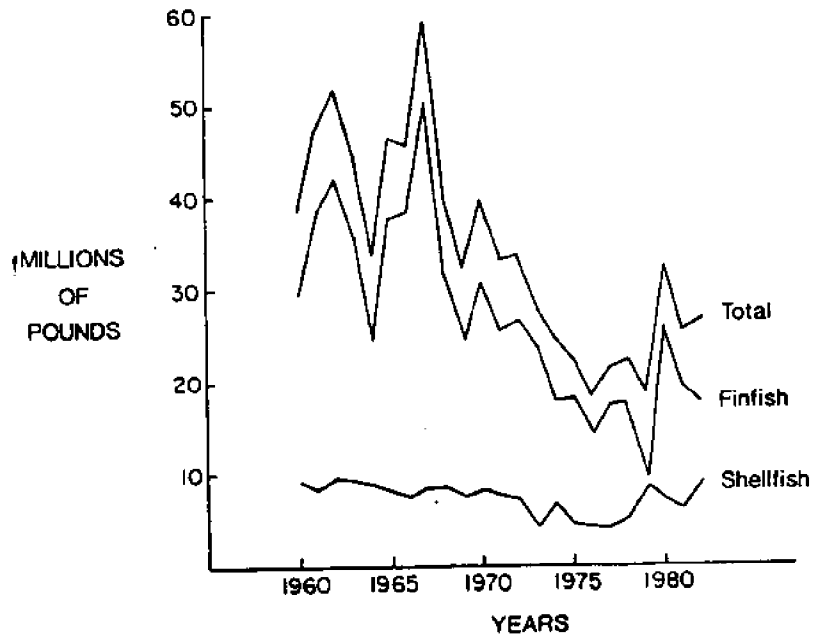
Figure 12



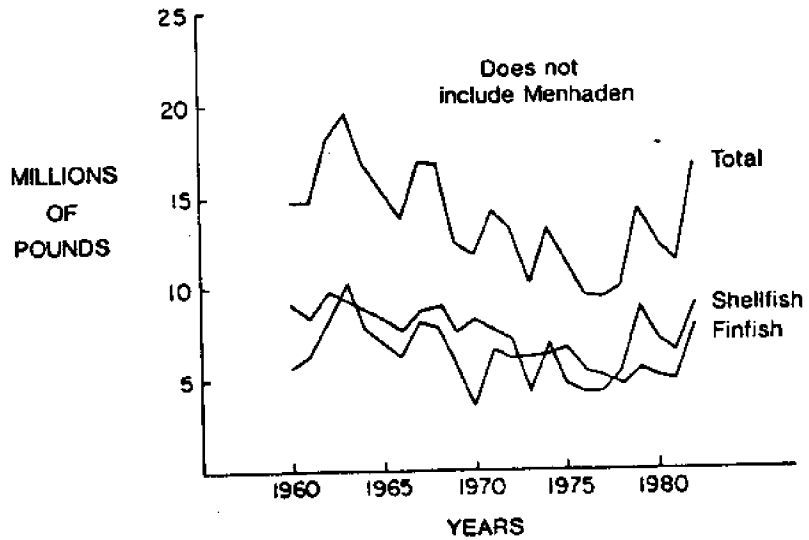
Landings of Rock Shrimp
in Northeast Florida and Georgia, 1960-82
Figure 13



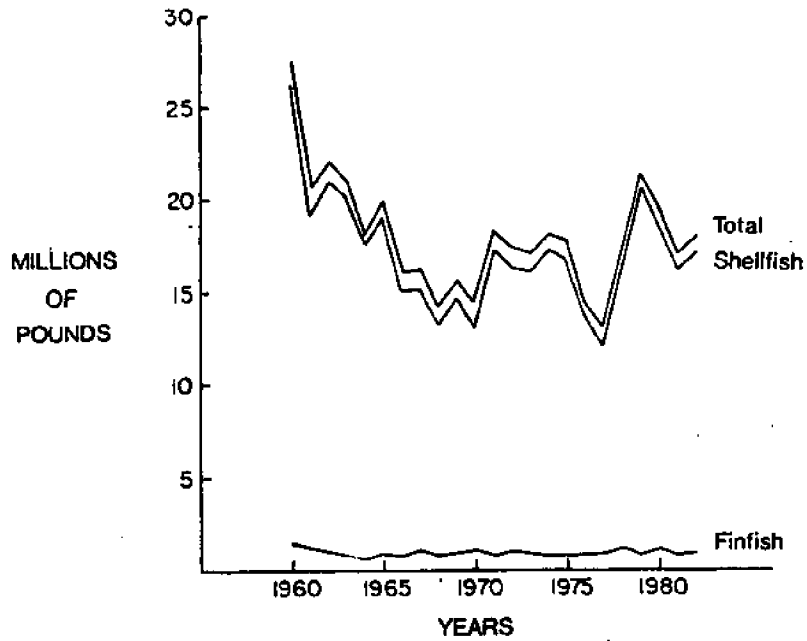
Landings of Shrimp
in Northeast Florida and Georgia, 1960-82
Figure 14



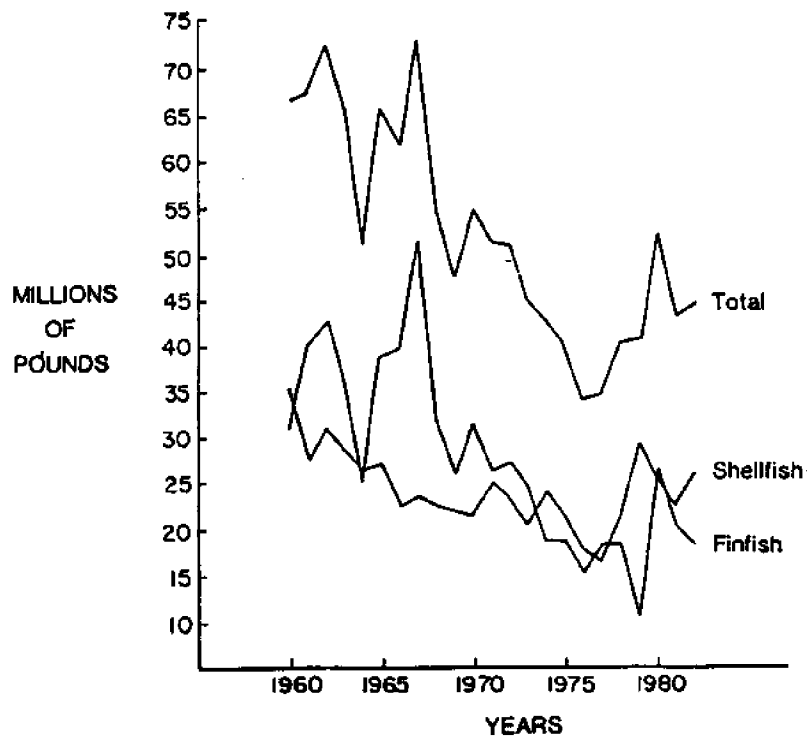
**Landings of Finfish
and Shellfish in Northeast Florida, 1960-82**
Figure 15



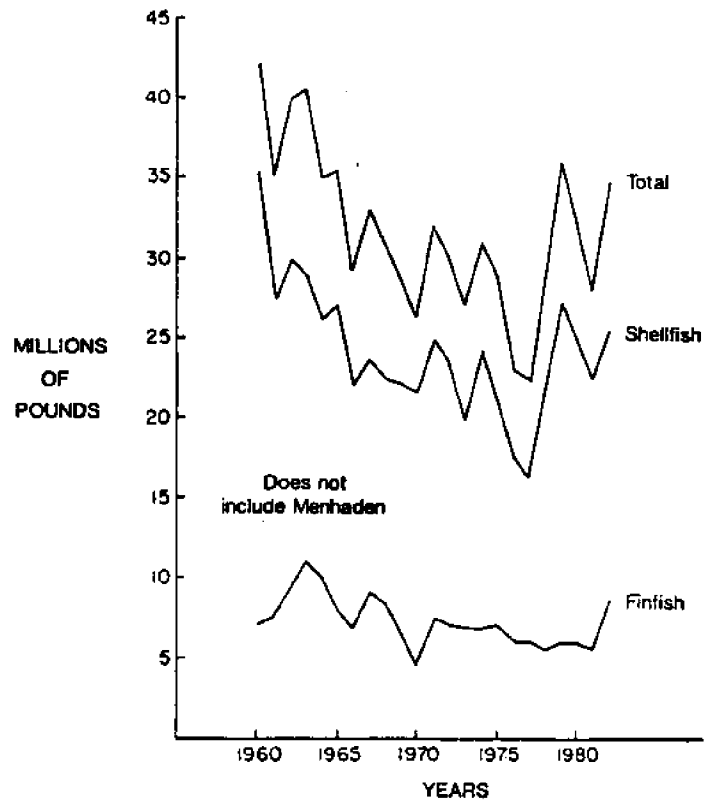
**Landings of Finfish and
Shellfish in Northeast Florida, 1960-82**
Figure 16



Landings of Finfish and Shellfish in Georgia, 1960-82
Figure 17

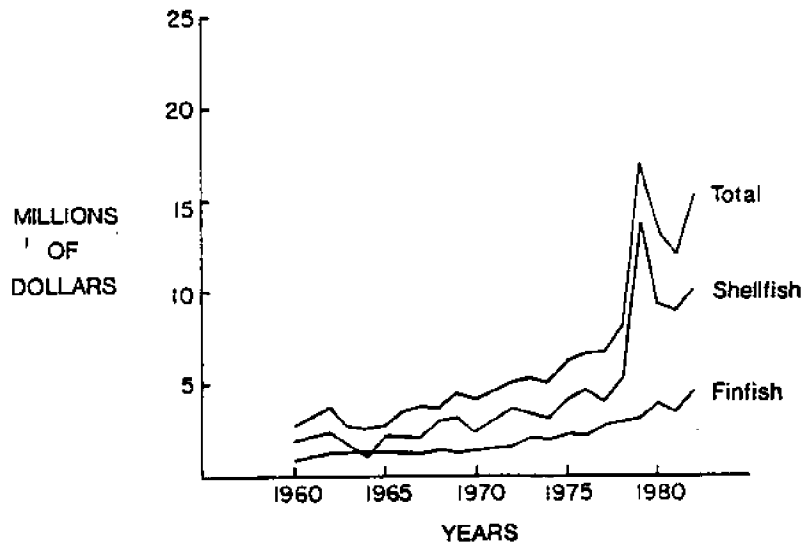


Landings of Finfish and Shellfish in Northeast Florida and Georgia, 1960-82
Figure 18



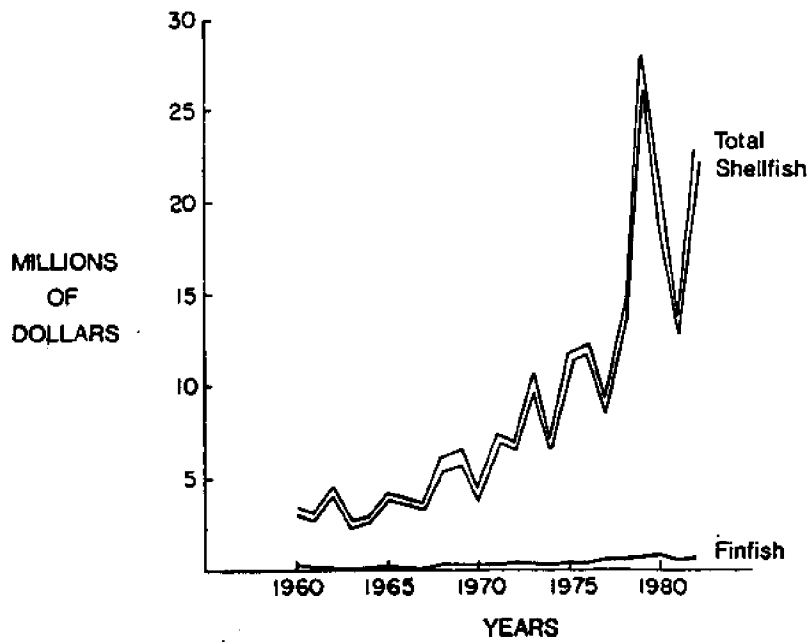
Landings of Finfish and Shellfish
in Northeast Florida and Georgia, 1960-82

Figure 19



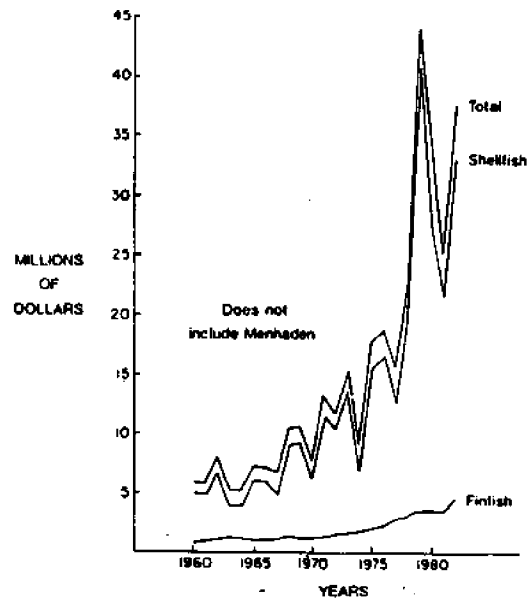
Dockside Value of Landings of
Finfish and Shellfish in Northeast Florida, 1960-82

Figure 20



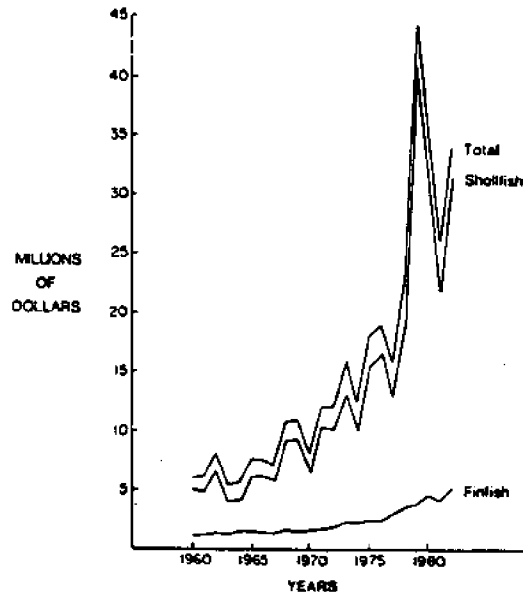
Dockside Value of Finfish
and Shellfish Landings in Georgia, 1960-82

Figure 21



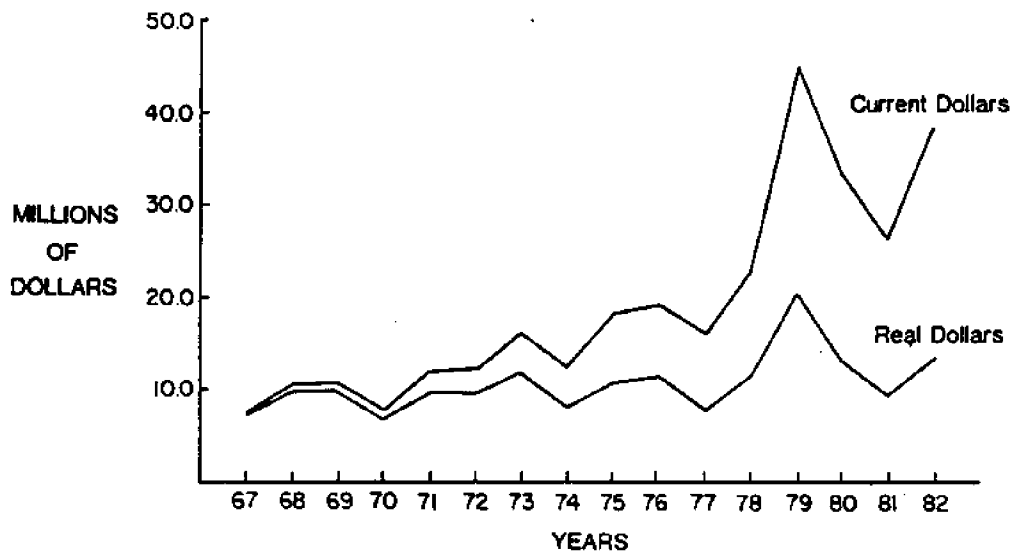
Dockside Value of Landings of Shellfish and Finfish in Northeast Florida and Georgia, 1960-82

Figure 22



Dockside Value of Landings of Finfish and Shellfish in Northeast Florida and Georgia, 1960-82

Figure 23



Dockside Value of Finfish and Shellfish Landings in Northeast Florida and Georgia, 1967-82

Figure 24

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Coastal Habitats and Fisheries of Northeast Florida -
Issues and Impacts.

M. J. Durako, M. D. Murphy, and K. D. Haddad

Since the 1950's, Florida's population has soared, with up to 7,000 people establishing residence in the State each week. Recent projections by the U.S. Census Bureau indicate that, if present trends continue, Florida will be the third most populous state by the year 1995. Northeast Florida's population has increased 21% over the last decade with a 103% increase in unincorporated areas compared to only a 19% increase in towns. Although the rate of population growth in this region is about half the statewide average, the low density development pattern results in significant changes in land use to accommodate the additional growth. Seventy-five percent of the population resides in coastal areas. Major northeast Florida urban centers are adjacent to bodies of water which are important breeding and nursery areas for finfish and shellfish, which support the region's fishing industries. Loss or alteration of wetland habitats and degradation of water quality, due to impacts related to population growth and development activities, are probably the most important growth issues affecting coastal fisheries resources in the northeast Florida region.

The following discussion represents a summary of a more comprehensive review on the physical and biological characteristics of coastal northeast Florida and how growth impacts are directly and/or indirectly affecting coastal habitats and fisheries resources. For a more detailed treatment of the points presented, the reader is referred to a soon to be published Florida Marine Research Publications (Florida Department of Natural Resources, Bureau of Marine Research, 100 Eighth Avenue S.E., St. Petersburg, FL 33701).

Northeast Florida lies in the southern part of the Atlantic coastal plain. The coastal region occupies a physiographic division known as the coastal lowlands, which are nearly level plains that are poorly drained. Barrier islands, coastal lagoons and estuaries, and a series of coastal ridges with intervening valleys are the characteristic land forms. These features parallel the coast, reflecting the influence of marine forces. The presence of relatively large quantities of clay, coupled with low to moderate wave energies, is thought to account for the salt marsh dominated Sea Islands of extreme northeast Florida. South of the mouth of the St. Johns River, barrier island/lagoon complexes predominate, reflecting the decrease in percentages of clay and silt, the increase in wave energies, and the presence of

a coquina rock ridge known as the Anastasia Formation which forms the backbone of the Atlantic Ridge.

Surface fresh water resources in northeast Florida are supplied by three drainage basins. These drainage basins act as a link between the coastal zone and the interior; therefore, careless management and use of upland resources can affect coastal resources. The St. Mary's-Nassau River Basin and the St. Johns River Basin originate in inland areas, while the East Coast Basin primarily drains land directly along the coast. With the exception of the Tolomato River and Moultrie Creek, the "rivers" of the East Coast Basin are really coastal lagoons. These are connected via artificial channels to establish continuity of the Intracoastal Waterway. Coastal drainage and lagoons are connected to the ocean by inlets, which occur at 30-40 mile intervals in the northeast Florida region as compared to about every 10 miles in Georgia. The infrequency of inlets reflects basic physiographic and hydrologic differences between the two states and this has important management implications.

Most of the estuaries along the northeast Florida coast are characterized as being well-mixed since tidal flow exerts, on the average, a greater force than does fresh water inflow. This generally results in homogenous vertical profiles of salinity, dissolved oxygen, and temperature. The St. Johns River is consistently tidal 170 km upstream from the mouth. Numerous salt springs that drain into the river result in locally elevated salinities and appear to be partly responsible for the presence of a number of oceanic fish (25 known species) in the upper region bounded by Ocala National Forest. The St. Johns River is also unusual in that it discharges directly into the Atlantic Ocean rather than into an embayment typical of most estuaries.

Although the coastal lagoons of northeast Florida receive fresh water mainly from surface runoffs, they exhibit estuarine characteristics. The Tolomato River system is characterized by a series of small lagoons and wetland areas that are adjacent to the man-made Intracoastal Waterway. Physical modifications resulting from Waterway improvements and a dam which seals off a portion of the Guano River has altered the flushing characteristics of this system. The Matanzas River system is similar to the Tolomato system, except that it lacks extensive man-made modifications and has less flushing. Freshwater inflow to the Matanzas River from several creeks, the San Sebastian River, and a number of artesian springs creates salinity conditions favorable to numerous marine and estuarine species. The Halifax River, which is intersected by the Tomoka River north of Ormond Beach, is highly urbanized, resulting in poor to moderate water quality. Mosquito Lagoon is unusual in that fresh water inflow and evaporation are approximately balanced, resulting in relatively high salinities. This coupled with its restricted circulation results in portions of the lagoon being hypersaline for much of the year. Species such as red drum (Sciaenops ocellatus) that normally migrate offshore to spawn remain within this "miniature ocean" to complete their life cycles.

Coastal northeast Florida possesses a diverse array of habitats, ranging from salt marsh dominated Sea Islands of the north to mangrove and seagrass habitats of the more southern coastal lagoons. Estuaries north of Port Orange generally are dominated by salt marsh vegetation while those to the south are characterized by mangroves. Thus, the Port Orange/Ponce Inlet area forms an important vegetational transition zone, although most of the mangroves in this area were killed in the 1983 and 1984 freezes. These habitats fringe estuaries which form vital ecological links between inland fresh water habitats and the ocean. Coastal wetlands and estuaries are economically important as well; at least 72% of the 89 commercially landed species of finfish and shellfish and 74% of the 84 recreational species depend on them at some stage of their life cycle.

Salt marshes in northeast Florida tend to be dominated by smooth cordgras (*Spartina alterniflora*) with black needle rush (*Juncus roemerianus*) being found at slightly higher elevations, often behind *Spartina*. Zonation patterns are typical of South Atlantic salt marshes, but somewhat distinct from those of Florida's Gulf coast marshes where *Juncus* is dominant. The importance of salt marshes to the production of fisheries resources results, to a great extent, from their high rate of primary productivity which sets an upper limit to the flow of energy through the marsh-estuarine food web. Ninety or more percent of the net primary production of a salt marsh may form detritus, the export of which, known as outwelling, has long been considered to be the most important contribution of the marsh to estuarine and coastal productivity. Salt marshes also provide a favorable environment for early life stages of many species and this nursery function has been proposed as an alternative to outwelling as the most important function of salt marshes.

Mangroves, which are relatively intolerant of freezing temperatures, form the tropical and sub-tropical equivalent of salt marshes. Black mangroves (*Avicennia germinans*) occur as far north as St. Augustine. Red mangroves (*Rhizophora mangle*) occur as far north as Ponce de Leon Inlet, while white mangroves (*Laguncularia racemosa*) only extend as far north as Brevard County. In northeast Florida the incursions of freezing temperatures rather than elevation or salinity seem to control mangrove zonation. This results in the dominance of black mangroves intertidally with the succulents glasswort (*Salicornia* spp.) and saltwort (*Batis maritima*) occurring above mean high water. These communities are characterized as high marshes and they receive less tidal and fresh water flow energy subsidies than low marshes. Low marsh and high marsh ichthyofaunas are distinct, the former being numerically dominated by juvenile sciaenids, killifishes (*Fundulus* spp.) mullets (*Mugil* spp.), menhaden (*Brevoortia* spp.) and anchovies (*Anchoa* spp.), with juvenile ladyfish (*Elops saurus*), drum (*Pogonias cromis*), spot (*Leiostomus xanthurus*), tarpon (*Megalops atlanticus*), and snook (*Centropomus undecimalis*) being associated with the latter. Twenty fish species, eight of sport and commercial value, have been recorded from the upper

marsh. The fishery value of many of these areas has been diminished by the extensive mosquito control impoundment isolation which has taken place in the last twenty years.

Three important non-macrophyte dominated coastal habitats-- mud flats, oyster reefs, and exposed beach surf zones--are fairly extensive in northeast Florida. Mud flats have been assumed to be relatively unimportant as a consequence of their lack of macrophytes. However, the microalgae that are present can be directly utilized by herbivores and these flats are a major site of conversion of plant detritus into invertebrates which ultimately serve as prey for larger species. Oysters (Crassostrea virginica) are the most abundant epifaunal invertebrates in northeast Florida. Oysters form reefs which are important in providing hard substrate in an otherwise soft sediment environment. Their filter feeding behavior and sedentary nature make them particularly susceptible to a variety of man-induced and natural system stresses, particularly those resulting in degraded water quality. The seemingly harsh and unstable environment of the surf zone is an important habitat for Florida pompano (Trachinotus carolinus), whiting (Menticirrhus littoralis), scaled sardines (Harengula jaguana), and striped anchovy (Anchoa hepsetus). Surf zones may be the most sensitive regions of the coastal environment, but their dynamic nature makes detection of man-made perturbations difficult. They are the first coastal environment affected by offshore pollution sources, such as oil spills, as well as being impacted by the bulkheading of coastal beaches, which alters sand movement patterns and usually results in more acute erosional problems. Although only 10-15% of the total land area in northeast Florida is developed, over 50% of the ocean-fronting shoreline is developed and less than 20% of the shoreline is held in public ownership.

Baseline and post-operational studies of power plant sites, environmental impact studies, and 208 Federal Water Pollution Control studies have contributed most to the recent understanding of the fish communities of northeast Florida. Early work was primarily conducted in the St. Johns River, including its estuarine portions. These studies determined that the coastal fish fauna of this region can be characterized as being temperate with species of tropical Caribbean affinities occurring during warm periods of the year. Over half of the fish species known to occur in the St. Johns River are euryhaline or marine.

Sciaenids are the most commercially and recreationally important finfish family in the region. Croakers (Micropogon undulatus), whiting, drum and trout (Cynoscion nebulosus), like most other sciaenids, require estuaries or shallow coastal waters for spawning or development. Anchovies and herrings are important as prey for many larger commercially and recreationally important species. Menhaden are an important forage fish, and the target species for the largest fishery by landings weight in the U.S. In northeast Florida, mullet dominate the catch by weight. Mullet spawn offshore, but when the young reach about 2.5 cm in length they seek out estuarine habitats. They remain in estuarine and coastal waters, except during their fall

spawning migration. The bothids, or left-eyed flounders, are important commercially and recreationally. Adults migrate offshore during fall and winter to spawn; juveniles inhabit shallow sand and mud bottoms and grass flats in estuaries. American shad (*Alosa sapidissima*) are the most important anadromous fish in this region. Shad spawn in rivers such as the St. Johns River in late winter and early spring. Bluefish (*Pomatomus saltatrix*) represent a coastal pelagic species whose young utilize the estuary as a feeding ground. Large schools of young bluefish frequently feed on small fish in the lower reaches of the estuary.

Important shellfish resources of northeast Florida consist of three species of penaeid shrimp, blue crabs (*Callinectes sapidus*), oysters and clams (*Mercenaria mercenaria*). Brown and white shrimp (*Penaeus aztecus* and *P. setiferus*) are economically very important to both northeast Florida and Georgia. Both share a common dependence on the estuary as juveniles; brown shrimp prefer higher salinities than white shrimp as adults. Pink shrimp (*Penaeus duorarum*) form only a small part of the commercial catch in northeast Florida, but are a major constituent of the live bait fishery from Ponce Inlet south. Blue crabs are the target species of a large commercial and recreational fishery. Blue crabs mate in brackish waters, the females then migrate offshore to spawn. After passing through several zoeal stages, megalops ride tidal currents back into the estuary. Along the northeast coast of Florida, female blue crabs exhibit predominantly an offshore/onshore migration pattern that tends to keep crabs from adjacent systems from mixing. Oysters are common along salt marsh creeks, where they form large mounds or bars. They require a free exchange of water and salinities between 5-30 ppt. Hard clams, or quahogs, like oysters, are filter feeders and also require good water circulation, but clams are restricted to areas of sand, sand-mud, or shell-rubble substrates and require salinities from 20-38 ppt. Highly successful sets in the past few years have resulted in a virtual explosion of the clam population in the Indian River area. This bonanza crop is presently subject to heavy exploitation, creating a number of volatile issues and raising important management questions in this region.

A review of landings data for the region shows highest productivity in Brevard and Volusia counties. Although there is no information on the number of fishermen or the effort expended in each county, the landings data may be interpreted as a measure of abundance of fish in each county. Greater landings occur in counties with the largest expanses of estuary, reflecting the high productivity of the estuarine environments in those counties. Brevard and Volusia counties include the Mosquito Lagoon/Upper Indian River complex. Duval County, which also contributes a major portion of northeast Florida landings, includes the St. Johns River estuary. In contrast, St. Johns and Flagler counties have less estuarine acreage and probably less potential for fish production.

Thematic Mapper (TM) data for an October 1984 pass of the LANDSTAT satellite, analyzed using Florida Department of Natural

Resources, Marine Resources Geobased Information System (MRGIS). indicated that northeast Florida has 37,451 hectares wetlands, or about 10% of the state's total. Salt marshes comprise 92% of the region's total. Three locations were analyzed in a historical assessment of fisheries habitat alteration from the 1940's and 1950's to the present. The Ponce de Leon Inlet area has had an overall 20% decline in wetlands since 1943. Marsh/mangrove habitats have declined 19% while 100% (30 ha) of the seagrasses in this area were lost. The St. Augustine Inlet segment analysis indicated a 20% loss of marsh since 1952. Most of this loss was associated with the damming of Guano Lake. St. Johns Inlet to 16 km up the St. Johns River has experienced a 36% loss of marsh habitat since 1943, primarily due to dredge and fill activities. Highest rates of habitat loss have occurred around inlets which, coincidentally, are the first "habitats" encountered as juveniles and adults of various fisheries species enter the estuary.

Some specific perturbations resulting in coastal habitat losses include: oceanfront development, dredge and fill, channel dredging and maintenance, causeway construction; bulkheading and mosquito impoundments. Oceanfront development results in increased stormwater runoff and may exacerbate beach erosion (as evidenced by the severe erosion that occurred along the northeast Florida coast during the fall of 1984). With less than 20% of the shoreline in public ownership, relatively rapid development of beachfront property may be expected to continue. The most acute impact in estuarine areas is the direct removal or burial of parts or all of a habitat. This impact is associated with channel dredging and maintenance, dredge and fill operations, causeway construction, and shell mining. Channelization represents the most widespread form of estuarine alteration in northeast Florida. Causeway construction is also frequently cited as a major disruptive impact in this region. Causeways have two major impacts, the direct burial of habitat and the modification of water circulation. Whereas causeway construction frequently follows population growth, bulkheading and backfilling represent the first steps in a chain of events which lead to habitat losses. Bulkheads promote erosion of the foreshore and eliminate the transition zones between intertidal and subtidal habitats. The deep zone in front of bulkheads has an adverse effect on fish. Mosquito impoundments, which are more prevalent in Volusia and Brevard Counties, reduce availability of wetland habitats to marine organisms and cause losses and/or changes in vegetation. Almost 16,000 ha of coastal wetlands have been impounded in this region.

In addition to habitat destruction, population growth can also result in system stresses which negatively affect the quality of remaining coastal habitat. Foremost among these impacts is a decline in water quality due to increasing point and non-point pollution sources. Municipal discharges and package sewage treatment plants represent the most significant point pollution sources. Sewage chlorine and turbidity are major causative factors in reducing species diversity of fish communities in areas adjacent to outfalls; increased fecal coliform levels result in

closure of many shellfish harvesting areas. Other major point pollution sources in northeast Florida include: dairy and seafood processing plants and pulp mills. These sources release high BOD (biological oxygen demand) effluents which have been shown to reduce numbers of individuals and species of estuarine and marsh fish assemblages. Power plants are major contributors to thermal pollution; they can also entrain and impinge juvenile and adult finfish and shellfish. Jacksonville Electric Authority has studied fish return systems (FRS) which minimize impingement and/or entrainment impacts.

The major form of non-point source pollution in northeast Florida is urban runoff. This problem has grown to such a great extent nationwide that the U.S. Environmental Protection Agency has established the National Urban Runoff Program (NURP) for the purpose of developing technologies to control water pollution from urban runoff. Runoff from city streets, ship yards, and marinas contains oil, grease, and heavy metals. Another significant non-point source pollution category, which is a special problem in northeast Florida due to the low density development patterns in this region, is the overflow or leaking of septic tanks. This material is transported during rainfall events and results in high turbidity and fecal coliform levels and low dissolved oxygen concentrations in receiving water bodies.

In conclusion, some primary needs to be considered in terms of major growth issues affecting the coastal northeast Florida region, are the prevention of continued environmental degradation through countless seemingly unrelated small impacts and an increase in scientific and public awareness of the complex requirements and dynamics of important fisheries species. The region has currently lost a lower percentage of its wetlands compared to most other areas of the state, although some areas have suffered acute losses. However, environmental degradation is continuing due to a phenomenon known as the "tyranny of small decisions." This is a series of small independent decisions (and/or impacts) made by individuals or small groups, resulting in a big decision being made in reaction to the accreted effects of the small decisions. As a result, the important central question (e.g., habitat preservation/fisheries management) is never addressed at the higher decision levels. It is hoped that through efforts such as this symposium publication, decision-making in the northeast Florida region can begin to take a large-scale or holistic perspective and thereby avoid the problems of cumulative effects in the future.

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OFFSHORE FISHERIES AND RELATED HABITATS

Donald R. Ekberg¹ and Gene R. Huntsman²

In this discussion we shall first describe the environment and principal habitat types of the outer continental shelf of northeastern Florida and Georgia, secondly describe the principal groups of communities of open ocean fishes, then briefly relate the different groups of fishes to continental shelf habitats and, where pertinent, to nearshore wetlands, and finally describe the role of environment in moulding fish behavior.

I. ENVIRONMENT AND HABITATS

We will subdivide the description of the environment into two parts. First we will discuss, in general, the hydrology of the outer continental shelf. Second we will describe benthic habitats.

The oceanography of the region's outer continental shelf is both complex and variable, and its precise state at any particular time is presently unpredictable. For convenience we propose that three principal water masses occupy the continental shelf (Table I). The average position of those masses largely determine what fishes will occur at any given site. The interaction of these masses at their boundaries result in important oceanographic phenomena which ultimately affect fishery production.

The nearshore mass occurs from the shoreline to approximately the 25m isobath. This mass is greatly affected by continental weather and exhibits marked seasonal variation in properties, especially temperature. Further, drainage from rivers can drastically alter the salinity, clarity and nutrient content of the water and consequently its short term productivity. This variation is especially prevalent from Savannah to Jacksonville where major rivers discharge.

The outermost water mass is the Gulf Stream. While the Stream is highly variable in position, it has extremely constant properties. The Gulf Stream commonly exhibits meanders that migrate northeastward along the outer boundary of the continental shelf and the main axis of the stream may consequently lie

1 National Marine Fisheries Service, NOAA, Southeast Regional Office, St. Petersburg, Florida 33702.

2 National Marine Fisheries Service, NOAA, Southeast Fisheries Center, Beaufort Laboratory, Beaufort, North Carolina 28510.

TABLE 1

SIMPLIFIED OCEANOGRAPHY
OF GEORGIA - NORTHEAST FLORIDA SHELF

<u>WATER MASS</u>	<u>LOCATION</u>	<u>PROPERTIES</u>
NEARSHORE	NEARLY CONSTANT SHORELINE -25M	HIGHLY VARIABLE, SEASONALLY COLD, VARIABLE SALINITY, CLARITY.
MIDSHELF	25-M ISOBATH TO GULF STREAM	MODERATED SEASONAL VARIABILITY. BASICALLY WARM, CLEAR GREEN LATITUDINAL EFFECTS AS IMPORTANT AS SEASONAL ONES.
GULF STREAM	HIGHLY VARIABLE, MEANDERS	VERY CONSTANT, UNIFORMLY WARM, CLEAR, HIGHLY SALINE, LOW NUTRIENTS AND PLANKTON POPULATION.

SPECIAL EVENTS:

UPWELLING - COMMON, ASSOCIATED WITH GULF STREAM MEANDERS.
LONG AND SHORT TERM FISHERY EFFECTS.

COLD CORE RINGS - UNCOMMON, SHORT TERM UNIMPORTANT
FISHERY EFFECTS.

anywhere from 30 to 70 Km offshore. Regardless of position the Gulf Stream is characterized by water that is clear, warm, highly saline and generally low in nutrients (Mathews and Pushuk, 1977). Between the nearshore waters and the Gulf Stream lies the large mid-shelf water mass which generally occupies the zone from the 30m to the 200m isobath. The mass is neither as constant as the Gulf Stream nor as variable as the nearshore mass. The water is generally warm (16-27°C), and while seasonal changes in temperature occur, they are buffered by the immense volume of water and are not large. In general, the temperature of the mass reflects latitude as much as season and the biota of the middle mass becomes increasingly tropical from Savannah to Cape Canaveral. Salinity varies little. The water is moderately nutrient rich, usually green to blue green, with nutrients derived from continental and oceanic sources.

The interaction of the midshelf mass and the Gulf Stream produces one of the most striking and important oceanographic features of the region. Where the Gulf Stream meanders offshore, that is when it loops to the eastward, cold bottom water from beyond the continental shelf is forced up and onto the shelf (Atkinson and Targett, 1983). This upwelling is a major source of nutrients, especially nitrogen, for the midshelf watermass and in the long run contributes to fisheries production. The short run effects of upwelling on fisheries are very poorly understood. It appears that upwelling modifies the distribution of pelagic prey and sportfishes and that the incursion of cold water over reef areas temporarily disrupts fishing success for reef fishes. Upwelling occurs all along the U.S. South Atlantic coast but seems to be particularly prevalent off St. Augustine and Daytona (Atkinson and Targett, 1983). A less common, but very interesting interaction of the midshelf water mass and Gulf Stream occurs when a westerly meander of the Gulf Stream closes, or pinches off, in its eastern side, and forms a circulating loop of warm Gulf Stream water enclosing a core of cooler shelf water. These cold core rings are known to track westerly across the continental shelf, sometimes to the shoreline, carrying the distinctive Gulf Stream fauna and flora including sargasso weed, Portugese men-of-war and dolphin Coryphaena hippurus. The rings, unlike upwelling, are relatively uncommon and their contribution to the properties of the midshelf water mass are unimportant. Most rings dissipate on the midshelf while a few rejoin the Gulf Stream.

In summary, most of the Georgia-northeast Florida shelf is overlaid by water that is, on the average, warm the year around. However, the conditions prevailing at any particular place and time are extremely unpredictable because of the complex and dynamic interactions of the three water masses.

There are two principal types of the benthic habitats on the outer Continental Shelf, unconsolidated sediments and reef areas (Table II).

TABLE II

BENTHIC COMMUNITIES
OF THE GEORGIA - NORTHEASTERN FLORIDA SHELF

SANDY PLAIN - APPROXIMATELY 70% OF SHELF
REEFS - 30% OF SHELF

MAJOR REEF TYPES

SPONGE-CORAL SITES	LOW RELIEF MOSTLY BETWEEN 25 AND 75 M ISOBATHS. DENSE SESSILE MACROBENTHOS
ROCK RIDGES	MIDSHELF-OUTCROPPINGS 1-3 METERS OF RELIEF.
SHELF-EDGE	BETWEEN 75 M and 150 M ISOBATHS. STEEP CLIFFS AND LEDGES.
OCULINA THICKETS	OCCUR MOSTLY SOUTH OF CAPE CANAVERAL.

Loose sediments, sand or occasionally mud, occupy most (70%) of the shelf area (Parker et al., 1983). Reefs which occupy approximately 30% of the outer shelf in this zone occur in several types. Approximately 22% of the shelf is occupied by low relief (<1m) rock outcroppings and flat shelving rock which are overgrown macrobenthos. About 7% of the shelf area is high relief (>1m) rock ridges and ledges overgrown with macrobenthos (Parker et al., 1983). At and slightly beyond the shelf edge (approximately between the 100 and 1000m isobaths) rock outcroppings of high relief are common. Sessile macrobenthos are present at these depths but in general are less richly developed than in shallower areas (Parker and Ross. in press).

Immediately to the south of the area of immediate interest to this discussion (between 27°N and 28°30'N) lie large, unique thickets of the coral Oculina varicosa at depths of 75 to 100m (Reed, 1980). O. varicosa occurs as far north as Cape Hatteras, North Carolina, although usually only as single or scattered colonies, but some thickets may occur slightly north of Cape Canaveral.

II. OCEANIC FISHES

Fishes of the Georgia-northeast Florida shelf can be reasonably well assigned to five groups (Table III).

1. Nearshore and estuarine benthic species.
2. Open shelf sandy-plain dwellers.
3. Reef fishes.
4. Coastal pelagics.
5. Open-ocean pelagics.

We shall principally discuss the last three groups (Table IV). The nearshore species, primarily sciaenids and flatfishes, are excluded from our assignment, and the sandy plain dwellers, mostly triglids and synodontids rarely occur in sufficient concentrations to be of interest to man for food or sport (Wenner, 1983).

Oceanic pelagics include the billfishes, blue marlin, Makaira nigricans, white marlin Tetrapturus albidus, spearfishes, Tetrapturus spp., Atlantic sailfish Istiochorus platypterus, several tuna of the genus Thunnus, the skipjack tuna, Euthynnus pelamis, wahoo Acanthocybium solanderi, dolphin Coryphaena hippurus and several sharks. Coastal pelagics include such species as king, Spanish and cero mackerels Scomberomorus cavalla, S. maculatus and S. regalis, bluefish Pomatomus saltatrix, Atlantic bonito Sarda sarda, little tuna Euthynnus alletteratus, and menhaden Brevoortia spp.

The reef fishes are an extremely large and complex group including more than 300 species. Prominent to man's usage are snappers Lutjanus and Rhomboplites, groupers Epinephelus and Mycteroperca, porgies Pagrus and Calamus and grunts Haemulon. Reef fish species can be assigned to several communities related to depth and latitude, and ultimately to water temperature

TABLE III

MAJOR FISH COMMUNITIES
OF
GEORGIA - NORTHEAST FLORIDA SHELF

<u>COMMUNITY</u>	<u>HABITATS</u>	<u>MAJOR COMPONENTS</u>
NEARSHORE-ESTUARINE	ESTUARIES, SURF ZONE NEAR SHELF TO 25M	SCIAENIDS-FLATFISHES
SANDY PLAIN BENTHIC	SANDY PLAIN OF MIDSHELF 25 - 100M	SEA ROBINS AND LIZARDFISHES
COASTAL PELAGICS	NEARSHORE TO MIDSHELF	KING AND SPANISH MACKEREL, LITTLE TUNA, COBIA, BLUEFISH, MENHADEN
REEF FISHES	HARD BOTTOM AND SPONGE-CORAL AREAS MID AND OUTER SHELF	SNAPPERS, GROUPERS, PORGIES, GRUNTS (BLACK SEA BASS AT INNER LIMIT, TILEFISH AT OUTER LIMIT)
OCEANIC PELAGICS	GULF STREAM AND OUTER SHELF WATER COLUMN	BLUE AND WHITE MARLIN, SPEARFISH, SAILFISH, TUNA, WAHOO, DOLPHIN

TABLE IV

RELATIONSHIP OF
FISH COMMUNITY TO NEARSHORE AND WETLANDS

<u>COMMUNITY</u>	<u>RELATIONSHIPS</u>
OCEAN PELAGICS	<u>WEAK</u> - INDIRECT TRANSFER FROM ESTUARIES OF SOME ENERGY AND NUTRIENTS THROUGH FOOD CHAIN AND WATER CURRENTS. NEARSHORE DEVELOPMENT WOULD HAVE LITTLE IMPACT.
REEF FISHES	<u>MODERATELY WEAK</u> - INDIRECT TRANSFER FROM ESTUARIES OF SOME ENERGY AND NUTRIENTS THROUGH FOOD CHAIN AND WATER CURRENTS. A FEW SPECIES <u>MAY</u> USE ESTUARIES AS NURSERY AREA.... GAG, GREY SNAPPER, RED GROUPER. NEARSHORE DEVELOPMENT MIGHT IMPACT THESE.
COASTAL PELAGICS	<u>STRONG</u> - FEEDING OF BOTH ADULTS AND JUVENILES IN ESTUARIES IS COMMON. SOME, LIKE MENHADEN, USE ESTUARIES AS NURSERY AREA. NEARSHORE DEVELOPMENT CAN HAVE MAJOR IMPACTS.

(Grimes et al., 1982, Chester et al., 1984, Miller and Richards 1980). Headboat catches suggest an important faunal shift occurs in northeastern Florida. South of Jacksonville black sea bass Centropristis striata ceases to be important to catches, and at about St. Augustine the grey snapper Lutjanus griseus is at its northern limit of abundance. Red grouper are common at Daytona and occasionally north of there, while truly tropical species like yellowtail snapper Ocyurus chrysurus figure prominently in the catch from St. Augustine southward.

Tilefish Lopholatilus chamaeleonticeps are an important resource of Georgia and northeast Florida that does not fit precisely into any of our categories. Tilefish live in burrows in rough rocky terrain at the outer limits of the continental shelf (approx. 200m), and occur in relatively cold water (about 13C). The distribution of tilefish overlaps the seaward range of deepwater groupers (Epinephelus nigritus, E. flavolimbatus and E. niveatus). Tilefish have life history characteristics like those of many reef fish, and are included with them for management purposes (South Atlantic Fishery Management Council, 1983).

III. FISH-HABITAT RELATIONSHIPS

Habitat usage and dependency of both the pelagic and reef groups are relatively easy to define. All life stages of oceanic pelagic species are found almost exclusively in the warm waters of the Gulf Stream and outer shelf. Eggs and larvae are pelagic, apparently drifting freely with ocean currents, and the adults feed and spawn without requirement for association with nearshore or estuarine conditions. We can hypothesize only indirect links between production of oceanic pelagic species and estuaries and wetlands. There is little doubt that at least some energy is transferred from the shore zone to oceanic pelagic fishes through interconnecting food chains. Similarly some nutrients must pass to the outer shelf from river mouths, as off the Savannah River. The importance of these contributions is unknown but circumstantial evidence suggests that the short run effects may be small. Indeed some of the most important fisheries for oceanic pelagic species occur where continental contributions to fishery production are small but where oceanic features such as upwelling are important.

Production of most reef species seems similarly independent of nearshore habitats. Again eggs and larvae of most important sport and commercial species are pelagic and develop totally in the open ocean. By and large, feeding and reproduction of adults takes place on reefs without migration to the shore zone. For the bulk of reef species it again appears that the only connection with nearshore habitats is the indirect transfer of nutrients and energy through food chains and water circulation. Good circumstantial evidence for the independence of reef production is the existence of thriving reef communities on oceanic banks far from land masses. On the other hand some reef production, unlike that of oceanic pelagics, can be tied to the benthic

production of a certain locality. Grass flats adjacent to reefs provide grazing for reef dwelling herbivores and carnivores in south Florida and elsewhere in the tropics. North of Cape Canaveral algal flats adjacent to reefs on the mid- and outer shelf may function like grass flats in supporting nominal reef production.

Finally a few reef species of the south Atlantic region may be dependent on estuarine areas to complete their life cycle. Prominent among these species is the gag grouper Mycteroperca microlepis, the most abundant grouper of the region. Juvenile gag grouper are found in estuaries during their first year of life from Cape Hatteras southward. Researchers have yet to collect juvenile gag grouper in the open ocean. Thus, there is strong circumstantial evidence that the gag grouper is estuarine dependent. Yet collecting of young fish in the open ocean is difficult and uncertain, and juveniles may occur there. Also juveniles of other reef species which are apparently not estuarine dependent also occasionally appear in estuaries. Thus, the appearance of juvenile gag grouper in estuaries might only reflect the great abundance and fecundity of the species and not a life history pattern. The exodus of juvenile gags from South Atlantic estuaries at the onset of cold weather may result in the production of the entire new year class of this large, valuable species or it may only result in the consignment of a group of misplaced juveniles to wandering and death in the cold winter water of the inner shelf. Among other reef species common in estuaries are juvenile black sea bass, a temperate reef fish important off Georgia and North Florida. The importance of these young fish is unknown. Young grey snapper are also moderately abundant in estuaries as far north as Pamlico Sound. The estuarine phase of the life history of this species may be critical. Finally, juvenile red grouper Epinephelus morio, a species which in the South Atlantic is only consequential from St. Augustine southward, are also moderately abundant in estuaries. The significance of that abundance is again unknown.

Although nearshore development is unlikely to have an immediate impact on reef fishes, these species are susceptible to mismanagement of their habitat. Ocean pollution and disruption of reefs through petroleum development have generated some concern, but these have not yet affected offshore reefs of Georgia and northeast Florida. Current regulations may prevent negative impacts.

The most immediate potential threat to live-bottom reefs is posed by roller trawls. The few semi-quantitative studies of the effects of roller trawls on sponge-coral habitats suggest that trawling can seriously disrupt the macrobenthos. Many believe that his disruption will heal slowly and that it will eventually result in reduced fishery yields. It is clear that the Oculina reefs could be devastated by trawling, but trawling in the known Oculina reef zone is proscribed by the coral management plan. The research necessary to answer questions about trawling effects

is expensive, and no quantitative research on the problem is currently funded.

We have left consideration of the coastal pelagic species till last because this group, of all discussed, is clearly the most dependent on nearshore habitats and thus clearly most susceptible to man's alterations of wetlands and estuaries. The coastal pelagics are opportunistic in their feeding and make use of a wide range of habitats. King mackerel, for instance, will prey on aggregations of baitfish in and at the mouths of estuaries, around midshelf reefs and in the Gulf Stream. Little tuna and cobia, Rachycentron canadum, are similarly wide ranging.

Spanish mackerel and especially bluefish are even more tightly bound to the shoreline and commonly occur and feed in estuaries (Kendall and Walford, 1979). Although spawning and transformation of larvae to juveniles apparently occurs in the open ocean, all other stages from juvenile through adult are linked closely to coastal wetland by a very short food chain. Among the prey species in the coastal pelagic community Atlantic menhaden and mullet (Mugil sp.) are the most valuable to man and are both tightly connected to estuaries and wetlands. Menhaden can possibly directly digest marsh-generated detritus (Lewis and Peters, 1985) and thus have the most direct link possible to coastal wetlands. Water quality in estuaries and production of coastal marshes figures largely in the maintenance of the menhaden and mullet resources. Because coastal pelagic species are so often found near the coast they are readily available to both commercial and recreational fishermen and their value is immense. Yet the same characteristics that make these species valuable to man make them easily vulnerable to his mismanagement of the coastal environment.

IV. ENVIRONMENTAL REQUIREMENTS

Now that we have shown the relationships of communities of fishes to their habitats, the next step could be to show the ecological factors that drive a single fish to a particular portion of his habitat. In order to sense its environment a fish must be sensitive to components of its environment. Table V gives some of these sensitivities. No single fish has been depicted here. The table has been assembled from a number of sources. Fish are extremely sensitive to a number of environmental variables. Chemicals may be sensed up to the parts per trillion range. This concentration level poses no survival danger to the fish nor to people who might eat the fish, but since fish do have the capability to sense chemicals at extremely low concentrations, they may also utilize this information for survival in their complex environment. A fine temperature sense and possibly even the ability to determine small magnetic fields, as has been demonstrated in the yellowfin tuna, may be utilized for migration. Diurnal and seasonal rhythms may be triggered by the amount and duration of light. It appears, therefore, that a very small perturbation of a fish's environment could attract or repel

TABLE V

FISH SENSORY SYSTEMS

<u>ENVIRONMENTAL VARIABLE</u>	<u>SENSITIVITY</u>	<u>REFERENCE</u>
pH	0.04-0.10 UNITS	BULL (1940)
TEMPERATURE	0.05°C	BULL (1936)
PRESSURE	0.5-1.0 cm H ₂ O	DYKGRAAF (1942)
SALINITY	0.06%	BULL (1938)
POLLUTANTS	PPTRILL. (10 ⁻¹²)	HASLER (1954)
NOISE	16-7,000 HERTZ 50DB	BULL (1957) POPPER (1970)
LIGHT	A FEW PHOTONS	LYTHGOE (1978)
ELECTRIC FIELDS	1mV/cm. (SHARKS & SKATES)	SCHWASSMANN (1978)
MAGNETIC FIELDS	1-100 NANO TESLA (GAMMA) (YELLOWFIN TUNA)	WALKER, ET.AL. (1982)

that fish from a given area. Since pH, salinity and oxygen concentration probably are not major factors in determining the behavior of an oceanic fish, one must consider food a major attractant for fish under normal circumstances. If such is the case, a study of predator prey relationships should produce quantitative results answering a number of questions. Do fish hunt in a random fashion and then zero in on their prey using their sensors? What prey species are preferred? Will predators brave hostile environments to find prey? What is the correlation between predator and prey stocks? We can give partial answers to some of these questions now. Gut analysis gives us information about species preferred (Tables VII and VIII). Oceanic predators seldom venture into low salinity (estuaries) in search of prey. They generally wait for their prey to exit the estuaries and head for open sea. Can we then predict the catch of prey species based on the size of available prey stocks?

Table VI was developed to compare the two predators, king and Spanish mackerel, and their preys, menhaden and shrimp. Based on landings data from North Carolina, South Carolina, Georgia and Florida, no such relationship is apparent.

Oviatt (1977) collected menhaden, bluefish and striped bass landings data over a period of thirty years (Figure 1). Even at very low levels of menhaden, bluefish and striped bass had sufficient food to only maintain their population but to increase it somewhat. Although a positive correlation between prey and predator is intuitively expected, present information does not permit such a conclusion. Perhaps more detailed stock data (temporal and spatial) are needed. Perhaps other factors combine to limit stock sizes. Temperature and salinity data have been used (Barnett and Gillespie, 1973, 1975; Barrett and Ralph, 1976) to predict shrimp catch, but meager data are available about oceanic species. Fable and co-workers (1981) studies the relationship between a king mackerel catch and the average temperature of the preceding winters. This study revealed a positive correlation between catch and the temperature of the preceding winter.

Utilizing a tops down systems approach to connect primary and secondary production, Peters and Schaaf have shown that the fishery yield of fish from New York to Georgia requires 66% of the primary production of that area, which includes algae, vascular plants and submerged seagrasses. They concluded that algal production is insufficient to support this yield and must be augmented by vascular plants. Such is the case with menhaden who are known to ingest detritus directly and thus, since they are a major food source for coastal and oceanic pelagics, shorten the link between offshore fisheries and inshore habitats.

Another approach is relating fish to habitat is to develop a matrix of environmental requirements as shown in Tables VII and VIII.

TABLE VI

ATLANTIC SPECIES
 COMMERCIAL LANDINGS - IN THOUSANDS OF POUNDS
 NORTH CAROLINA, SOUTH CAROLINA, GEORGIA, FLORIDA

YEAR	MENHADEN	SHRIMP	KING MACKERAL	SPANISH MACKEREL
1983	8,285	26,615	4,132	5,989*
1982	10,358	25,580	6,045*	3,950
1981	15,456	16,514	5,739	4,227
1980	21,257*	32,996*	3,799	5,763
1979	5,036	32,295	3,824	4,901

*79-83 MAXIMUM

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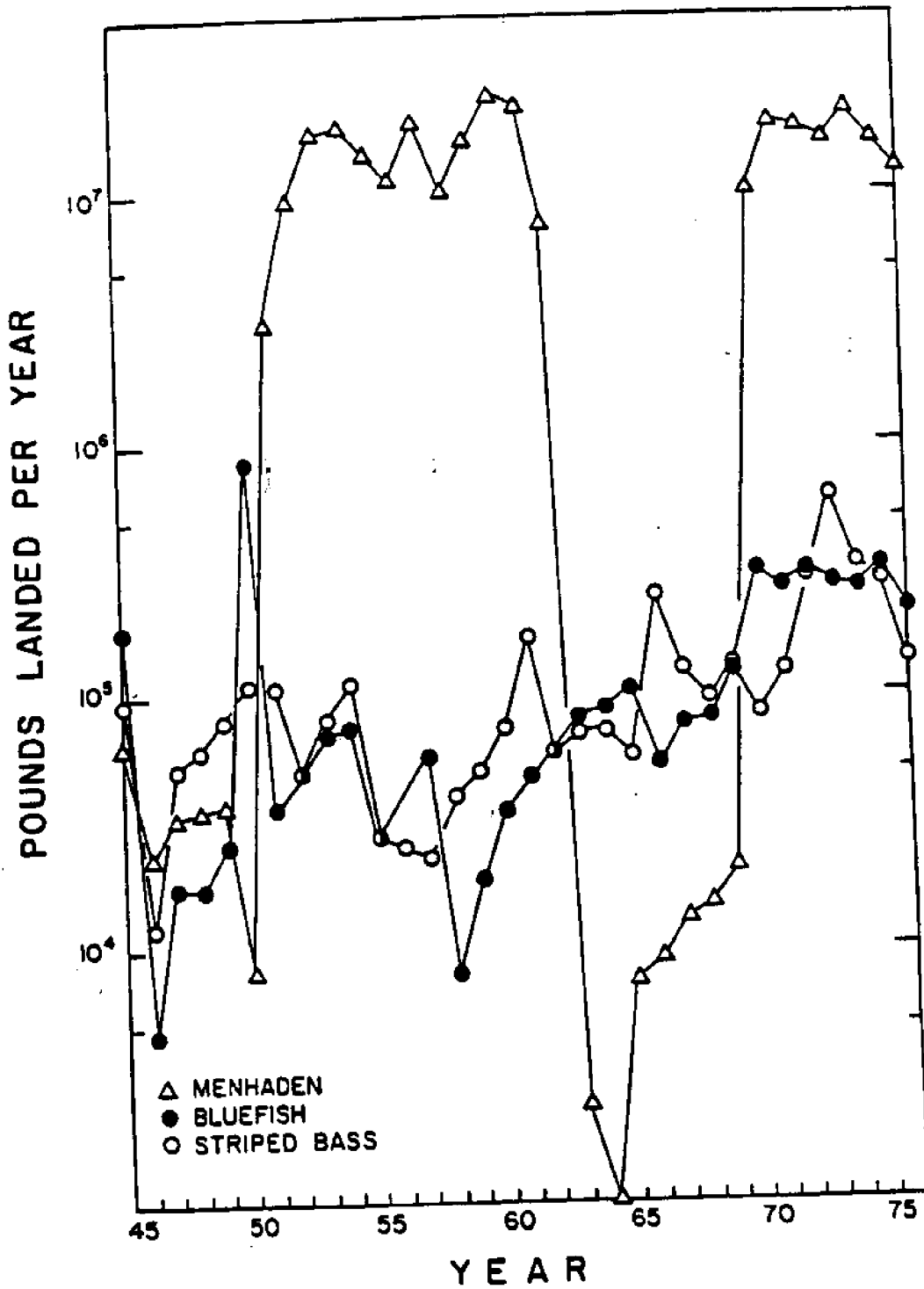
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KING MACKEREL S. Cavalla	TEMP °C	SALINITY ‰	O ₂ ppm	TURB.	METALS	ORGANICS ppm	LIGHT	FOOD	SUBSTR.	BENTHIC STRUCTURE	PREDATORS	PARASITES/ PATHOGENS	NOISE/ ELECT.
Eggs/ Embryo													
Larvae		25.85 to 34.47 2/											
Juvenile	26.3 to 31.0 2/	26.9 to 35.5 2/											
Adult	> 20 3/	< 36 3/			Hg, Se, Pb, Cd, As 0.02 - 18ppm 4/			clupeid fish (mainly thread herring & scaled sardines pensaeid shrimp + squid, jacks snapper grunts 3/		Prefer bottom relief (holes, reefs, wrecks, & rigs) 3/	tursiops sharks 3/	copepods cestodes trematodes nematodes 1/	

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Rhode Island landings of menhaden, bluefish, and striped bass from 1945 to 1976. (Oviatt, 1977)

Environmental requirements for menhaden are given in Table VII. Even though these fish, which are the most numerous ones in U.S. waters, have been studied extensively, there are several gaps in our knowledge of environmental parameters. Furthermore, most of the information that we have has been gathered by observation of these coastal pelagics in their natural environments. Little data are at hand derived from experimental laboratory studies. We are beginning to understand the food and feeding requirements of these fish but environmental variables such as temperature, salinity, organics and metals need to be determined experimentally.

Table VII, a similar matrix for the king mackerel, demonstrates an even greater paucity of information.

In this review we have attempted to show the relationship of offshore fisheries to their various habitats. In particular, the strong link between coastal pelagics and wetland primary production. Furthermore, we have attempted to show that a system approach in which the requirements of the fish are utilized as the starting point, complements those studies showing the dependence of fish on primary production.

Assembling such information into a matrix such as that shown in Tables V and VI could be used to provide summarized information to decisionmakers and act as a framework for condensation of literature. We are currently inundated with "grey" as well as "white" literature. The decisionmaker who must act in a short period of time, such as those of us who respond to permit requests, have insufficient time to analyze all of the available data. The matrix could also serve as a focus for describing research needs.

In view of the lack of precise or accurate experimental data concerning the relationships of fish to their environments, it is suggested that experimental facilities be developed to determine these relationships. Such facilities would provide needed quantitative information and could be used to test research or fishing gear prior to starting elaborate and expensive field studies.

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GROWTH AND MANAGEMENT OF COASTAL WETLAND
AND WETLAND ADJACENT LANDS:
FISH HABITAT QUALITY AND THE DECISION-MAKING PROCESS

James W. Stoutmaire

The State of Florida is one of the fastest growing in the nation with some 75% of the state's population residing on or near the coast. If current trends continue, and every indication is that they will, by the year 2000 there will be a permanent coastal population of some 10 million people combined with a temporary and/or tourist population of three to four times as many. This tremendous growth in coastal regions has and will continue to put tremendous pressure on coastal resources. These pressures directly and indirectly have had and could continue to have tremendous impacts on coastal and interior wetlands.

Impacts on these wetlands can occur for a number of reasons including:

1. Filling of coastal wetlands areas for development as more suitable land becomes scarcer and more expensive;
2. Draining of wetlands to provide flood protection or dry land for development or agriculture;
3. Interference with the natural flooding cycle of wetlands associated with flood control, water storage, or mosquito control;
4. Dredging or filling of isolated wetlands to provide lakes for development or more accessible land for agriculture or timber; and
5. Siltation and/or pollution of wetlands from non-point sources such as stormwater runoff or fertilizers and pesticides.

The list of potential sources of impacts on wetlands is virtually endless. The activities noted above and others have, in the past, resulted in the destruction of significant areas of wetlands as functioning habitat.

Recent research by the DNR Marine Laboratory in St. Petersburg has found that Charlotte Harbor, a relatively undisturbed area has, between 1945 and 1982, lost 29% of its seagrass and 51% of its salt marsh while gaining 10% in mangroves. The gain in mangroves appears to be partially due to colonization of mud flats and active management to discourage mangrove destruction. In contrast, Tampa Bay, a heavily developed area, has suffered a

much larger decline. On the east coast from 1952 to 1984, the Indian River suffered an 86% decline in mangrove areas due to destruction of mangroves or their withdrawal from the system due to mosquito impoundment dikes. Seagrasses have suffered a 36% decline during the same period. While these losses seem to be correlated with declining commercial and recreational fisheries, the relationship between decreased fish stocks and habitat loss is imperfectly understood. This is due in part to poor information on catches resulting from incomplete data collection techniques and in part to a general lack of information on habitat carrying capacity.

Florida has a number of growth and land management and regulatory programs which deal with wetlands and adjacent lands either directly or indirectly. These include:

1. DER permitting programs regulating water pollution and dredge and fill activities and the Coastal Management program;
2. DCA growth management programs such as DRI's and ACSC's;
3. DNR land management authority for leasing and land purchasing of Aquatic Preserves and coastal construction control;
4. Various regional programs conducted by Water Management Districts, Regional Planning Councils and Mosquito Impound Districts.

The Department of Environmental Regulation (DER) is the state's primary regulatory agency. The DER's permitting authorities with the most direct impact on fishery habitat are contained in Chapters 253 and 403, F.S. These statutes deal, respectively, with dredge and fill and water pollution. Until the recent enactment of the Warren S. Henderson Wetlands Protection Act of 1984, regulatory programs governed by these two statutes were poorly coordinated due to conflicting boundaries of jurisdiction and regulatory authority based on the distinction between sovereignty submerged lands, also called navigable waters, and waters of the state. Navigable waters were those available for commerce in their natural condition at the time Florida entered the union while waters of the state encompassed all other water bodies subject to certain exclusions such as areas owned entirely by one person and "lakes" which lack standing water and are dry each year. These distinctions led to numerous disputes over jurisdiction and limitations on regulatory authority since the two chapters provide differing performance standards. The Wetlands Protection Act dropped the distinction between navigable waters and waters of the state for the purposes of Chapters 253 and 403 and substituted waters of the state as defined in the statutes and supported by a detailed vegetation list and/or the presence of hydric soils combined with the 10 year flood line. In areas where waterbodies are temporarily dry, the DER's jurisdiction extends to the mean or ordinary high water line even if it is

landward of the vegetation line. It should be noted that these changes did not significantly impact on the linkage between DER's regulatory responsibility and DNR's land management responsibilities except to establish a time limitation on DNR's processing of a lease application. The DNR still holds title to sovereignty submerged lands and must grant permission to use those lands through a lease or sale before any activity may be conducted on the property. In addition, DER is still responsible for issuing permits to dredge or fill certain sovereignty lands which are no longer owned by the state but which have not been converted into uplands.

One of the major benefits of the Wetlands Protection Act was to consolidate the criteria used for permit review. In essence, water quality has become the primary consideration. However, other factors which are to be considered to determine the impact of permit issuance on the public interest include effects on fish, wildlife and habitat; health, safety, and welfare; the effect on navigation or flow of water; whether the project will cause erosion or shoaling; impacts on commercial and recreational fisheries; the duration of the project and its impacts; and impacts on archaeological and historic resources. The Act has also made it easier for DER to consider the cumulative impact of numerous small projects by allowing the agency to consider the impacts of past and future projects in the same area.

Finally the Act allows the DER to develop more stringent water quality protection standards in Outstanding Florida Waters, Aquatic Preserves, Areas of Critical State Concern, and certain areas with approved resource management plans and it grants clear authority to regulate peat mining.

The DER is responsible for two other programs that are of interest to the effective regulation and management of fishery habitat. These are the permitting of long term maintenance dredging projects as authorized under Chapter 403, F.S., and the Coastal Management Program under Chapter 380, Part 2, F.S.

The 1981 legislative session authorized DER to develop separate water quality standards for ports and to issue maintenance dredging permits for up to 25 years. In addition it established a funding source within the Department of Natural Resources to provide up to 50% of the cost of purchase of spoil disposal sites. This has provided an opportunity to implement more effective long term management strategies to deal with ongoing activities that have a significant impact on estuarine resources. The long term nature of the permits has allowed the development of more sophisticated permitting and monitoring standards than can be applied to the normal short term project. In addition, it is encouraging the ports to take a long range look at their requirements and potential environmental impacts. An indirect benefit of the project has been the refinement of analysis techniques to be used in evaluating water and more importantly sediment quality in estuarine areas. The DER, Office of Coastal Management, is currently investigating extending this concept to long term maintenance dredging associated with the Intracoastal Waterway.

The DER was charged by the 1978 legislature with developing a coastal management program under the terms of the Federal Coastal Zone Management Act. The legislature specified that this program had to work within existing authorities. The program was developed and received federal approval in September of 1981. The program is oriented around a number of issues of special focus, many of which are directly or indirectly related to management of fishery habitat. The two major components of the program that are of immediate interest to the management of fishery habitat are the grants program and the Interagency Management Committee. In brief, the grants program is based on allocating federal coastal management funds to a variety of coastal research projects including fishery habitat loss and carrying capacity, wetlands protection at the local level, improvements in mosquito impound management strategies, development of aquatic preserve management plans, etc. The Interagency Management Committee (IMC) was created in 1980 by resolution of the Governor and Cabinet. This group consists of the heads of 10 state agencies such as DER, DNR, DCA, HRS, OPB, GFWFC, etc. having significant management of policy responsibilities related to coastal resources. The IMC is responsible for resolving interagency conflicts as they relate to coastal resources, interpreting coastal policy directives such as the Governor's Executive Order on barrier islands, and developing legislative initiatives such as the Save Our Coasts legislation. The IMC is staffed by the DER/Office of Coastal Management supported by the Interagency Advisory Committee (IAC) consisting of staff from the respective agencies.

The Department of Community Affairs is the state land planning agency. Part of its activities as specified in Part I of the Chapter 380 F.S. are to conduct the state's Development of Regional Impact (DRI) and Area of Critical State Concern (ACSC) Programs. Neither of these two programs are primarily concerned with wetlands regulation, however, since they both are concerned with growth management they do impact on wetlands.

A DRI is defined as "any development which, because of its character, magnitude, or location, would have a substantial effect upon the health, safety, or welfare of citizens of more than one county; s. 380.06(1), F.S." While many of these developments are defined in DCA administrative rules, developments may be included in the DRI process if they meet this statutory definition. The DRI process is primarily implemented at the county and Regional Planning Council (RPC) level and will be discussed later. However, it is important to note that the act empowers various levels of government, including DCA, to seek injunctions to secure compliance with the act and DRI decisions. This includes determination that a development must complete the DRI process, the terms of a DRI decision, implementation of conditions of that decision and review of projects which have deviated from approved plans. While this process does provide an opportunity to ensure that adjacent land uses are compatible with wetlands, it must be noted that relatively few developments enter the DRI process. Discussions of refinements to the process by

the ELM's II committee indicate that rarely are as many as 10% of the projects in any given area subject to review for a variety of reasons.

The ACSC program provides a more direct opportunity for the state to influence local events. Geographic areas may be designated ACSC's based on an evaluation of impacts on environmental and natural resources of regional or statewide importance, archaeological or historical resources, or public facilities. Three areas have been designated ACSC's for reasons which include a concern with the management of wetlands and fishery habitat. These areas are Monroe County (Florida Keys), Big Cypress, and the Green Swamp. The Keys designation was the result of a concern over the inadequate regulation of development and its impact on the area. The Big Cypress designation was associated with creation of the Big Cypress National Preserve designed to protect a major portion of the upstream drainage basin for the Everglades. The Green Swamp designation was designed to protect a major recharge area for the Florida Aquifer.

Since this process results in more direct state control than the DRI process, designation is much more formal. Upon determination by DCA that an area should be considered for ACSC designation the Governor must appoint a Resource Planning and Management Committee (RPMC). This committee contains members of appropriate state agencies and all affected local and regional governments. This committee is charged with developing a program to correct the problems that led to the proposed designation. Should this voluntary plan be adopted by appropriate levels of government the process is brought to a halt at this point except for later reviews to assure implementation. This voluntary effort has been successful in the Charlotte Harbor and Suwannee River areas. Should the voluntary effort fail then DCA may recommend to the Governor and Cabinet sitting as the Administration Commission that the area be designated an ACSC, this designation is subject to review by the legislature and must include boundaries, the RPMC report, reasons for designation, principles for guiding development and an identification of public lands within the area. The affected governments must then adopt and enforce regulations which comply with the principles for guiding development or DCA acting through the Administration Commission will write the regulations. The DCA may then seek an injunction to secure compliance. An area may be removed from designation upon determination that appropriate governmental bodies are in compliance with the principles for guiding development.

The Department of Natural Resources is the state's primary land management agency. The department is charged with management, purchase and disposal of state lands under Chapter 253, F.S.; management of selected state lands under the Aquatic Preserve program under Chapter 258, F.S.; and regulation of coastal construction under Chapter 161, F.S.

The Governor and Cabinet sitting as the Trustees of the Internal Improvement Trust Fund hold ownership and management responsibility over public lands including many wetlands areas such as overflowed lands, sovereignty tidal lands, and waters of the state within 3 miles of the Atlantic coast and 10.35 miles of the Gulf coast. Proposals to sell or lease public land for private use must be evaluated to determine how the public interest is impacted. This includes evaluating impacts on wetlands and their productive capacity. In contrast to years past when the state disposed of millions of acres of wetlands to pay state bills or encourage various types of development, leasing of wetlands areas is severely restricted and is conducted in a public forum where all views are heard. The Trustees also conduct two major land buying program; Conservation and Recreation Lands and Save Our Coasts; designed at least in part to purchase critical wetlands habitat areas.

Under Chapter 258, F.S., the DNR maintains some 36 aquatic preserves designed to provide additional management and protection for critical fresh and salt water habitat. State lands and private property, at the owners request, are selected for inclusion on the basis of their values as natural habitat with the goal being to maintain them in their natural or existing conditions or to restore them. Designation as an Aquatic Preserve is made by the Trustees subject to approval by the legislature. Once an area is designated additional protection is afforded by: 1) DER designation of the area as an Outstanding Florida Water; 2) a requirement that sale or lease of lands in the area must be in the public interest instead of merely not contrary to the public interest; and 3) further restrictions on dredge and fill and water discharge activities. To date DNR has developed and adopted specific management plans for preserves in Charlotte Harbor and Estero Bay and plans are being developed for several other preserves including four in the Indian River.

While not as directly impacting on wetlands and fishery habitat as other programs, the Coastal Construction Control Line and other programs under Chapter 161, F.S., administered by DNR under the direction of the Governor and Cabinet, indirectly provide some resource protection by regulating coastal structures. These programs provide some regulation of the type and design of structures which may be placed immediately adjacent to sandy coastal areas and govern beach nourishment programs. Obviously regulation of activities impacting on sand transport patterns and coastal erosion can impact on coastal wetlands areas.

Regional Planning Councils (RPC's) provide the main planning link between several adjacent counties and, in turn, the DCA. As such, the RPC's are responsible for reviewing all DRI applications from their areas. Generally speaking this is the single most important review since an RPC is most familiar with regional issues of concern. State input through DCA is usually directed toward controversial development and occasionally to broader statewide concerns. The affected RPC coordinates review of a project with the appropriate local and state agencies and pre-

pare an evaluation of a development with respect to its impact on the environment and natural resources; economy; waste disposal systems; transportation facilities; access to employment facilities; etc. The final decision to grant or deny approval resides with the directly affected local government which must consider the extent to which the development complies with the state land development plan, local land development regulations and the report and recommendations of the RPC. Typically, approval includes a number of conditions or modifications of the original development plan designed to improve the development as related to issues noted above.

Water Management Districts (WMD) were created under Chapter 373, F.S., to regulate the withdrawal, diversion, storage, and consumption of water on a regional basis. These activities are conducted under the general oversight of DER and the Governor and Cabinet, sitting as the Land and Water Adjudicatory Commission. In addition to regulatory powers the WMD's are allowed to levy taxes to conduct their activities and to acquire property under the Save Our Rivers program funded by documentary stamp taxes. Until recently WMD's dealt primarily with injection of water into underground formations, consumption of water for non-domestic uses, water wells, and dams and other water control works. However, with the passage of the Warren S. Henderson Wetlands Protection Act of 1984 the WMD's took on significant new responsibilities to regulate impacts on wetlands associated with agricultural activities. The Act exempts "normal and necessary" agriculture operations and agricultural water management systems from regulation by DER and assigns them to the WMD's. Normal and necessary activities include clearing, fencing, contouring, plowing, planting, access roads, etc., while water management systems refer to irrigation systems and farm ponds. Governor Graham's instructions to the WMD's are that these activities and systems are to be regulated to at least the same standards as DER's regulation of other uses of wetlands. This is to include consideration of fish and wildlife impacts; maintenance of state water quality standards; protection of Aquatic Preserves, OFW's and the Everglades; and consideration of the ecological value to the wetlands impacted.

Under Chapter 388, F.S., mosquito control programs are the responsibility of the Department of Health and Rehabilitative Services (HRS) and various county programs. In years past these efforts included extensive ditching and diking of coastal wetlands and wide use of oil and other chemicals. Today the use of oil is severely restricted and the use of chemicals is limited by an agreement between HRS and DER although DNR has recently expressed considerable concern about the use of certain agreed upon chemicals. In addition, only those activities necessary to actual maintain structures are exempt from DER's dredge and fill permitting process. Obviously, the numerous mosquito impoundments have an adverse impact on fishery habitat as these areas are usually completely closed to normal water circulation patterns. Several years ago Governor Graham appointed an interagency task force to deal with mosquito control issues as related to fishery habitat. This effort has been supported by research funded by

the DER/OCM and conducted by the Indian River Mosquito Control District, Institute of Food and Agricultural Science, and Harbor Branch Foundation designed to explore innovative impound management techniques. These efforts are just beginning to pay off in programs allowing for mosquito control while returning selected impounds to active tidal circulation.

In closing, this discussion has provided a brief and necessarily incomplete overview of Florida's regulatory and growth management programs as they relate to fishery habitat. I would like to stress that the regulatory and management programs discussed above are only as good as scientific information utilized to implement them. Unless the research community is willing to make an effort to communicate their findings, including implications for changes in regulatory and management programs, to the general public, politicians, and agency decision makers, no significant improvements can be made in the programs outlined in this discussion.

CONTRIBUTED PAPERS

THE NASSAU RIVER BASIN ENVIRONMENTAL STUDY

Joel S. Steward

Introduction

The Nassau River basin, located in northeast Florida, is situated between the St. Johns River estuary to the south and the St. Marys River estuary to the north (Figure 1). The 350 mi² basin is composed of a variety of land types: fresh and saltwater marshes, mixed hardwood swamps characteristic of the Nassau's headwater creeks, and pine flatwood areas interspersed with light urban, agricultural and silvicultural land use. The Nassau River is a typical, southeast coastal plain drowned river estuary whose freshwater inflows are contributed by several major creeks. Three of these creeks, Thomas, Mills and Boggy, are the main headwater creeks (Figure 1).

Despite the low-level development in the basin, hydrologic and fishery impacts have occurred. A major portion of Mills Creek has been channelized since 1974 to prevent flooding in the town of Callahan and surrounding agricultural lands (USDA, 1976). The channelization has altered the hydrology of the Mills Creek watershed and may be affecting water quality as far downstream as the creek's confluence with the Nassau River. The lower reach of the Nassau estuary has been closed to bivalve harvesting since 1977 because fecal coliform densities have been above the ISSP standard of 43 MPN (Florida Dept. of Natural Resources, 1984). Surface runoff and septic tank leachate from residential development has been implicated as the contamination sources.

It is likely that further growth in the basin will create additional environmental impacts unless preventive management strategies are developed and employed. Toward this end, the St. Johns River Water Management District, in cooperation with the U.S. Geological Survey, has initiated a hydrologic and water quality monitoring program. The objectives of the program are to (1) develop a computerized hydrologic and ambient water and sediment chemistry data base, (2) delineate and describe the chemical and physical characteristics of the freshwater/saltwater interface, (3) describe water quality problems, and (4) determine spatial and temporal water quality trends.

A wetland vegetative survey of the basin will also be conducted. This survey will entail classification and detailed mapping of the wetland areas. The information can be used to develop technical criteria for wetland management plans for the Nassau basin.

Environmental Specialist, St. Johns River Water Management District, P. O. Box 1429, Palatka, Florida 32078.

Methods

A hydrologic and water quality monitoring network, fully established since 1982, covers the major subbasins (Figure 2). The hydrologic network includes remote, continuous stage and discharge recorders placed on the three headwater creeks, the mid-reach and mouth of the Nassau River. Continuous measurements of conductivity and temperature are also recorded at the mid-reach site (Rt. 17 bridge) which has been determined to be in the area of the freshwater/saltwater interface. Rainfall is gaged throughout the basin and, concomitant with stage and discharge data, will be factored into a one-dimensional hydrodynamic model for the Nassau.

The water quality stations (Figure 2) are monitored on a quarterly basis. In addition to the typical in-situ measurements, several analyses are performed on grab samples including major nutrients, anions, cations, dissolved and suspended solids, and chlorophylls. At this time, the water quality data collected over the last 2 1/2 years is most readily accessible for interpretation and forms the basis of this interim report.

Results and Discussion

Preliminary analysis of salinity and conductivity data indicate the freshwater/saltwater interface is a broad mixing zone rather than a well-defined salinity wedge (Figure 3). This mixing zone, as defined by large salinity fluctuations, is located in the approximate geographical center of the basin. Salinities in the mixing zone range from <1 o/oo to 24 o/oo, a greater than 80% variability; whereas, salinities near the river mouth are notably higher with lower variability, averaging 34 ± 6 oo/oo. The estuary overall is vertically well-mixed, with top to bottom homogeneity of salinity, temperature and dissolved oxygen.

The spatial distribution of major nutrients, analyzed thus far, reveal excessively large concentrations of total nitrogen (TN) and total phosphorus (TP) in Mills Creek near Callahan (Figure 4). Apparently, these large concentrations are related to domestic effluent discharges from the Callahan primary sewage treatment facility and may be elevating downstream nutrient concentrations at the confluence of Mills and Boggy. In the Nassau River estuary, TN and TP concentrations drop by nearly an order of magnitude (Figure 4). Throughout the mixing zone (Figure 3), concentrations of TN (1.4 ± 0.4 mg/l) and TP (0.16 ± 0.03 mg/l) are consistent and consistently tight in variability. Finally, these concentrations decline somewhat through dilution and assimilation near the river mouth.

Examining the inorganic or organic levels of nitrogen and phosphorus can expose further trends and environmental relationships. The large nutrient levels in Mills Creek (Figure 4) largely consists of inorganic species, 90% for TP and 48% for TN. This, again, is a probable consequence of primary effluent discharges from Callahan. A majority of the inorganic nitrogen

in Mills Creek is ammonia with a mean concentration of 2.4 mg/l. The highest concentration of un-ionized ammonia, 0.03 mg NH₃/l., was measured in Mills Creek. This concentration of NH₃ is potentially toxic to aquatic organisms, especially at the low level of dissolved oxygen measured, 0.10 mg/l (Alabaster and Lloyd, 1980). In contrast to Mills Creek, inorganic percentages in the estuary are much lower, comprising 40% of the TP and 21% of the TN near the mouth. In typical fashion, the inorganic percentages for TP and TN are similar for all three sampling sites in the mixing zone, 70% and 16%, respectively.

It is interesting to note that even though poor correlations exist between concentrations of inorganic nutrients (nitrate + nitrite, orthophosphorus) and salinity, there is a discernable trend of decreasing concentrations with increasing salinity, particularly with salinity range groupings: 0-9 o/oo, 10-20 o/oo, 25-40 o/oo (Figures 5a and b.). This may be a function of dilution, however, an equally discernable trend of decreasing inorganic percentages of TP and TN with higher salinity groupings (Figure 6) suggests some additional influence from other factors.

One factor to consider is biological assimilation. The predominance of organic over inorganic nutrients in the higher salinity areas may be explained in part by the increased phytoplankton densities represented by surface water chlorophyll a concentrations (Figure 7). An increase in the production of chlorophyll can induce a higher rate of assimilation of inorganic nutrients. Regression analysis demonstrates that salinity and chlorophyll a concentrations contribute to 25% of the variability in percent inorganic phosphorus in the Nassau ($F=6.66^*$, $.025>P>.01$); but was an insignificant influence on the variability in percent inorganic nitrogen. Absorption/precipitation processes and other routes of biological assimilation and release (littoral, benthic, etc.) may be other factors influencing the variability in inorganic percentages of TN and TP but are more difficult to substantiate.

Conclusion

Aware of water quality problems in Mills Creek, the town of Callahan is presently constructing a secondary level sewage treatment facility. This should significantly reduce the large nutrient levels in the creek, particularly ammonia.

Completion of this basin monitoring program within a year or two will result in a long-term water quality data base enabling analysis of temporal trends (seasonality) and further analysis of spatial trends. Accordingly, the hydrologic data base will then be utilized to relate hydrodynamics to water quality in the Nassau basin.

Acknowledgements

Two colleagues deserve credit for the valuable time and expertise they provided. Mr. Bruce Ford has displayed his diverse talents through his technical assistance in the field and graphic illustrations presented in this report. Ms. Carol Fall, as project manager during the first year of this study, was responsible for establishing the original water quality monitoring network and enlisting USGS in the hydrologic program for the Nassau.

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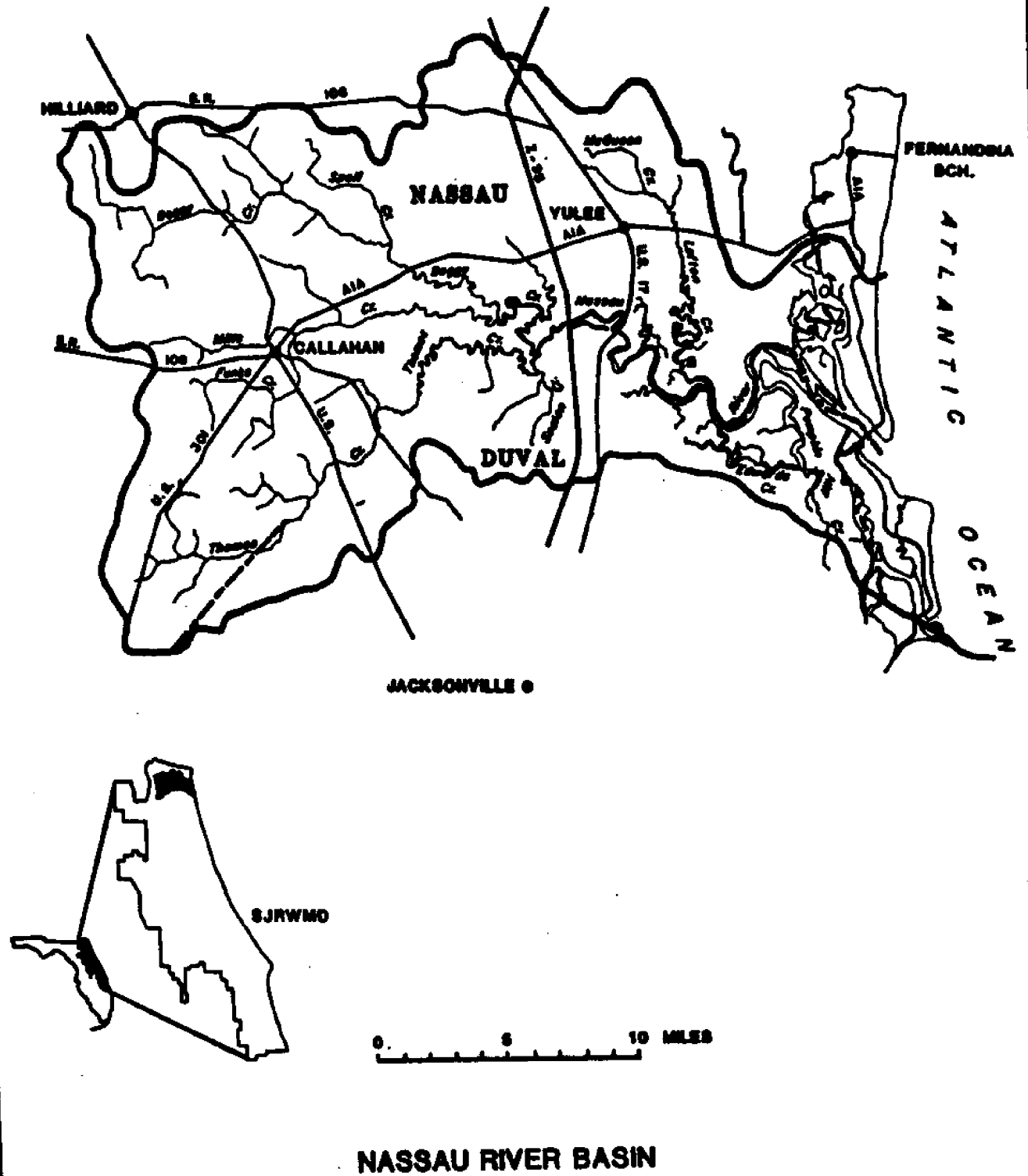
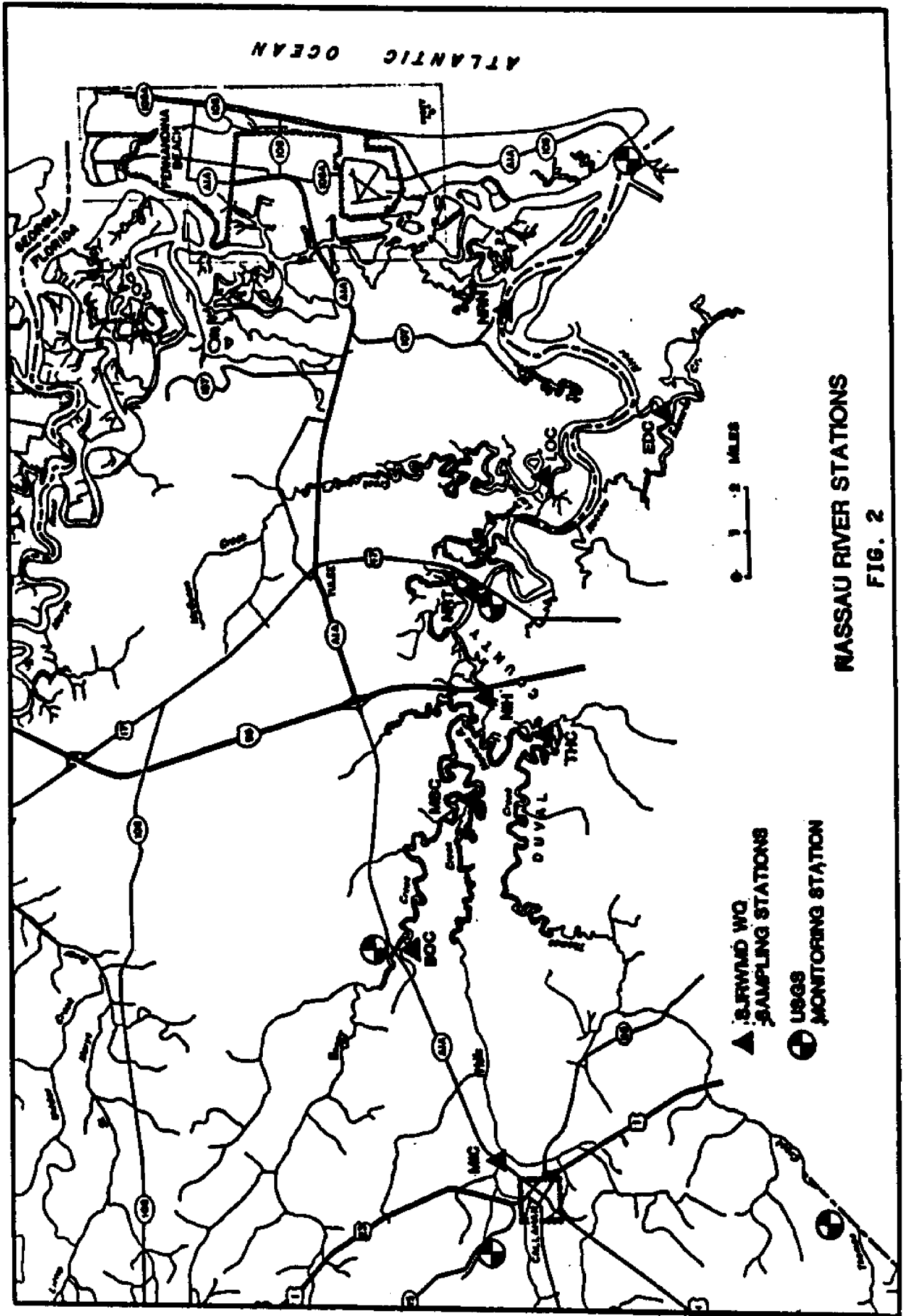


FIG. 1



NASSAU RIVER STATIONS
FIG. 2

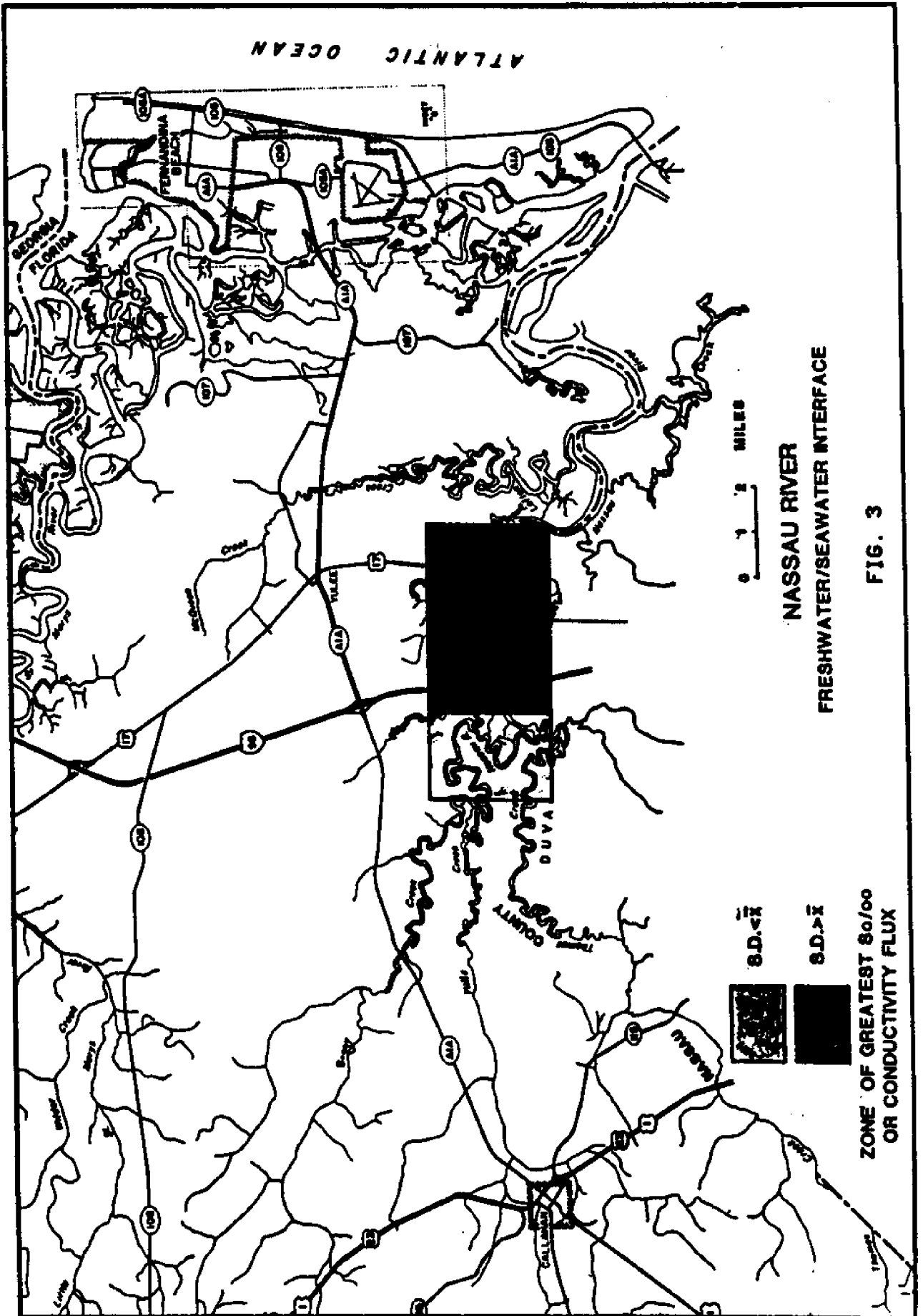


FIG. 3

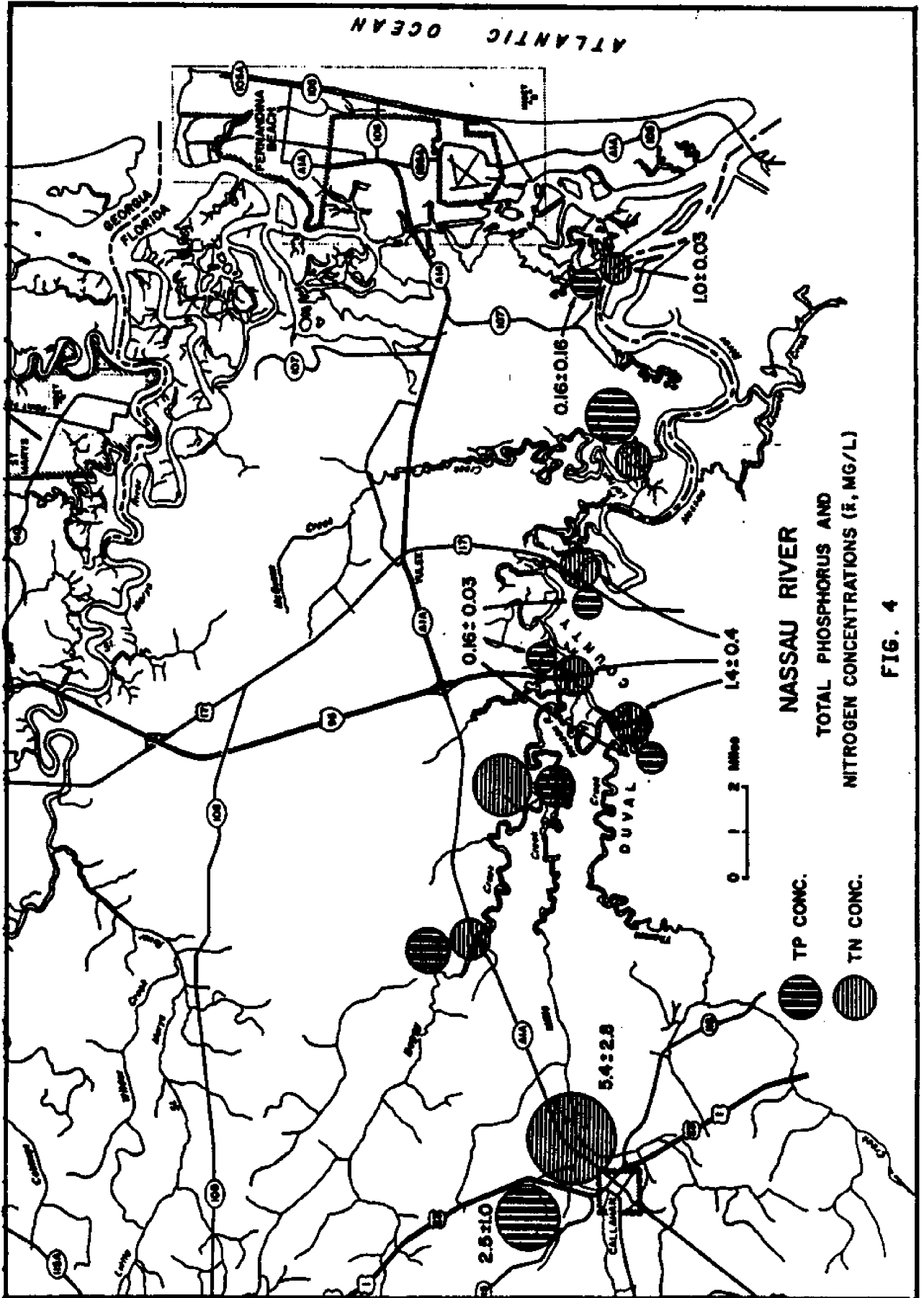


FIG. 5a
NASSAU RIVER ESTUARY
NITRATE + NITRITE VS. SALINITY

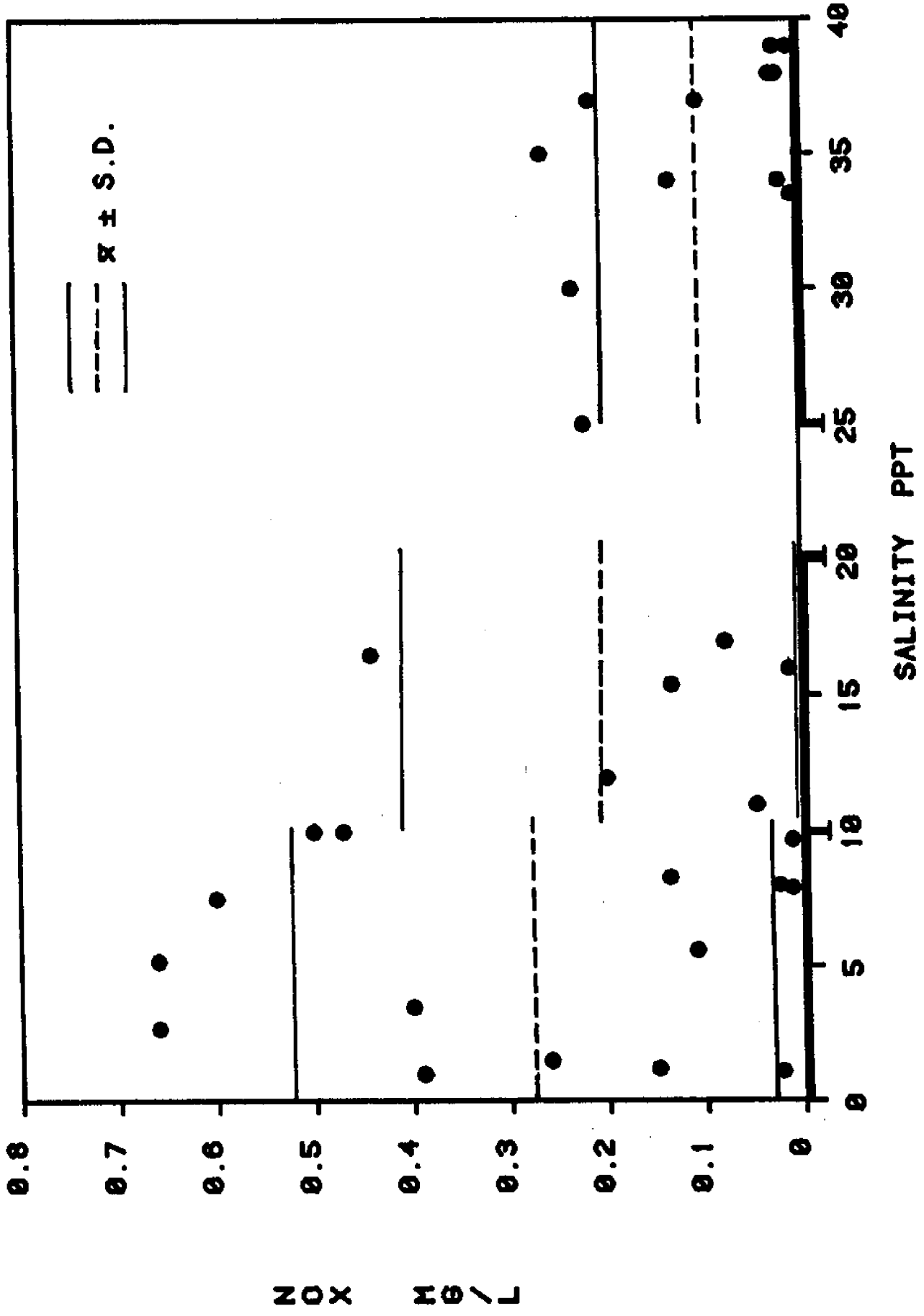


FIG. 5b
 NASSAU RIVER ESTUARY
 ORTHOPHOSPHORUS VS. SALINITY

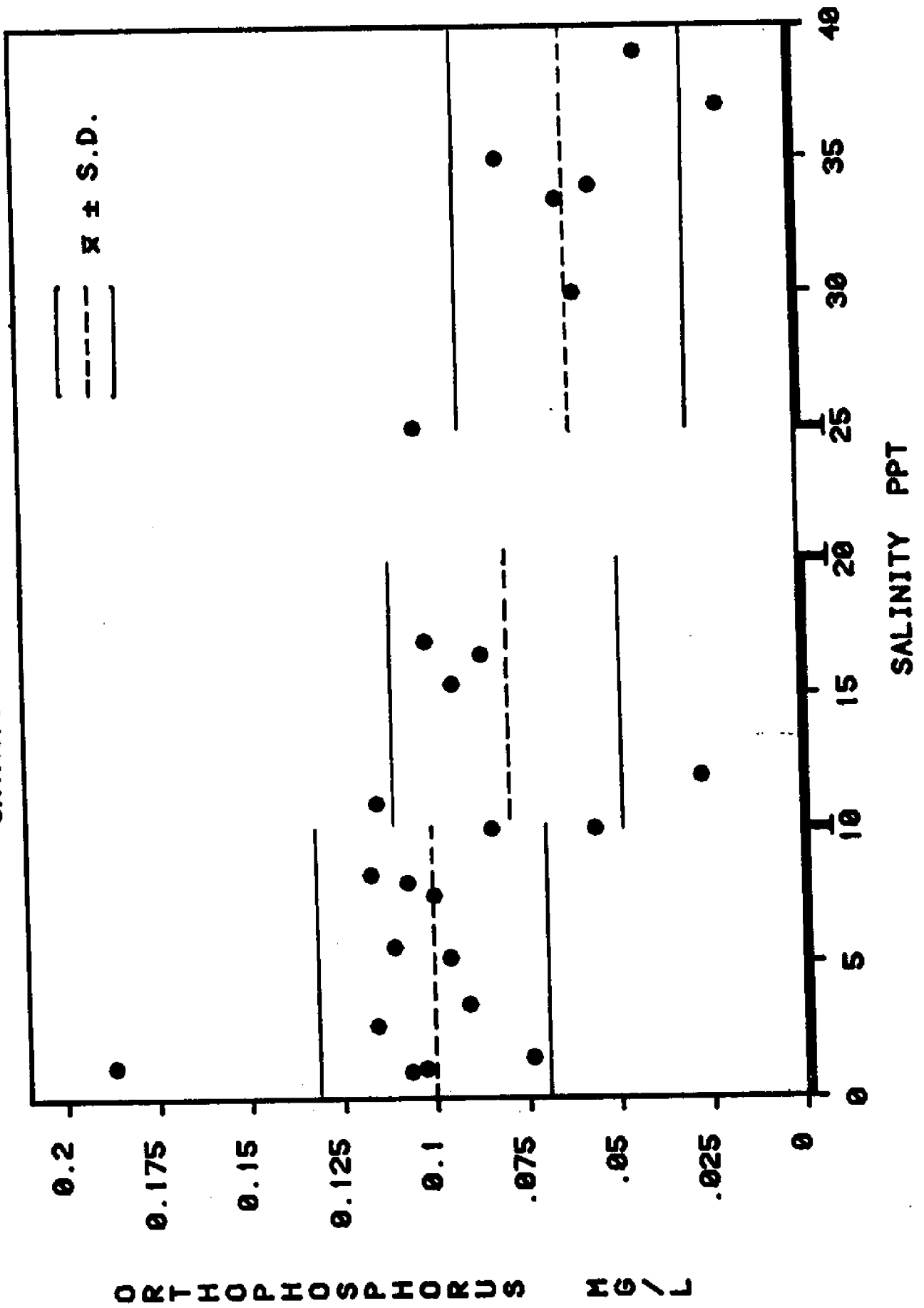


FIG. 6
 NASSAU RIVER ESTUARY
 % INORGANIC PHOSPHORUS AND NITROGEN VS. SALINITY

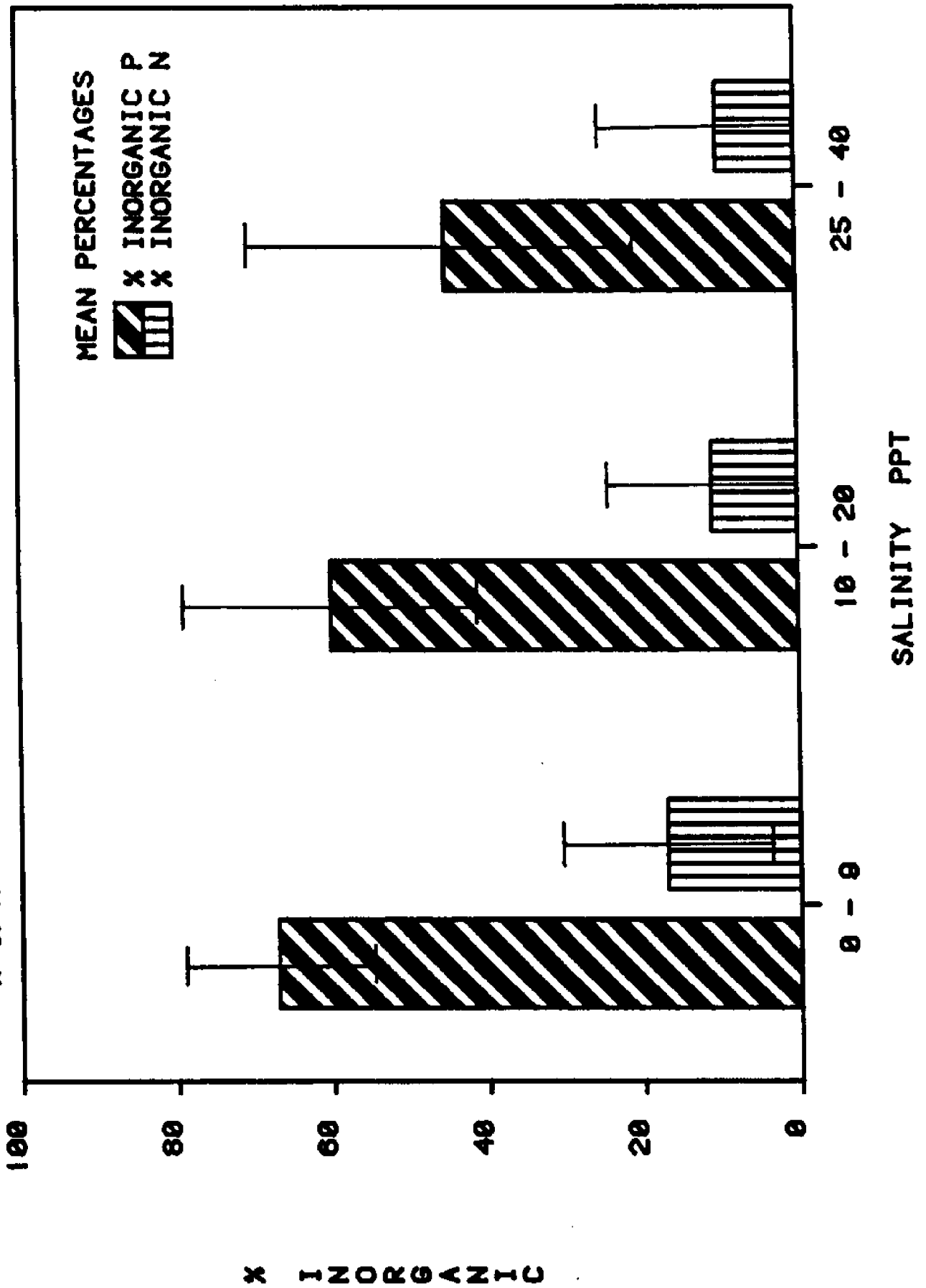
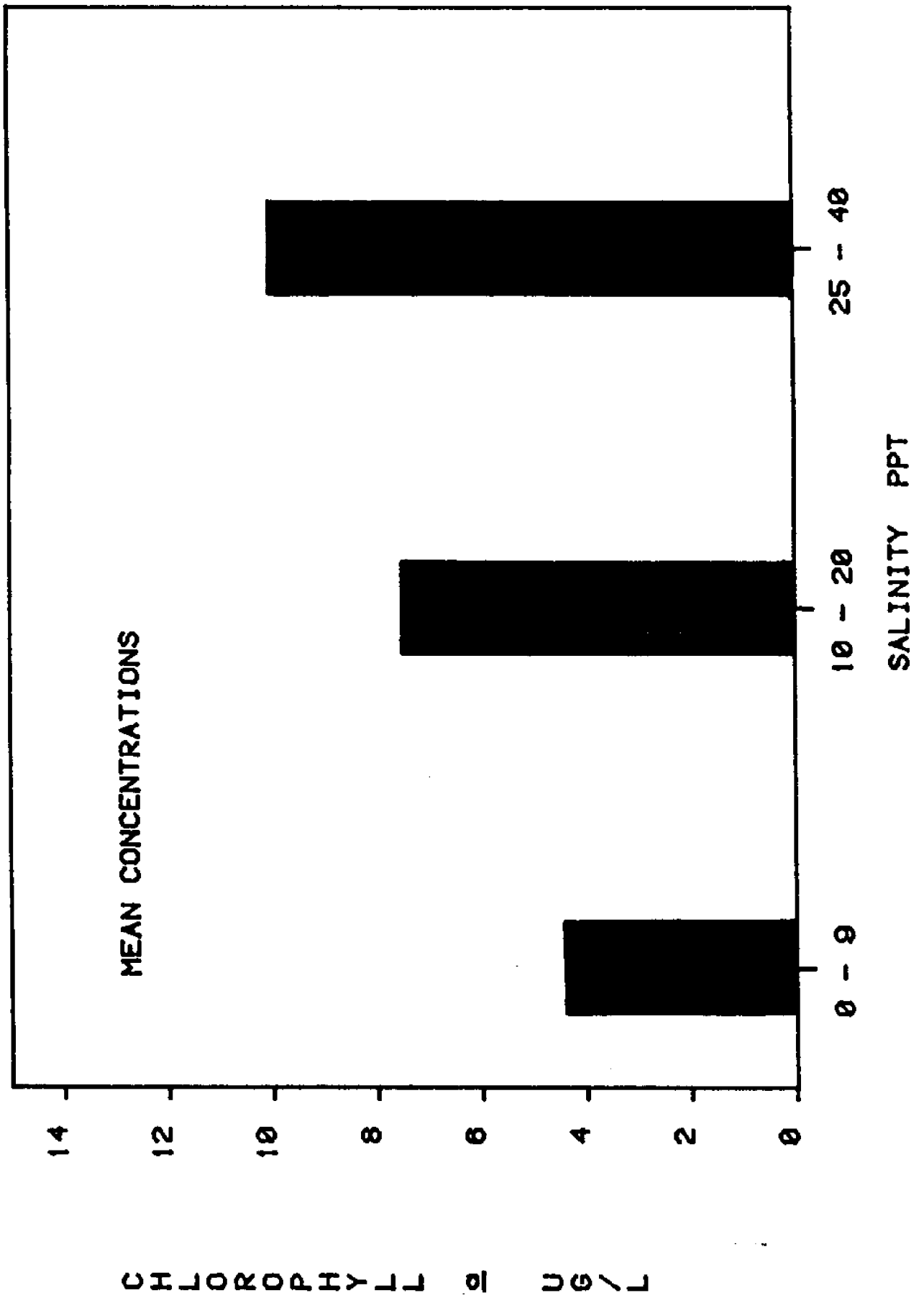


FIG. 7
NASSAU RIVER ESTUARY
CHLOROPHYLL μ VS. SALINITY



FISH-NURSERY USE IN GEORGIA SALT-MARSH ESTUARIES:
THE INFLUENCE OF SPRINGTIME FRESHWATER CONDITIONS

S. Gordon Rogers, Timothy E. Targett, and Scott V. Van Sant

Extensive and highly productive salt-marsh estuaries are a dominant feature along much of the Atlantic and Gulf of Mexico coasts of the southeastern United States. Shallow areas within estuaries provide habitat for fish assemblages that are highly dynamic both spatially and temporally. Some species are resident year-round, but an important component of these assemblages is a transient group of young-of-the-year clupeiform, perciform, and pleuronectiform fishes that are spawned in deeper estuarine, nearshore, and offshore waters (Gunter 1945; Reid 1954; Kilby 1955; Darnell 1958; Tagatz and Dudley 1961; Miller and Jorgenson 1969; Dahlberg 1972; Turner and Johnson 1973). These species enter the shallow portions of estuaries primarily in the winter and early spring, occur in very high densities during their recruitment and residence periods, and leave the shallows as they grow or as the water begins to cool in late summer and early fall (Herke 1971; Adams 1976; Weinstein 1979; Bozeman and Dean 1980; Weinstein et al. 1980b; Weinstein and Brooks 1983). Comparisons of their spatial and temporal nursery use between studies are complicated by differences in habitats sampled, timing of sampling with respect to tidal-lunar cycles, and gear design and efficiency. However, it is apparent that fishes generally exhibit similar patterns throughout the region. "Waves" of recruitment and peaks of abundance unique to each species are separated through time during the late fall, winter, spring, and early summer (Herke 1971; Dunham 1972; Adams 1976; Chao and Musick 1977; Govoni and Merriner 1978; Weinstein 1979; Bozeman and Dean 1980; Subrahmanyam and Coultas 1980; Weinstein et al. 1980b). Each species associates with particular ranges of physicochemical and biotic factors, including salinity, substrate composition, vegetation, and water depth (Gunter 1956; Herke 1971; Chao and Musick 1977; Kobylinski and Sheridan 1979; Weinstein 1979; Weinstein et al. 1980b). Temporal and spatial use patterns combine to produce a dynamic mosaic of transient species assemblages. Several workers have proposed, and Weinstein and Brooks (1983; see also references cited therein) have demonstrated, size-specific use of shallow estuarine habitats. Spots Leiostomus xanthurus "loaded" into the upper portion of tidal creek system and "bled off" with increasing size. This phenomenon likely occurs on an estuary-wide scale as species move down the estuary or into deeper water with growth (see Herke 1971; Chao and Musick 1977).

The timing of recruitment of many larval and juvenile fishes into estuarine nursery areas in southeastern coastal waters coincides with the winter-spring period of maximum river discharge. This pulse of fresh water significantly alters the

salinity structure and displaces the freshwater boundary (here defined as the location of the high-tide surface front between brackish and fresh water) many kilometers seaward. Large areas of the upper portions of estuaries with direct riverine input thus are exposed to prolonged periods of freshwater conditions (Dunham 1972; Schroeder 1978; Weinstein et al. 1980a). These shifts are accompanied by fluctuations in current velocity, turbidity, and other factors linked to variation in river discharge. Seasonal fluctuations in current velocity, turbidity, and other factors linked to variation in river discharge. Seasonal fluctuations in estuaries with no direct riverine input are less pronounced.

Certain of the transient species are known to associate with the oligohaline-to-freshwater portions of the estuaries (Massman 1954; Massman et al. 1954; Gunter 1957; Wilkens and Lewis 1971; Tagatz and Wilkens 1973; Turner and Johnson 1973; Govoni and Merriner 1978; Weinstein 1979; Weinstein et al. 1980a; Weinstein et al. 1980b). However, the influence of increased river discharge and the functional importance of freshwater areas in processes of recruitment and nursery utilization are poorly known.

Young-of-the-year spots and Atlantic croakers Microponias undulatus in the Cape Fear River estuary, North Carolina, were restricted from a section of the main-stem channel during periods of high freshwater flow, but postlarval flounders Paralichthys spp. largely were unaffected (Weinstein et al. 1980a). Newly recruited Atlantic menhaden Brevoortia tyrannus and gulf menhaden B. patronus concentrate in oligohaline and freshwater areas of both minimally and intensively flushed estuaries (Wilkens and Lewis 1971; Tagatz and Wilkens 1973; Turner and Johnson 1973; Weinstein et al. 1980b). Over longer periods, abundances of spot and Atlantic croaker did not correlate with year-to-year variation in river discharge in Apalachicola Bay, Florida (Kobylnski and Sheridan 1979). Structural patterns of the shallow-water fish assemblage in the Cape Fear River estuary also were not affected by annual differences in river discharge (Weinstein et al. 1980b).

Although annual variation of river discharge may not affect overall community patterns or the population dynamics of estuarine fishes, significant local influences of freshwater encroachment and increased flow velocity can occur. This study was designed to investigate the spatial and temporal patterns of recruitment and residence of transient fishes in shallow areas along the main stem of an estuary with direct freshwater river input. Of particular interest were the effects of extended periods of high river discharge and freshwater encroachment on continued use of shallow nurseries.

Study Area

The Ogeechee River-Ossabaw Sound estuarine complex is located on the northern portion of the Georgia coastline (Fig. 1). Deeper portions of the estuary are surrounded by intertidal salt

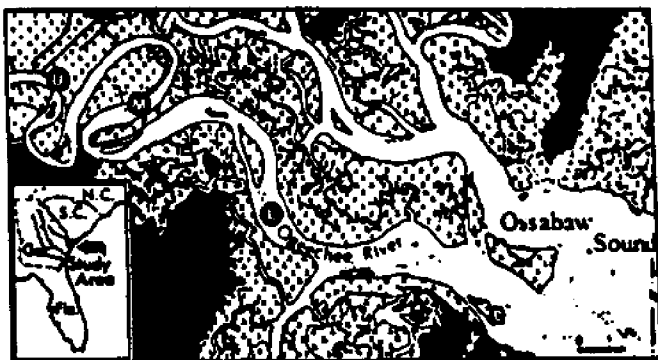


FIGURE 1.—Locations of the upper (U), middle (M), and lower (L) sampling stations in the Ogeechee River estuary, Georgia. Patterned areas adjacent to rivers are salt marshes; shaded areas in the river are sand bars or mud flats; black areas are dry land.

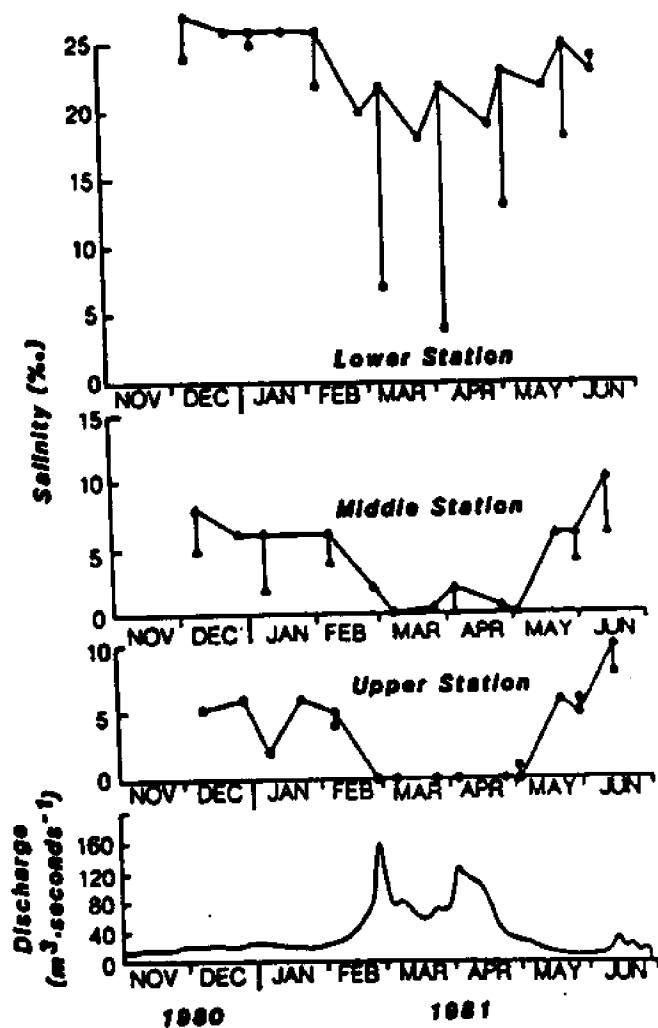


FIGURE 2.—Daily mean river discharge of the Ogeechee River, Georgia, November 1980–June 1981, and surface salinities at three stations along the mainstem of the estuary. Salinity plots connect high-tide values. Vertical lines connect high- and low-tide values on fish-sampling dates.

marshes dominated by smooth cordgrass Spartina alterniflora, and are drained by intertidal and subtidal watercourses. The entire complex covers approximately 18,000 hectares. Semidiurnal tides average 2.1 m and range from 1.6 to 2.7 m above mean low water. Mid-ebb tide current velocity in the Ogeechee River, 25 km upriver from the mouth of Ossabaw Sound, has been measured at $0.76 \text{ m}\cdot\text{second}^{-1}$ (Windom and Beck 1971) at a river discharge of approximately $50 \text{ m}^3\cdot\text{second}^{-1}$ (USGS 1970).

The Ogeechee River drains approximately $14,300 \text{ km}^2$ of Georgia's lower piedmont and coastal plain. Since 1937, the mean daily discharge has been $82.0 \text{ m}^3\cdot\text{second}^{-1}$ within a range of $3.71\text{--}745 \text{ m}^3\cdot\text{second}^{-1}$ (United States Geological Survey [USGS] data). Peak discharges normally occur during the winter and spring or are associated with brief tropical weather systems in late summer and early autumn.

Three stations were established at the mouths of intertidal creeks draining salt marsh along the main stem of the estuary (Fig. 1). They were chosen so that at least one station would experience freshwater conditions during periods of high flow. The lower station, 13 km inland from the mouth of Ossabaw Sound, was located in a zone of considerable mixing of riverine and ocean waters, resulting in a wide seasonal and diel range of salinities (Howard et al. 1975). The middle and upper stations were situated at 13-km intervals upriver in a more stable salinity regime (0 to approximately 15‰; Howard et al. 1975). The freshwater boundary was approximately 10 km above the upper station during low-flow periods.

The mouths of the creeks where samples were taken were 7 to 9 m wide and approximately 1.5 m deep at mean high tide. At low tide, the creeks drained completely at the lower and middle stations, and almost completely at the upper station. Substrates were soft mud. Salt-marsh vegetation was smooth cordgrass at the lower station and smooth cordgrass, rough cordgrass Spartina cynosuroides, and black needlerush Juncus roemerianus at the upper and middle stations.

Methods

Fishes were sampled by two hauls of a 1.2 x 10-m sein (5-mm mesh and a 1.2 x 1.2 x 1.2-m bag) extended completely across the mouth of the intertidal creek, then pulled into the creek over a roughly triangular area, and pursed on a mudflat inside the creek mouth. The areas sampled were approximately 50 m^2 at the upper, 78 m^2 at the middle, and 75 m^2 at the lower stations. All stations were sampled during ebb tide on the same day at 28-30-day intervals from 9 December 1980 through 30 May 1981, and during a 3-day period in June 1981. Sampling was conducted within 60 hours of the highest-amplitude spring tides of the month except in June, when they were sampled during 3 days of lower-amplitude spring tides.

On each collection date, surface salinity ($\pm 0.5\%$ range, measured by refractometer) and temperature (± 0.25 C) were recorded at each station and at midriver during high tide, midebb tide, and at low tide. Salinity and temperature profiles at high and low tide were determined from midriver values recorded at 1.3-km intervals between stations. Between monthly collections, high-tide values were recorded at all stations and a midriver profile was determined. River-discharge data were obtained from records published by the Georgia Water Resources Division of the USGS for gauging stations located 60 to 80 km upriver from the study area. These data and results from other studies (Windom and Beck 1971; Howard et al. 1975) were used to correlate river discharge and salinity at given locations.

After collection, fishes were placed in 10% formalin. In the laboratory they were sorted, identified, counted, and measured to the nearest 1 mm total length (TL); the total weight of individuals from each species was determined to the nearest 0.1 g wet weight. When more than 100 individuals of a species were collected, they were randomly subsampled for length determinations.

Seasonal recruits (transient species) are defined as those fishes spawned in deeper estuarine, nearshore, and offshore waters that are present in shallow estuarine habitats as young-of-the-year. Length frequencies were used to distinguish seasonal recruits from age 1+ individuals of the same species. The catch for each species at each station was standardized to individuals per 100 m². Analyses of species distribution were based on species ranks determined from catch values. Kendall's (1962) coefficient of concordance W was used to test the hypothesis that species' ranks were independent among stations within months. A statistically significant concordance would indicate that species hierarchies were the same at all stations.

To minimize statistical error, only the nine most abundant seasonal recruit species (of 15 total) were included in these calculations. These comprised over 99.9% of all seasonal recruits collected and over 98% of the transient fishes at any station in a monthly calculation if it was present at at least one station.

Periods of recruitment of transient species were determined from monthly mean lengths of the smallest 10% of sample populations (see Weinstein and Walters 1981) and from lengths of the smallest individuals captured each month. Both show a marked increase when recruitment ends. Means were not calculated for samples containing fewer than five fish. Size-specific distribution patterns were examined by month-to-month comparisons of the size composition of species populations at their uppermost and lowermost stations of abundance. For each comparison, the proportions of the populations in several (≥ 5 -mm TL) size classes were calculated for both stations. Chi-square tests were performed on each pair of proportions to test for differences between stations.

Repetitive seine hauls were conducted during June 1981 to assess the adequacy of two hauls in determining use patterns. Sampling at each station was continued during ebb tide until the creek mouths were drained (lower and middle stations) or until low tide (upper stations). Fishes from the four or five seine hauls were preserved and processed separately. Species ranks and abundances were determined for all transient species present based on (a) the first two hauls and (b) all hauls at each station. Spearman's rank correlation statistic (r_s) was used to test the hypothesis that species' ranks were independent between (a) and (b). Significant correlations would show that two hauls yielded rankings similar to those produced by several additional hauls. Length comparisons were based on t-tests of mean lengths from two and all hauls combined.

Three collections were made at each station between 8 February and 9 April 1982 to determine if patterns of nursery use were repeated the following year under different flow regimes. Procedures were similar to those used in 1981 except that lengths were not recorded, and the March samples were processed in the field with species ranks assigned based on relative abundances. In March, the middle and upper stations were sampled one week earlier than the lower station. Kendall's W was again used to compare species hierarchies among stations within months. Spearman's r_s was used to test the hypothesis that species' ranks were independent between years for the same month and station.

Results

Sampling Considerations

Comparisons of species' ranks between two and all four or five seine hauls during June 1981 yielded highly significant correlations at all stations ($r_s = 0.85-0.98$; $P < 0.005$). Nine transient species were taken by the first seine haul at each station, and no additional species were collected in subsequent hauls. Although species ranks did not vary significantly between early hauls and all hauls combined, the majority of a few species were collected in later hauls. To eliminate any bias in estimates of species abundance, all comparisons are based on large (≥ 1 order of magnitude) differences in species catch.

There were no significant differences in the mean lengths of any species between two and all hauls combined at any station. Additionally, there were very few differences in length ranges between the early hauls and all hauls combined. Our mesh size prevented efficient capture of the smallest seasonal recruits (Weinstein 1979). However, the range of lengths in our samples compares well with those in other studies using smaller mesh sizes (Weinstein 1979; Weinstein et al. 1980a). It is unlikely that size-class capture efficiency varied between months or locations, thus validating our temporal and spatial length comparisons.

Salinity and Temperature

Surface salinity ranged from 0 to 27‰ during the study (Fig. 2). Values at high tide were generally greater than at low tide although in the vicinity of the upper station, low-tide values were occasionally 0.5 to 1‰ greater than those at high tide due to connections with the northern arm of the estuary via 18th-Century rice-irrigation canals.

River discharge with sustained flows exceeding 50-60 m³·second⁻¹ displaced the freshwater boundary to a point below the upper station (Fig. 2). The 1981 high-flow period was of relatively short duration and had low discharge peaks (Fig. 3), but it was sufficient to maintain fully freshwater conditions (0‰ at high and low tide) at the upper station for at least 60 days (Fig. 2). At the middle station, in a zone of somewhat greater tidal influence, the relationship between river discharge and salinity was less clear. During high river discharge, salinity ranged from 0 to 2‰. Fully freshwater conditions were measured on only two occasions and the freshwater boundary was likely downstream of this point for no more than a few days at a time during 1981. Salinities at the lower station were reduced during high flow and the diel range was much greater (up to 20‰) than at upriver locations.

The high-flow period in 1982 was of much greater magnitude and duration than in 1981, and discharge was comparable to long-term means (Fig. 3). Fully freshwater conditions were recorded at the upper station on all three sampling dates and salinities ranged from 0 to 0.5‰ at the middle station. The freshwater boundary remained downstream of the upper station for approximately 130 days from early January through mid-May 1982.

Surface temperatures ranged from 6.5 C in late December 1980 to 30.0 C in mid-June 1981 (Fig. 4). Temperature differences between stations on the same day were never greater than 3.0 C, although temperatures in the upper portion of the study area were generally less than in the lower portion during cooler months, and greater during warmer months. Temperatures in February and March 1982 were higher than those during the corresponding period of 1981 (Fig. 4). Measurements of surface temperature in an adjacent estuary indicate that water temperatures were generally warmer during the winter of 1981-1982 than in 1980-1981 but were cooler following mid-April during the second year.

Fishes

We collected 46,908 fishes from 41 species between December 1980 and June 1981. More than 95% were transient species. Young-of-the-year spots, Atlantic menhaden, and striped mullet Mugil cephalus together made up nearly 93% of the total. Transient species dominated samples at all locations even after about 45 days of fully freshwater conditions at the upper station.

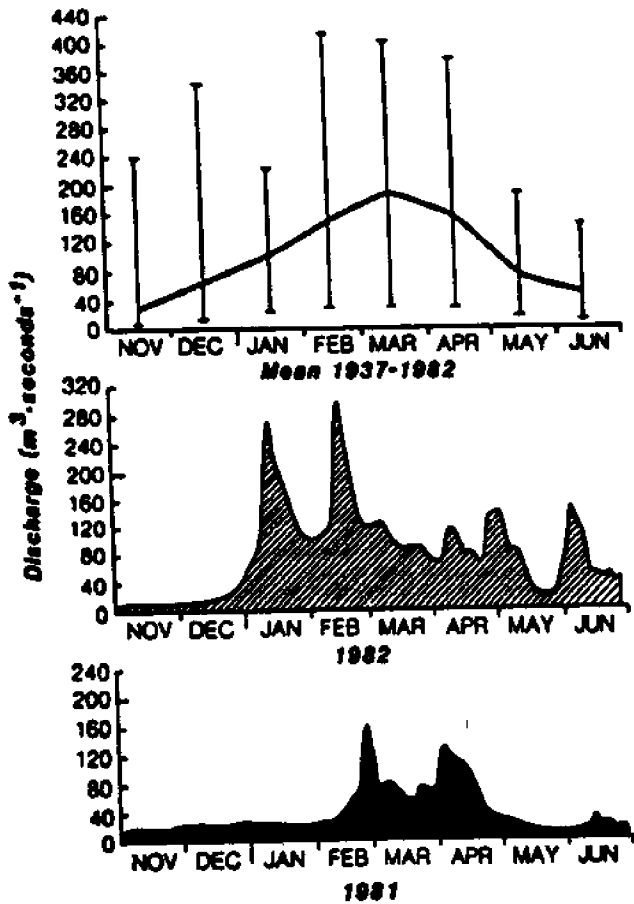


FIGURE 3.—Daily mean discharge of the Ogeechee River, Georgia, for November–June 1980–1981 and 1981–1982, and long-term monthly mean discharge, 1937–1982. Vertical bars indicate the range of monthly means.

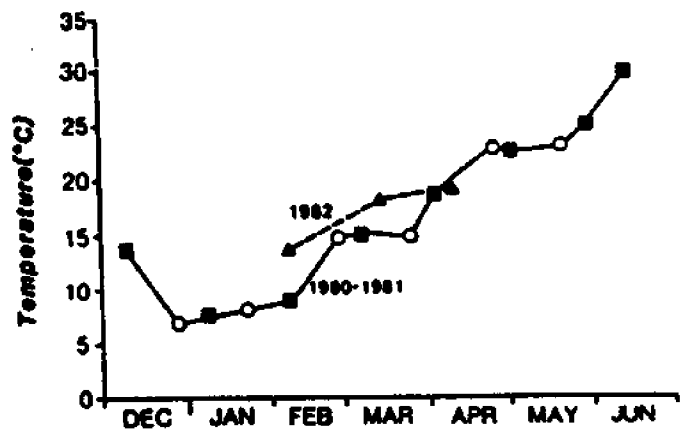


FIGURE 4.—Mean surface temperature from three locations in the mainstem of the Ogeechee River estuary, Georgia, December–June 1980–1981 and February–April 1982. Closed symbols are from fish-sampling dates; open symbols are values from other dates.

Rank analyses yielded significant correlations from February through June 1981, including the period of high river flow (Table 1; Fig. 2). Nonsignificant values in December and January resulted from high catches of Atlantic croakers and southern flounder Paralichthys lethostigma at the middle or upper stations. These two samples also preceded the arrival of most seasonal recruits, resulting in low numbers of species in calculations of significance. The highest catches of Atlantic croaker, southern flounder, Atlantic menhaden, silver perch Bairdiella chrysoura, and hogchoker Trinectes maculatus, were recorded at the upper or middle stations through May. This pattern combined with very low catches of striped mullet at upriver locations in April and May to produce low ($W < 0.80$) but significant coefficients of concordance for these months. In June, the number of transient species had decreased greatly, contributing only 60% of the total numbers of all fishes, although several species still were being recruited to the study area (Table 2).

Concordance of species ranks indicates that all three sampling locations functioned as nursery areas in a similar fashion throughout the 1981 recruitment season, particularly during the period of fully freshwater conditions at upriver locations. Differences in species ranks and abundances were due primarily to higher catches at the upper and middle stations throughout the period.

Striped mullet was the only species that seemed to actively respond to high river discharge and the presence of fresh water. This species nearly disappeared from the upper station during the latter part of the high-discharge period and also decreased in abundance at the middle station (Table 1). Abundances increased again at upriver locations by June.

Spot abundance at the upper station also dropped off sharply during the latter part of the high-discharge period, but this occurred as recruitment was ending and spot abundance was declining throughout the study area. This also followed an absolute increase of spot abundance at the upper station during the initial phases of recruitment and freshwater conditions (Tables 1 and 2; Fig. 2)

Pooled species abundances show rather distinct periods of nursery use: Atlantic croaker (December); striped mullet (February-March); southern flounder (March); spot (March-April); Atlantic menhaden (May); silver perch (May-June); and white mullet Mugil curema (June). Length data (Table 2) indicate that southern flounder recruitment ended during March, coinciding with their peak abundance. Spot recruitment, on the other hand, did not end until late May, after their March-April period of peak abundance. Striped mullet recruitment ended during April, although peak abundance had occurred in February and March. More than 96% of all Atlantic menhaden captured were 30-40 mm TL, but based on a slight increase in mean and minimum lengths plus a sharp decrease in catch, recruitment had probably ended by mid-June. Silver perch, hogchoker, and blackcheek tonguefish

TABLE 1.—Monthly catches (individuals · 100 m⁻³), ranks (in parentheses), and rank analyses (W = Kruskal's coefficient of concordance) of dominant seasonal recruit fish species collected at the upper (U), middle (M), and lower (L) stations in the Ogeechee River-Osawabaw Sound estuarine complex; asterisks denote *P < 0.05 and **P < 0.01.

Species	Station	1982											
		9 Dec	8 Jan	8 Feb	7 Mar	4 Apr	2 May	30 May	13-15 Jun	8 Feb	9-16 Mar	9 Apr	
Atlantic croaker	U	274 (1)	6 (1.5)	56 (3)	0	0	0 (6.5)	0	0	0	0	0	0
	M	94 (1)	155 (1)	0 (4)	0	0	0 (6.5)	0	0	0	0	0	0
	L	0 (3.5)	0 (3)	9 (3)	0	0	4 (6.5)	0	0	0	0	0	0
Striped mullet	U	0 (4)	2 (3)	188 (2)	2,122 (2)	2 (3)	0 (6.5)	26 (4)	196 (2)	16 (1)	0 (3)	0 (6)	0 (6)
	M	0 (3)	31 (2)	1,134 (1)	320 (2)	86 (3)	13 (4)	18 (5)	71 (2)	13 (1)	0 (2)	6 (3)	6 (3)
	L	1 (1.5)	5 (1)	321 (2)	485 (2)	100 (2)	457 (2)	391 (1)	0 (7)	47 (1)	0 (2)	0 (5)	0 (5)
Southern flounder	U	0	6 (1.5)	14 (4)	168 (3)	26 (3)	4 (3)	8 (6)	14 (7)	0	0	4 (3)	4 (3)
	M	0	0 (4)	15 (3)	19 (3.5)	9 (4)	22 (3)	24 (4)	6 (3)	0	0	5 (4)	5 (4)
	L	0	0 (3)	4 (4)	5 (3)	0 (4.5)	7 (4)	3 (6.5)	0 (7)	0	0	3 (3)	3 (3)
Spot	U	0	0 (4)	850 (1)	5,608 (1)	818 (1)	790 (1)	194 (2)	96 (4)	0 (2)	0 (1)	556 (2)	556 (2)
	M	0	3 (3)	22 (2)	12,493 (1)	8,397 (1)	209 (1)	48 (3)	4 (3.5)	3 (2)	0 (1)	1,080 (1)	1,080 (1)
	L	0	0 (3)	629 (1)	12,195 (1)	4,144 (1)	2,148 (1)	340 (2)	123 (1)	33 (2)	0 (1)	4,933 (1)	4,933 (1)
Atlantic menhaden	U	0	0	0	56 (4)	198 (2)	788 (2)	6,060 (1)	56 (3)	0	0 (2)	1,320 (1)	1,320 (1)
	M	0	0	0	19 (3.5)	92 (2)	200 (2)	59 (2)	4 (3.5)	0	0 (3)	174 (2)	174 (2)
	L	0	0	0	4 (4)	56 (3)	217 (3)	132 (3)	63 (3)	0	0 (3)	423 (2)	423 (2)
White mullet	U	0	0	0	0	0	0 (6.5)	0 (7.5)	452 (1)	0	0	0	0
	M	0	0	0	0	0	0 (6.5)	0 (7)	5 (4)	0	0	0	0
	L	0	0	0	0	0	4 (3.5)	85 (4)	64 (2)	0	0	0	0
Silver perch	U	0	0	0	0	0	0	56 (3)	108 (3)	0	0	0	0
	M	0	0	0	0	0	0	363 (1)	199 (1)	0	0	0	0
	L	0	0	0	0	0	0	45 (5)	11 (4)	0	0	0	0
Hogchoker	U	2 (3)	0	0	4 (5)	6 (4)	2 (4)	14 (5)	18 (6)	0	0	2 (4.5)	2 (4.5)
	M	0 (3)	0	0	0 (5)	0 (5)	0 (6.5)	0 (7)	0 (7.5)	0	0	0 (5.5)	0 (5.5)
	L	0 (3.5)	0	0	0 (5)	0 (4.5)	0 (8)	0 (8)	0 (7)	0	0	0 (5)	0 (5)
Blackcheck tonguefish	U	8 (2)	0	0	0	0	0 (6.5)	0 (7.5)	0 (8)	0	0	2 (4.5)	2 (4.5)
	M	0 (3)	0	0	0	0	0 (6.5)	0 (7)	0 (7.5)	0	0	0 (5.5)	0 (5.5)
	L	1 (1.5)	0	0	0	0	3 (7)	3 (6.5)	8 (5)	0	0	0 (5)	0 (5)
W	0.22	0.30	0.82	0.97	0.75	0.75	0.70	0.52	1.00	0.78	0.80	0.80	
P	NS	NS	*	**	*	**	*	*	NS	NS	**	**	

1982

1980-1981

TABLE 2.—Mean total lengths (mm) of lower 10% (TL₁₀) of sampled populations and lengths of smallest individuals captured of dominant seasonal recruit species from the Ogeechee River-Ossabaw Sound estuarine complex during 1980-1981; a dash indicates a total catch of five or fewer fish, and zero indicates no fish were captured.

Species	Sample	9 Dec	8 Jan	8 Feb	7 Mar	4 Apr	2 May	30 May	13-15 Jun
Atlantic croaker	TL ₁₀	15.5	12.8	16.0	0	0	—	0	0
	Smallest	14	11	16	0	0	19	0	0
Striped mullet	TL ₁₀	—	25.5	24.4	24.1	24.9	31.6	33.1	40.9
	Smallest	25	25	21	22	21	30	28	33
Southern flounder	TL ₁₀	0	—	13.0	13.0	19.0	29.0	—	35.0
	Smallest	0	12	12	12	16	26	36	35
Spot	TL ₁₀	0	—	18.2	22.6	23.1	24.5	34.3	35.4
	Smallest	0	12	16	20	21	19	27	31
Atlantic menhaden	TL ₁₀	0	0	0	31.0	30.1	29.3	32.4	34.6
	Smallest	0	0	0	30	29	26	28	34
White mullet	TL ₁₀	0	0	0	0	0	—	26.5	30.3
	Smallest	0	0	0	0	0	29	24	29
Silver perch	TL ₁₀	0	0	0	0	0	0	13.7	21.5
	Smallest	0	0	0	0	0	0	11	14
Hogchoker	TL ₁₀	0	0	0	—	—	—	—	—
	Smallest	0	0	0	43	21	35	34	16
Blackcheck tonguefish	TL ₁₀	—	0	0	0	0	—	—	—
	Smallest	20	0	0	0	0	52	57	23

TABLE 3.—Comparisons of ranks between 1981 and 1982 for dominant seasonal recruit fish species in the Ogeechee River-Ossabaw Sound estuarine complex; r_s is Spearman's rank correlation statistic and asterisk denotes $*P < 0.05$. U, M, and L are upper, middle, and lower stations.

Statistic	Feb			Mar			Apr		
	U	M	L	U	M	L	U	M	L
r_s	0.70	1.00	0.70	0.60	0.90	0.80	0.83	1.00	0.40
N	4	3	4	5	4	4	6	4	4
P	NS	NS	NS	NS	NS	NS	*	*	NS

Symphurus plagiusa recruitment was still in progress when the 1980-1981 study period ended.

The largest southern flounder and silver perch composed significantly ($P < 0.05$) greater proportions of their populations at the upper station during initial recruitment periods, while the smallest size classes were relatively more abundant at the middle (southern flounder) and lower (silver perch) stations. Later in their residence period, the largest southern flounder were more abundant at the middle station while smaller fish dominated at the upper station ($P < 0.001$).

Spots exhibited no clear pattern of size-class distribution during recruitment, but by late May and June, the largest individuals were relatively more abundant at the lower station and smaller fish dominated at the upper station ($P < 0.05$). Although no consistent trends of relative size-class abundance were evident for Atlantic menhaden, fish longer than 40 mm TL were proportionately more abundant at the lower station in late May, while fish shorter than 35 mm TL dominated at the upper station ($P < 0.01$).

Rank analyses of collections in 1982 yielded high coefficients of concordance in all three months, yet the correlation between stations was statistically significant only in April (Table 1). This was due more to low numbers of species entering the calculations in February and March than to differences in species hierarchies between stations. Monthly rank-correlation analyses between years were statistically significant only for April collections at the upper and middle stations (Table 3). Atlantic croakers, southern flounder, and hogchokers were absent in 1982 samples taken during months when they were present in 1981 (Table 1). Many fewer spots and striped mullet were collected in 1982 than in corresponding 1981 collections. More Atlantic menhaden were collected in 1982. Despite these interesting differences, by April six seasonal recruit species were present in the study area and species ranks were correlated among stations and between years. At this time river discharge had been sufficiently high to maintain freshwater conditions at the upper station for approximately 95 days (Figs. 2 and 3).

Discussion

Shallow marsh habitats along the margin of the upper Ogeechee River estuary serve as nurseries for several fish species. The fish assemblage in upriver areas in winter and spring was dominated by seasonal recruit species, similar to the patterns at the more saline lower station and to higher-salinity locations in other estuaries (for example, Weinstein 1979; Bozeman and Dean 1980; Weinstein et al. 1980b). Species recruited from deeper estuarine, nearshore, and offshore spawning grounds used upriver portions of the study area during periods of fresh water conditions. Only striped mullet showed a pronounced "avoidance" of freshwater encroachment. Rank analyses further emphasized a similarity of function among stations.

Thus, the role of shallow upriver areas as nursery grounds was not substantially altered by the encroachment of freshwater for approximately 45 days in 1981 and nearly 100 days in 1982. Because all collections were made during the highest-amplitude spring tides of each month, riverine influence was even more pronounced between collection dates. It is unlikely that brackish water penetrated upriver locations between sampling dates.

Differences in the numbers of several species between 1982 and 1981 may have been due to variations in the size of spawning stocks, the timing of spawning, spawning success, larva survival, or to cross-shelf and estuarine transport processes. Several of these factors have been correlated with water temperature (Nelson et al. 1977; Ferraro 1980; Johns and Howell 1980; Johns et al. 1981) and warmer temperatures during the winter of 1982 may have contributed to the high catches of Atlantic menhaden at a relatively early date (Table 1). It is also likely that higher river discharge in 1982 delayed or prevented the recruitment of some species.

Weinstein, et al. (1980) have demonstrated that transport mechanisms based on diel vertical migrations, correlated with a combination of tidal-current direction and photoperiod, allow postlarval spots and flounders to recruit into and remain in specific portions of the Cape Fear River estuary. They proposed that flood-tide migration into surface layers also facilitates movement over the river shoals and into tidal creek systems. In contrast, Atlantic croakers remain primarily in bottom layers and depend on net upstream flow in the saline wedge to concentrate in upriver channel areas. Weinstein et al. (1980a) further noted that increased river discharge "flushed" spot and Atlantic croaker postlarvae from an upstream location to which they returned following the freshet. In the Ogeechee River estuary during low discharge, the point above which upstream flow does not occur during flood tide and the inland extent of the saline wedge are many kilometers above the freshwater boundary. As discharge increases the saline wedge is compressed toward the freshwater boundary, which is concurrently being displaced downstream (see Windom and Beck 1971; Dorjes and Howard 1975; Howard et al. 1975; Schroeder 1978). The hydraulic head similarly diminishes or prevents net floodtide displacements at all points (Schroeder 1978).

Therefore, it is likely that, in 1982, river discharge increased to the point where net upstream transport of new recruits was inhibited (for example, spot, southern flounder; Table 1). If this was the case, only those fishes that were established in shallow areas prior to increased discharge or were able to maintain position in channel areas would remain in upriver nurseries. Recruitment to the study area likely would be limited to episodes between discharge peaks and after the high-flow period, delaying and diminishing immigration to upriver nurseries. Spots and southern flounder were able to use the study area under fully freshwater conditions. Therefore, any effects of increased discharge on these species' nursery-use

patterns are related to recruitment and retention mechanisms rather than to salinity "preferences" or the physiological ability of fishes to utilize freshwater areas. In contrast, striped mullet were apparently unable to occupy freshwater areas independent of the effects of increased flow, and Atlantic menhaden were not likely affected by either factor, as they were most abundant at the upper station in 1981 and 1982 (Table 1).

Trends in spatial and temporal use patterns, combined with the relative abundances of species size classes, indicate that newly recruited southern flounder, Atlantic menhaden, and silver perch concentrated into the least-saline portion of their total distribution. Additionally, Atlantic menhaden were present at sampling locations primarily as metamorphosing postlarvae (30-40 mm TL; Lewis et al. 1972) and were concentrated from the vicinity of the high-tide freshwater boundary up to 14 km above the front (1981 and 1982 data combined).

Previous studies of southern flounder also have shown that young of the year are found in upriver, low-salinity areas (Powell and Schwartz 1977; Weinstein 1979; Weinstein₁ et al. 1980; Weinstein₂ et al. 1980). In Virginia, Atlantic menhaden are present in the shore zone primarily as postlarvae (Massman et al. 1954); and larvae and postlarvae concentrate in a zone extending from low-salinity (1 ‰) waters to a few kilometers above the freshwater boundary in the mainstem of the White Oak River estuary, North Carolina (Wilkins and Lewis 1971). In contrast to our data, young-of-the-year silver perch have been reported to concentrate in more seaward, higher-salinity zones (Chao and Musick 1977; Weinstein₂ et al. 1980).

As residence periods continued, the largest juvenile southern flounders were relatively more abundant farther downstream. Atlantic menhaden were markedly less abundant when recruitment ended. Thus, it appears that as these fishes grew they moved into deeper or more saline waters. In Virginia, juvenile Atlantic menhaden are common in upriver channel areas as postlarva abundance in the shallows decreases (Massman et al. 1954). In North Carolina and Florida juvenile Atlantic menhaden first are collected in low salinity-freshwater zone, but become increasingly more abundant seaward as the season progresses (Wilkins and Lewis 1971; Tagatz and Wilkins 1973; Turner and Johnson 1973).

Although spots generally were distributed uniformly among the stations, size-class distributions indicate that, as fish grew, they moved to the lower portion of the study area. Spots have been reported to be ubiquitous in estuarine nursery areas (Chao and Musick 1977; Weinstein 1979; Weinstein et al 1980b); however, other studies (Turner and Johnson 1973; Weinstein₁ et al. 1980) have shown that spots occur in upriver, oligohaline, and freshwater areas primarily during recruitment.

In summary, individuals of several seasonal recruit species appear to move preferentially to primary zones of recruitment at the most inland, least saline extent of their total distribution,

subsequently moving to deeper or more saline waters as they grow. Several authors have proposed that the headwaters of estuarine nursery areas are used first and that the nursery "fills up backward" during recruitment (Haven 1957; Herke 1971; Chao and Musick 1977; Weinstein 1979). Weinstein and Brooks (1983) have shown that spot exhibit this pattern within a discrete tidal-creek system.

We have demonstrated that seasonally freshwater areas are important functional components of estuarine nursery zones. The winter-spring discharge peaks observed in the Ogeechee River are common to most drainage systems along the southeastern Atlantic and Gulf of Mexico coasts (for example, Dunham 1972; Schroeder 1978; Weinstein et al. 1980a; Weinstein et al. 1980b). Exceptions include the southern two-thirds of the Florida peninsula and the southwest coast of Texas, where tropical storms produce maximum precipitation in the summer and fall (personal communications: Donald Foote, USGS, Tallahassee, Florida; R. U. Grozier, USGS, Austin, Texas). Therefore, fishes entering and residing in estuarine nursery areas throughout most of the region confront freshwater encroachment into estuarine nursery areas. However, estuarine zones are only partially composed of river-fed systems and seasonal freshwater encroachment may occur at the head of such a system or along the inshore margins of minimally flushed basins. In Georgia, these two estuary types alternate, producing a highly complex mosaic of habitat types, punctuated temporally and geographically by marked riverine influence. The nursery function of specific locations will be governed by individual species responses (or lack thereof) to freshwater encroachment and hydrodynamic factors. It is striking that low-salinity and freshwater areas serve as primary zones of recruitment to so many species and that their peak recruitment and utilization periods occur during the period of maximum riverine influence that temporarily creates a much larger proportion of the "preferred" habitat.

It is not known how far into permanent freshwater areas (fresh tidewater) functional nursery habitat extends. These may be extremely important components of the estuarine nursery continuum in minimally flushed estuaries and at the heads of river-dominated zones during low-discharge years. Low-salinity and freshwater areas warrant additional attention from estuarine researchers and managers due to their importance in the overall function of estuarine nurseries and their acute vulnerability to human activities.

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FACTORS INFLUENCING THE PATTERNS OF ENERGY FLOW IN THE
SEAGRASS BEDS AND IMPOUNDED MARSHES OF THE
INDIAN RIVER'S MOSQUITO LAGOON, FLORIDA

James K. Schooley

Introduction

The Indian River on Florida's east central coast is an estuarine system that only recently has come under intensive study. The northern portion of the river is shown in Figure 1. Gilmore (1977) has done a summary of the geography and hydrology of the Indian River in his review of the fish fauna of the region. Pertinent findings on a variety of other topics also can be found in a symposium edited by Montgomery and Smith (1983).

Traditionally, the high marshes within the Indian River have been accessible to fishes of the open lagoon. However, since the mid-1950's, nearly all high marsh has been isolated from the lagoon by earthen dikes for mosquito control purposes (Provost 1969, 1973). On Merritt Island, this resulted in large areas of marsh being isolated, and some partitioned, by these management practices (Provost 1969, 1973). Snelson (1976) has done a preliminary survey of fishes of various impounded marsh habitats of northern Merritt Island. Initial studies of the impact of the impoundments on the entire estuarine fish community have just recently begun (Schooley 1980, Gilmore *et al.* 1982). Schooley (1980) showed the impoundment fish communities of Mosquito Lagoon were less diverse than those of nearby seagrass beds. However, the impoundments had higher fish density (2 to 8 times), higher fish biomass (8 to 10 times) and higher fish production (14 to 21 times) than the seagrass beds.

This paper examines some of the processes and factors which may influence fish community composition and production in the impoundments and seagrass beds. The seasonal cycles of temperature and salinity, rates of production by macrophytes and structure of the zooplankton communities in each habitat are examined.

Department of Zoology, University of Florida, Gainesville,
Florida; Present Address: Natural Sciences and Mathematics,
Northeastern State University, Tahlequah, Oklahoma 74464.

Study Area

The northern Indian River and Mosquito Lagoon are shown in Figure 1. The term "river" is a misnomer. Indian River is a large, shallow, mesohaline lagoon separated from the ocean by a barrier island but that is cut in five places by artificial inlets. The northernmost and widest part of the island is Merritt Island. Mosquito Lagoon is separated from the rest of the Indian River by a second strip of land which has been cut at Haulover Canal to form a passageway for the intra-coastal waterway. The closest access to the ocean from Mosquito Lagoon is through Ponce de Leon Inlet, 80 km north of Haulover Canal.

The average water depth of Indian River is 1.5 m, with the maximum depths in areas dredged for channels, harbors and land-fill. The bottom of the lagoon is covered by extensive seagrass beds dominated by Halodule wrightii and Syrinogodium filiforme. Tidal fluctuations are insignificant in the northern part of the system, with major water movements the result of wind-driven circulation (Dubbelday 1975). Mosquito Lagoon has salinity ranges of 21 to 36 ppt, with a yearly average of 31 ppt (Lasater 1975). Salinity of the lagoon at any given time represents a balance between evaporation and local precipitation (Lasater 1975).

Two seagrass beds within Mosquito Lagoon were studied. The first, S1, is located in Eddy Creek at the southern end of the lagoon where water depth was approximately 0.5 m. The second seagrass site, S2, is located off Van's Island, approximately 18 km from S1. Water depth at S2 was approximately 0.6 m.

In contrast to the relative homogeneity of the seagrass beds, the impounded marshes of Merritt Island and the barrier island east of Mosquito Lagoon do not have a uniform floral species composition or species density (Snelson 1976). This partially is due to variations in salinity and water level resulting from differing degrees of isolation among the impoundments. At I1, the southern impoundment site, the marsh was broken by large expanses of water bordered by stands of black mangrove (Avicennia germinans): however, some white mangrove (Laguncularia racemosa) and button mangrove (Conocarpus erecta) were also present. The open waters were found to have seasonal growths of Chara which, in some locations, filled the water column.

Site I2, the northern impoundment canal, was located approximately 200 m from site S2. This canal formed by draglining, is nearly continuous around the periphery of Van's Island and is approximately 1.25 m deep and 15 to 20 m wide. During the dry season, it is the only standing water in the area sampled. The dominant vegetation was black mangrove with some button mangrove along the dike and occasional growths of Chara.

Methods

Samples of air and water temperature, salinity, depth, submerged macrophyte density and macrozooplankton were taken monthly at all four sites during the period August 1978 through August 1979. The same parameters also were sampled during July 1978 at sites I1, S1, and S2.

Physical Data

Maximum-minimum thermometers were submerged at sites I1, I2, and S2. Thermometers could not be left at site S1 because of vandalism. Readings were taken monthly and the thermometers were reset. Salinity samples were taken at mid-water depth and analyzed using a temperature-correcting optical refractometer. In November 1979, surface sediment samples were taken at I1 and S1 and the percentage of combustible material determined by ignition of dry samples in a 475°C. oven for 8 hours. Values for rainfall and average monthly air temperature were obtained from recordings taken by Patrick Air Force Base, 60 km south of Mosquito Lagoon.

Zooplankton

Three replicate 10-m-long tows were taken monthly at each site. The net had a 363 micron mesh, 0.3 m diameter and 1 m length. The contents of each tow were individually preserved in 5% buffered formalin. Beginning in October, samples broke down rapidly and are, therefore, underestimated in data from July through September 1978. The mesh size and tow length were expected to produce comparatively dilute plankton samples, but were considered adequate for making qualitative comparisons between the impoundments and seagrass beds.

During sorting and counting, specimens were identified at the most practicable taxonomic level. Dissolved rose bengal was used to stain plankton and improve sorting efficiency of flocculent samples.

Densities and similarities of zooplankton communities are compared. The community similarity index used was Czekanowski's Quantitative Index (Bray and Curtis 1957) which is applied to percent abundance data. The index ranges from zero (no similarity) to one (identical). Indices are calculated for all combinations of two sites. The intrahabitat comparisons (I1 vs I2; S1 vs S2) are then compared to the average of the interhabitat indices (I1 vs S1; I1 vs S2; I2 vs S1; I2 vs S2). Community distinctiveness is indicated when both intrahabitat indices are greater than the average interhabitat index.

Primary Production Processes

The above-ground standing crop of macrophytes from five randomly thrown 0.25 m quadrats was harvested each month. Samples were taken in waters 50 to 75 m from shore at sites S1 and S2, along the edge of the canal at I2 and 25 to 50 m from shore at I1. The harvest from each toss was returned to the lab where shell and detrital materials were rinsed off prior to drying to constant weight at 80°C. The yearly net primary production of seagrass at sites S1 and S2 was calculated as twice the maximum standing crop (McRoy and McMillan 1977), assuming 1 mg dry weight is equivalent to 16 joules.

Net primary production for site I1 was computed in two components: contribution of the algae Chara and litter fall from the mangroves, primarily standing crop (Rich et al. 1971); mangrove litter production was calculated after determining a leaf area for the mangroves during the summer of 1979. Leaf area was calculated using the modified plumb-bob technique used by Benedict (1976). The technique was applied at five random sites, with ten replicates per site. Production was then calculated using a ratio of leaf area index to litter production for Florida mangrove forests derived from Pool et al. (1974). Based on forest descriptions in Pool et al. (1974), leaf-turnovers per year were assumed to be 1.0 and the ratio of leaf litter to wood litter to be 3:1. Unfallen dead leaves were assumed to contain 20.17 J.mg⁻¹ (Heald 1969) and twig 17.86 J.mg⁻¹ (Golley 1961) on a dry weight basis.

The percentage of marsh covered by open water versus mangrove canopy was determined by planimetry (cut and weigh) of recent aerial photographs of the I1 sampling area. This provided a proration to use in computing total marsh production from Chara and mangrove production data.

At site I2, the impoundment canal, the input of detritus was considered to be a complex, seasonal interaction of water transports to and from the impoundment flats. Therefore, an estimate of net primary production available within the canal habitats would be premature, based on limited Chara and fringing production data.

Results

Physical Environment

Average values and ranges of temperature and salinity are shown in Tables 1 and 2. The range of annual absolute minimum and maximum temperatures (Table 1) found in the two impoundment sites, I1 and I2, and one seagrass bed, S2, were nearly identical. The average monthly temperature ranges at I2, however, were significantly smaller (Student's t , $p < 0.05$) than average monthly ranges for deeper water buffering rapid daily temperature fluctuations. Site I2 had narrower average monthly temperature ranges than site S2, but the difference was not statistically significant. Overall, water temperatures closely paralleled the average air temperature and the two were roughly equal during January, February and March. As discussed in the Methods section, water temperatures are not available for S1.

Significant differences were found in salinity averages. Salinity at site I1 was lower than at the other three sites (Student's t , $p < 0.01$). Site I2 had higher salinity than did S1 (Student's t , $p < 0.01$). Salinities at S1 and S2 were not significantly different. Greater water depth reduced salinity fluctuations at I2, as compared to the other three sites. The greater range of salinity at S1 versus S2 is believed to result from the isolation of the shallow portion of the lagoon where site S1 is located (Eddy Creek). This probably reduces mixing, causing more dilution of waters at S1 during periods of heavy rainfall. The most dramatic change in salinities, a drop of 20 ppt, at S1 from December to January, was due to heavy rains in late December and early January.

Two peak periods of rainfall were observed, winter and early summer. The influence of rain on salinity levels appears to depend on the season. During winter, when rates of evaporation were relatively low, salinity was markedly depressed by heavy rainfall and did not recover rapidly. However, during summer, a period of rapid evaporation, heavy rains did not depress salinities to the same degree, nor for as long. Therefore, seasonality and amount of rainfall markedly affected salinity levels and fluctuations in the shallow water system studied.

The percentage of combustible organic material in surface sediment at I1 was more than five times greater than at S1 (22.6 vs 3.9%). With sample sizes of 9 and 8, respectively, this difference is highly significant (Student's t , $p < 0.001$). Therefore, the yearly accumulation of detrital material is assumed to be much greater within the impoundment than in the shallow seagrass bed. Some of the detritus originating in the shallows may be transported from the seagrass beds and deposited in deeper waters in the lagoon. Thomas (1974) found amounts of organic carbon in the sediment of barrow pits and infrequently-dredged portions of the intracoastal waterway to be 2 to 3 times higher than the shallower seagrass beds. The percentage of net detrital production exported to deeper water storage in the open lagoon is not known.

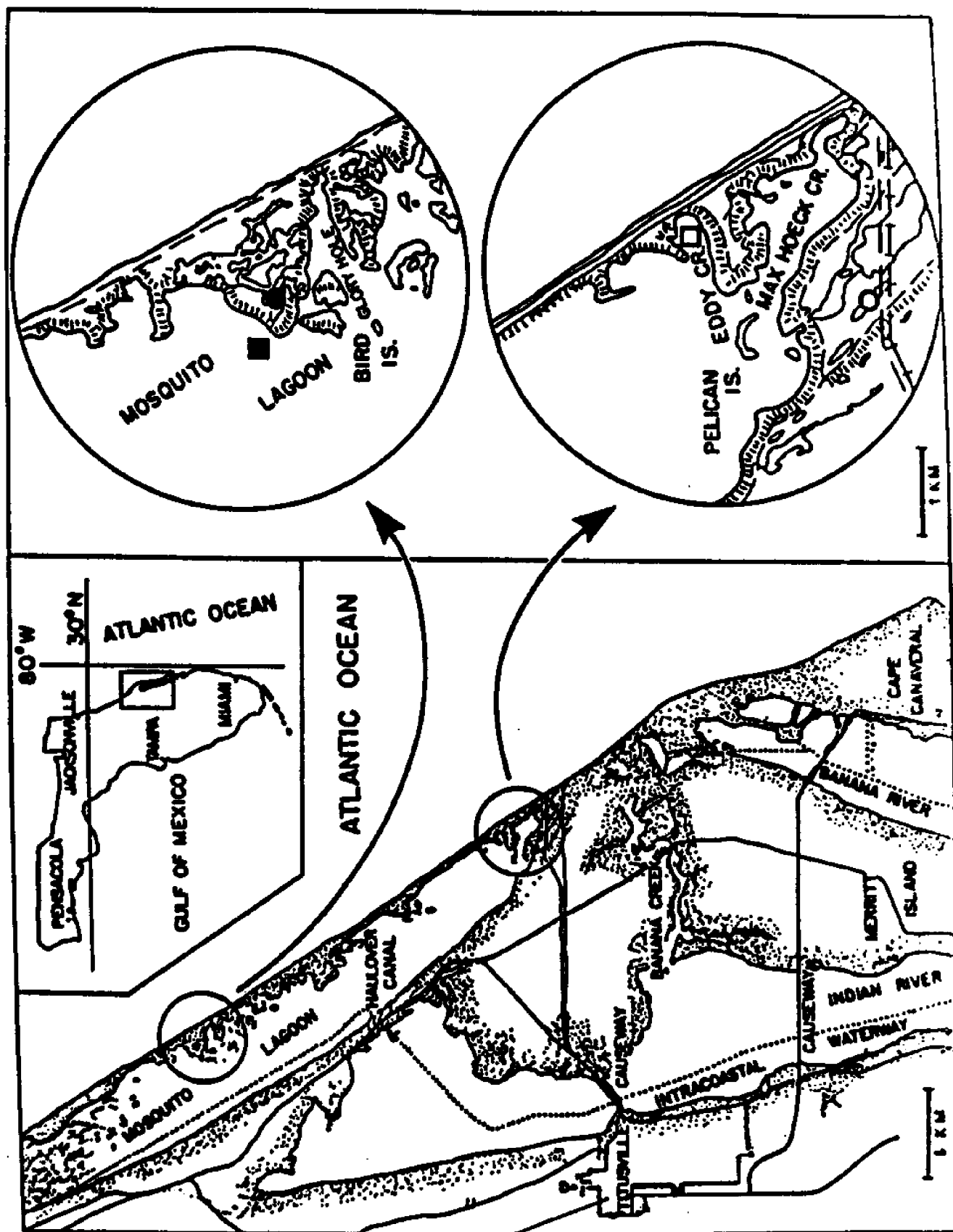


Figure 1. The northern Indian River and sampling locations; \square impoundment 1 (I1), \square impoundment 2 (I2), \square seagrass bed 1 (S1), \square seagrass bed 2 (S2).

Environmental Correlations

Table 3 shows correlations (Spearman Rank) of salinity, median water temperature and standing crops of seagrass (S1 and S2 only) to structural characteristics of fish community (Schooley 1980). The strongest correlations existed between fish standing crops and median water temperature, especially at sites I2 and S2.

Correlations of community structure to salinity show a contrasting pattern between the two impoundments. The number of fish species found at I1, the low salinity site, was positively correlated to salinity. Site I2 had much higher average salinities to which monthly numbers of fish species found were negatively correlated. Standing crop of energy had a significant ($p < 0.05$) positive correlation to salinity at I2, but almost no correlation at site I1. The seagrass beds had no significant correlations between fish community structure and salinity.

Sites S1 and S2 showed contrasting correlations between fish community structure and seagrass standing crop. Site S2 had significant ($p < 0.05$) positive correlations of species number and standing crop of energy to seagrass standing crop. The correlation of fish density to seagrass was highly positive, but not statistically significant at S2. In contrast, site S1 had very weak positive correlations of all three structural characteristics to seagrass standing crop.

Primary Production

Estimates of net primary production for three sites are presented in Tables 4 and 5. The ratio of mangrove production to Chara production within the impoundments was approximately 4:1. The ability to extrapolate from the estimates for I1 to the entire impounded marsh has not been demonstrated.

Zooplankton

Zooplankton collections (Tables 6, 7, 8 and 9) were divided by quarters based on seasonal rainfall and air temperature patterns (Tables 2 and 3). Quarterly averages resulted in a reduction of temporal variations in standing crops of zooplankton, causing sites to appear more similar. Since the zooplankton are used to interpret broad community differences, this reduction in information is not considered critical.

The impoundments were not significantly different from the seagrass beds in terms of zooplankton abundance. Densities varied greatly, but there was no pattern of both sites in one habitat having higher or lower densities than the two sites from the other habitat. The water column at site I1 was dominated by nematodes, except in midsummer when large swarms of calanoid copepods appeared. Also in midsummer, caridean shrimp and brachyuran larvae were reaching peak abundance at sites S2 and S1, respectively (Table 9). Site I2 was characterized by the sharp seasonality of calanoid copepods; densities peaked in

spring (Table 8) and dropped dramatically by midsummer (Table 9). In general, midsummer was a period of very low plankton standing crop at I2 relative to the other sites.

Quantitative comparisons of community structure did not show distinctiveness between seagrass and impoundment zooplankton communities when all taxa are included in the analysis (Table 10). Many of the taxonomic groups include benthic organisms that become suspended in shallow waters by wind-mixing. A similarity calculation was done excluding nematodes, numerically dominant in the plankton samples and abundant in the benthic meiofauna (Schooley unpublished data). When nematodes were excluded, winter (December - February) and spring (March - May) showed higher intra- than interhabitat similarity (Table 10). In winter, high similarity between the seagrass sites was largely due to caridean shrimp. In spring, both impoundments had high fractions of calanoid copepods.

The seagrass sites were distinguished somewhat from the impoundment sites by the greater densities of caridean shrimp and brachyuran larvae and were distinguished between themselves on the seasonality of these taxa. Caridean shrimp densities peaked at S1 during winter and spring and at S2 in midsummer. Brachyuran larvae were much denser at S1 than any other site; densities peaked at S1 and S2 in midsummer. Sites S1 and S2 were distinguished by consistent chaetognath populations.

Overall, spring was the period of peak plankton densities for both impoundments. Densities in one seagrass bed peaked in spring and the other in midsummer.

Discussion

Abiotic Factors

The controlling physical factor within the systems studied was the variation in solar radiation. This variation produced a dynamic balance among the influences of direct solar heating, evaporation and precipitation in generating the daily physical-chemical characteristics of the aquatic habitats studied. During winter, temperature depression was correlated with reductions in structure and function of fish communities.

In the seagrass beds Jones et al. (1975) suggested a two-season pattern for the resident fishes. During the warm/wet season they hypothesized an inverse relationship between rainfall, which led to lower salinities, and the number of species occupying the seagrass beds. Also hypothesized was that during the cold/dry season, even though rainfall was decreasing and salinity rising, the drop in water temperature resulted in a further decline in the number of fish species. Schooley (1977) demonstrated a bimodality in fish density and diversity in the shallow water habitats of the northern Indian River and Mosquito Lagoon. Because of their shallowness, these habitats may experience appreciable thermal stress at midsummer and midwinter, affecting residents and seasonal recruits. The seagrass beds had slight late-summer depressions in density followed by higher levels in fall.

At I2, the correlations of salinity and temperature to fish community structural characteristics were unclear due to the influence of marsh morphology. Small changes in water level can have vast surface area effects within impounded marshes (Snelson 1976). With heavy rainfall, total marsh area may increase dramatically during the cooler months, as at I2 in January. Therefore, subsequent density measurements are lowered as a function of the proximity of newly covered marsh for dispersal of the standing crop. Similarly, during the warmer, dry months, densities would increase as water evaporated from these shallows. This could lead to a positive correlation of standing crop to salinity. This theory may explain the correlations at I2, but density was not significantly correlated to mid-channel depth at this site. The significance of this shift in ecological density at I2 remains to be investigated. Similar phenomena were not believed significant at the other three sites.

Day et al. (1973) found temporal patterns in a Louisiana salt marsh and shallow estuarine system to be controlled by temperature, as did Adams (1976a) in a North Carolina Zostera bed. Subrahmanyam and Drake (1975) found no correlation of abundance (numerical or biomass) to seasonal temperatures or salinities in two north Florida salt marshes. However, several taxa did show significant correlations to either temperature or salinity.

Seasonal succession in recruitment of juveniles of several species found in earlier studies of seagrass beds (Jones et al. 1975, Schooley 1977) was observed. A similar recruitment sequence, expected in a marsh (Subrahmanyam and Drake 1975), did not occur in these impounded marshes. Some minor recruitment may occur at pumping stations (Jack Salmela, personal communication) when impoundment water levels are maintained with water from the open lagoon.

Snelson (1976) concluded that the major factors controlling spatial distribution of fishes in permanent impoundments were salinity and vegetative cover. Salinity and vegetative cover differed between the two impoundment sites studied; however, salinity differences between I1 and I2 would not appear to be significant physiologically to the dominant atheriniform fishes. Snelson (1976) and Gilmore et al. (1982) characterized the impoundments of the Indian River area as stressed environments to which only a small group of species are adapted. During this study, the impoundment sites did not appear any more "stressed", in terms of fluctuations of salinity or temperature, than did the shallow seagrass beds. However, due to the closed nature of the habitat, species in impoundments do not have a temperature and/or salinity refugium to which they can retreat when conditions become too stressful. Thus, it appears that factors other than environmental fluctuations, such as degree of potential recruitment and flushing of detritus, may be important to understanding differences between marsh and seagrass fish communities.

Biotic Factors

According to Clark (1975), the most important biotic factor controlling communities in Indian River seagrass beds is seasonal change in macrophyte standing crop. In spring and early summer, seagrass beds provide greater habitat complexity and strongly influence the physical, chemical and biological processes of the entire system. In fall the seagrass beds, often carpeted with diatoms, die-back, producing vast amounts of detritus resulting in a pulse of organic carbon into the sediment about six weeks later (Clark 1975). This seasonal pulse affect appears to be characteristic of seagrassbed based ecosystems (Phillips 1960, Odum 1967 and Phillips 1974).

Pulsing of detrital input was not observed in the impoundments. Pool et al. (1974) reported increased leaf-fall in the rainy season in mangrove forests of south Florida. If this is true for impoundment mangroves in the Mosquito Lagoon area, maximum leaf-fall, on average, would occur in June, July and August. The maximum standing crops of Chara occurred in December and September at site I1 and I5, respectively. Based on this limited information, but not synchronously. Mangrove litter is assumed to produce a late-summer pulse of fine detrital particles; winter die-backs of Chara, conversely, would produce a spring pulse in utilizable organic material as temperature increases speed up bacterial and meiofaunal detrital processing.

The amount of detritus produced in the impoundments appears to be greater than in the seagrass beds. Unfortunately, with complete data from only one impoundment, the significance of the difference found is not known. Chara, which was found in dense patches in various portions of the impoundments, contributed only twenty percent of estimated net production. The productivity estimate for the impoundment mangroves at site I1 ($0.47 \text{ g.m}^{-2}.\text{d}^{-1}$) is approximately the same level as those for mangrove scrub forests at Turkey Point in southeast Florida (Pool et al. 1974). This forest is about twenty-five percent as productive as basin forests of southern Florida, which have greater freshwater turnover than scrub mangrove forests.

Annual net production in the seagrass beds averaged $3,060 \text{ kJ.m}^{-2}.\text{y}^{-1}$ for sites S1 and S2. By comparison, using estimates of above ground monthly standing crop for other seagrass beds in the Indian River (Clark 1975; Eisman et al. 1976) and performing the same calculations and conversions, averages of annual net seagrass production of $1,273$ and $3,065 \text{ kJ.m}^{-2}.\text{y}^{-1}$ were derived. Red and brown algae, which were not significant in the shallow grassbeds at S1 and S2, did contribute to production in the deeper sites studied by Clark (1975) and Eisman et al. (1976). Maximum minus minimum standing crop was used as an estimate of net production of algae (Steve Davis, personal communication). Net production was converted to joules based on average calorimetry values of phaeophytes and rhodophytes of 12.79 and 13.27 J.mg^{-1} dry wt. respectively (Cummins and Wuycheck 1971). This would add $279 \text{ kJ.m}^{-2}.\text{y}^{-1}$ due to red algae production to the $1,273 \text{ kJ.m}^{-2}.\text{y}^{-1}$ produced by seagrass in the area studied by Clark (1975). Red algae are estimated to produce $783 \text{ kJ.m}^{-2}.\text{y}^{-1}$ and brown algae $224 \text{ kJ.m}^{-2}.\text{y}^{-1}$ for a total of $1,007 \text{ kJ.m}^{-2}.\text{y}^{-1}$ in the grassbeds studied by Eisman et al. (1976). In these two cases, estimates of net seagrass production were 3 to 4.5 times that estimated for macroalgae production.

The Seagrass beds of this system are on the low end of the range of annual production for seagrass-based ecosystems. Assuming 1 gC is equivalent to 42 kJ , production estimates in $\text{kJ.m}^{-2}.\text{y}^{-1}$ for Zostera beds were $8,943$ and $5,280$ in North Carolina (Adams 1976b), $24,528$ in Puget Sound (Phillips 1974) and, for a Thalassia bed in the Caribbean, up to $122,640$ (Thayer et al. 1975).

Clark (1975) gave four nonexclusive hypotheses for reduced production within seagrass beds for Mosquito Lagoon and the northern Indian River. They were:

1. lack of appreciable currents, leading to localized depletion of nutrients;
2. nutrient limitation due to sediment characteristics (i.e. coarse sediments with less surface area for microbial regeneration of nutrients);

3. seagrass intolerance to low temperatures at the northern limit of their range; and
4. carbonate limitation.

Production in both the impoundments and seagrass beds is very low relative to similar systems. The reduced circulation in mangrove impoundments such as 11 is believed to be partially responsible for lowered mangrove production. The frequency and duration of winter freezes also may be a significant factor.

Conclusion

The dramatic differences between the seagrass and impoundment fish communities (Schooley 1980) do not appear to result from differences in salinity, water temperature, macrophyte production or zooplankton abundance observed during this study. These factors may control the structure of fish communities through infrequent but dramatic changes (i.e. freezes, droughts, hurricanes) which might influence one habitat more than the other. But, they do not explain the large functional differences between the two habitats, especially the higher (14 to 21 times) fish production in the impoundments (Schooley 1980). To explain these functional differences, we should focus attention on the impact of primary production from epiphytes, microalgae and plankton; structure of the benthic invertebrate community and trophic dynamics of fish in each habitat.

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Table 1. Median water temperatures and average monthly air temperatures during the sampling period; absolute minimum, absolute maximum and temperature ranges from submerged maximum/ minimum mercury thermometers.

Year & Month	Water Temp (°C)			Air Temp (°C)
	I1	I2	S2	Cape Canaveral
1978				
August	----	----	31.5	25.6
September	31.0	31.0	31.0	25.0
October	26.0	30.0	24.0	22.0
November	23.0	23.0	22.5	22.0
December	21.5	22.5	20.4	17.0
1979				
January	15.0	15.0	----	15.0
February	16.4	16.8	17.5	15.0
March	18.5	19.3	18.5	18.0
April	24.0	25.5	24.5	22.8
May	27.5	27.0	----	23.9
June	29.0	31.5	29.0	26.7
July	20.5	33.0	----	28.3
August	31.0	31.3	----	27.2
Absolute minimum	6.0	8.0	8.0	
Absolute maximum	39.0	37.5	39.0	
Maximum monthly range width	17.5	15.5	19.0	
Average monthly range width	14.7	10.8	15.3	

Table 2. Salinity at each site and total rainfall at Cape Canaveral.

Year & Month	Salinity (ppt)				Rainfall (mm)
	I1	I2	S1	S2	Cape Canaveral
1978 August	14	38	35	38	32
September	16	38	32	36	88
October	17	36	38	36	56
November	20	36	34	34	16
December	28	38	38	38	103
1979 January	10	28	18	25	178
February	12	32	20	33	32
March	13	32	22	34	39
April	18	34	--	38	19
May	15	32	24	30	142
June	20	35	32	35	116
July	18	34	35	34	85
August	16	36	36	37	228
Mean (8/78-9/79)	16	34	30	34	
Range	10-28	28-38	18-38	25-38	

Table 3. Correlations (Spearman Rank) of structural characteristics of the fish communities found by Schooley (1980) with monthly salinity, median water temperature and seagrass density (S1 and S2 only); * = ($p < 0.05$); ** = ($p < 0.01$); N = 12.

Site	Structural Characteristics	Salinity	Median Water Temperatures	Seagrass Density
	Number of Fish Species	0.53	0.65*	
I1	Fish Density	-0.02	0.40	
	Fish Standing Crop-Energy	0.07	0.52	
	Number of Fish Species	-0.40	-0.48	
I2	Fish Density	0.32	0.70**	
	Fish Standing Crop-Energy	0.58*	0.83**	
	Number of Fish Species	0.36	0.32	0.11
S1	Fish Density	-0.33	0.33	0.04
	Fish Standing Crop-Energy	0.27	0.59**	0.24
	Number of Fish Species	0.20	0.49	0.68*
S2	Fish Density	0.15	0.68*	0.45
	Fish Standing Crop-Energy	0.32	0.72**	0.68*

Table 4. Net primary production entering the aquatic system at site I1; units given for each value, numbers in parentheses are one standard error, N = sample size.

Site I1

Mangrove

Leaf area index	1.66 (0.47), N = 50
Leaf weight/leaf area (g/m^2)	180 (51), N = 10
Net production as litter into the aquatic system ($\text{kJ}\cdot\text{m}^{-2}\cdot\text{y}^{-1}$)	7463
Percentage of marsh covered by mangroves	46%
Net Production ($\text{kJ}\cdot\text{m}^{-2}\cdot\text{y}^{-1}$)	3433

Chara

Maximum standing crop (g/m^2)	63.98 (51.66), N = 5
Minimum standing crop (g/m^2)	0.0, N = 5
Net production in open water ($\text{kJ}\cdot\text{m}^{-2}\cdot\text{y}^{-1}$)	1648 (1331)
Percentage of open water	53%
Net Production ($\text{kJ}\cdot\text{m}^{-2}\cdot\text{y}^{-1}$)	873 (705)
Total marsh net production ($\text{kJ}\cdot\text{m}^{-2}\cdot\text{y}^{-1}$)	4306

Table 5. Net primary production and standing crops of seagrasses at sites S1 and S2; numbers in parentheses are one standard error, N = sample size.

	S1	S2
Maximum standing crop (g/m ²)	75.83 (24.37), N = 5	116.5 (20.14) N = 5
Minimum Standing crop (g/m ²)	12.11 (4.4), N = 5	8.74 (6.34), N = 5
Net Production (kJ.m ⁻² .y ⁻¹)	2413 (387)	3707 (320)

Table 6. Mean standing crop of zooplankton (number per cubic meter), September to November 1978 at each sampling site.

Taxa	I1	I2	S1	S2
Cnidarians	----	1.6	0.2	1.0
Nematodes	21.0	0.8	0.5	2.8
Polychaetes	0.3	0.6	0.8	0.3
Gastropods	2.0	0.2	---	---
Bivalves	0.2	---	---	0.6
Ostracods	12.0	0.2	0.2	2.7
Copepod larvae	----	---	0.7	---
Calanoid copepods	01.0	1.0	1.7	5.6
Cyclopoid copepods	----	---	0.2	0.3
Harpacticoid copepods	----	0.2	1.0	1.0
Cypris larvae	----	---	0.2	---
Mysids	----	---	0.2	---
Amphipods	0.5	---	---	---
Caridean shrimp	1.2	0.4	2.0	15.1
Brachyuran larvae	0.2	0.2	1.0	1.0
Larvaceans	----	---	3.3	---
Chaetognaths	----	0.2	0.2	2.1
Other taxa	1.6	---	0.8	0.7
Total	40.0	5.1	12.3	33.2

Table 7. Mean standing crop of zooplankton (number per cubic meter), December 1978 to February 1979 at each sampling site.

Taxa	I1	I2	S1	S2
Cnidarians	---	---	---	0.6
Ctenophores	---	---	0.1	1.9
Nematodes	183.0	6.1	25.5	13.0
Polychaetes	0.2	2.7	1.0	1.0
Gastropods	1.4	---	---	---
Bivalves	---	---	1.1	0.7
Ostracods	1.6	0.2	8.8	3.5
Calanoid copepods	4.6	85.0	8.8	9.1
Cyclopoid copepods	1.2	0.3	2.1	0.4
Harpacticoid copepods	2.4	1.9	1.7	1.0
Cypris larvae	---	---	---	0.1
Mysids	---	---	0.7	---
Cumaceans	---	0.2	0.3	0.3
Isopods	0.2	0.2	3.9	5.7
Amphipods	---	2.4	3.9	1.1
Caridean shrimp	0.4	1.1	73.4	33.9
Brachyuran larvae	---	---	0.5	0.1
Pycnogonids	---	---	0.1	0.1
Hemipteran exoskeleton	0.4	4.0	---	0.7
Mosquito larvae	---	2.2	---	---
Chaetognaths	---	---	0.7	1.0
Fish eggs	---	1.3	0.1	---
Fish larvae	---	0.8	1.0	0.3
Other taxa	3.0	0.1	0.1	0.4
Total	<u>197.9</u>	<u>107.6</u>	<u>134.0</u>	<u>74.0</u>

Table 8. Mean standing crop of zooplankton (number per cubic meter),
March to May 1979 at each sampling site.

Taxa	I1	I2	S1	S2
Cnidarians	1.1	2.8	---	0.6
Ctenophores	---	---	0.01	15.7
Nematodes	282.3	15.7	17.6	34.0
Polychaetes	1.4	1.4	0.6	1.1
Gastropods	0.3	0.6	0.2	5.7
Bivalves	---	0.2	1.1	0.8
Ostracods	1.1	0.8	4.6	1.9
Copepod larvae	1.0	---	---	---
Calanoid copepods	37.1	152.8	56.4	2.7
Cyclopoid copepods	5.0	0.3	---	---
Harpacticoid	6.4	1.7	0.9	3.5
Isopods	---	0.3	0.5	1.4
Amphipods	0.6	0.6	0.6	1.1
Caridean shrimp	3.0	3.3	51.9	25.8
Brachyuran larvae	0.3	1.9	43.7	2.4
Chaetognaths	---	---	3.9	0.2
Fish eggs	---	---	0.2	---
Fish larvae	---	0.2	1.7	0.6
Other taxa	0.3	1.9	0.2	0.8
Total	339.9	184.5	184.4	98.3

Table 9. Mean standing crop of zooplankton (number per cubic meter), June to August 1979 at each sampling site.

Taxa	I1	I2	S1	S2
Cnidarians	---	---	0.3	2.7
Ctenophores	---	---	9.1	0.2
Nematodes	48.4	4.7	21.2	27.8
Polychaetes	---	---	0.9	2.0
Gastropods	---	---	1.4	1.7
Ostracods	1.3	---	4.6	3.0
Copepod larvae	0.8	---	0.2	0.2
Calanoid copepods	127.8	8.6	16.5	133.6
Cyclopoid copepods	1.1	---	0.8	0.5
Harpacticoid copepods	2.4	0.5	4.1	9.9
Isopods	---	---	1.6	7.5
Amphipods	0.2	0.3	---	1.3
Caridean shrimp	3.5	0.2	14.8	64.6
Brachyuran larvae	3.3	4.7	69.3	4.1
Hemipteran exoskeletons	---	1.1	---	---
Chaetognaths	---	---	0.5	3.8
Fish eggs	---	---	12.3	---
Fish larvae	---	---	1.1	0.9
Other taxa	0.03	0.4	1.1	1.8
Total	188.7	20.5	159.8	265.3

Table 10. Seasonal comparisons of percent similarity of zooplankton communities.

Year & Month	Salinity (ppt)				Rainfall (mm)	
	I1	I2	S1	S2	Cape	Canaveral
1978 August	14	38	35	38		32
September	16	38	32	36		88
October	17	36	38	36		56
November	20	36	34	34		16
December	28	38	38	38		103
1979 January	10	28	18	25		178
February	12	32	20	33		32
March	13	32	22	34		39
April	18	34	--	38		19
May	15	32	24	30		142
June	20	35	32	35		116
July	18	34	35	34		85
August	16	36	36	37		228
Mean (8/78 - 9/79)	16	34	30	34		
Range	10-28	28-38	18-38	25-38		

THE SOCIOECONOMIC IMPACT OF KINGS BAY NAVAL BASE
ON THE COMMERCIAL AND NONCOMMERCIAL FISHERIES
OF CAMDEN COUNTY, GEORGIA

Mary Margaret Overbey

Analyzing the impact of large-scale development projects on coastal communities entails consideration of the productivity of the local environment, the human use patterns of exploiting local resources, and the adverse effects of the construction, operation and incoming population on these activities. This case study examines the impact of a newly constructed nuclear submarine base on a rural, coastal community -- Camden County, Georgia. In this situation, the dependence of Camden County residents on a productive estuary competes with the national security needs of the United States Navy to utilize the estuary for submarine traffic.

This paper addresses some of the adverse impacts of base construction, operation and the associated influx of naval personnel on the productivity of the estuary on which commercial and noncommercial fishermen rely. The paper is based on research results gathered through field research conducted from 1979 through 1980 and literature research. Field research entailed residence and participant observation by the author of base development and community life in Camden County for 13 months. Research methods included formal interviews with a systematic sample of community residents, formal interviews with a sample of naval personnel, informal interviews with both community residents and naval personnel, tape recorded life histories of selected community residents, and historical literature research. The Department of the Navy's own environmental impact assessments of the biological impacts of base development on the provide the context for analyzing the impact of base development on the biological productivity of the estuary. The research on which this paper is based was funded by the National Science Foundation and Florida Sea Grant.

As a requirement of the National Environmental Policy Act (NEPA) of 1969, environmental impact assessments were conducted by the Navy in 1976 for the initial phase of base development (Department of the Navy 1977 a, b) and in 1979 for expansion of the base to accommodate the Trident nuclear submarines (Department of the Navy 1980 a, b).

While environmental impact assessments are required by NEPA to address the social and economic consequences of development, they typically consider the economic consequences, in terms of demographics or revenues, more fully than the social consequences

Department of Anthropology, University of Florida, Gainesville, Florida.

(Finsterbusch 1980; Little 1977; West 1975). The environmental impact assessments conducted by the Navy exemplify this tendency. Furthermore, Navy's environmental impact assessments concentrate on the economic impact of base development on a seven-county region, the "Kings Bay Region", and neglect the social and economic consequences of base development on the primary impact community, Camden County.

Camden County, located on the coastal strand of southeastern Georgia, is bounded on the east by the Atlantic Ocean, on the south by the St. Marys River, and on the north by the Little Satilla River (Figure 1.). The Navy is developing the base at Kings Bay, located eight miles up the Cumberland Sound from the St. Marys Entrance, the main access point to the Atlantic (Figure 2.). Initially designed to accommodate a fleet of Poseidon submarines originally based in Rota, Spain, the base is being further developed to provide a strategic east coast site for the deployment of the Trident nuclear submarines. Kings Bay will be the east coast counterpart to the Trident base in Bangor, Washington.

Development of the base entailed the immediate placement of 4,300 naval personnel and their dependents in Camden County from 1979 to 1981, the population associated with the operation of the Poseidon submarine fleet. The Navy refers to this phase of development as the T-1 phase. Plans further include development of the base for the Trident nuclear submarine complex. Between 1982 and 1998, an additional 25,000 naval personnel and dependents are expected to relocate at Kings Bay. The Navy refers to this phase of development as A-1.

The initial incoming population of 4,300 naval personnel and dependents is greater than any of the existing towns in the county and will increase the original county population by 34 percent. The projected additional population of 25,000 required for the A-1 phase will increase the original county population by over 200 percent. By any definition, the impact is one of boom town proportions.

Camden County and the Barrier Island Region

A suitable regional definition for the area surrounding Camden County is one based on a common economic base and shared geographical, historical, and social characteristics. This region, termed the Barrier Island Region (Overbey 1982), includes the coastal area from Fernandina, Florida, to Charleston, South Carolina. The most striking feature of the region is the chain of barrier islands that separate the mainland from the Atlantic Ocean and allow the development of an extensive marsh estuary.

The existence of barrier islands precludes the development of beaches on the mainland, limiting the resort potential of these areas. The mainland areas have, for the most part, remained poor and rural. Fernandina, Brunswick, Savannah and

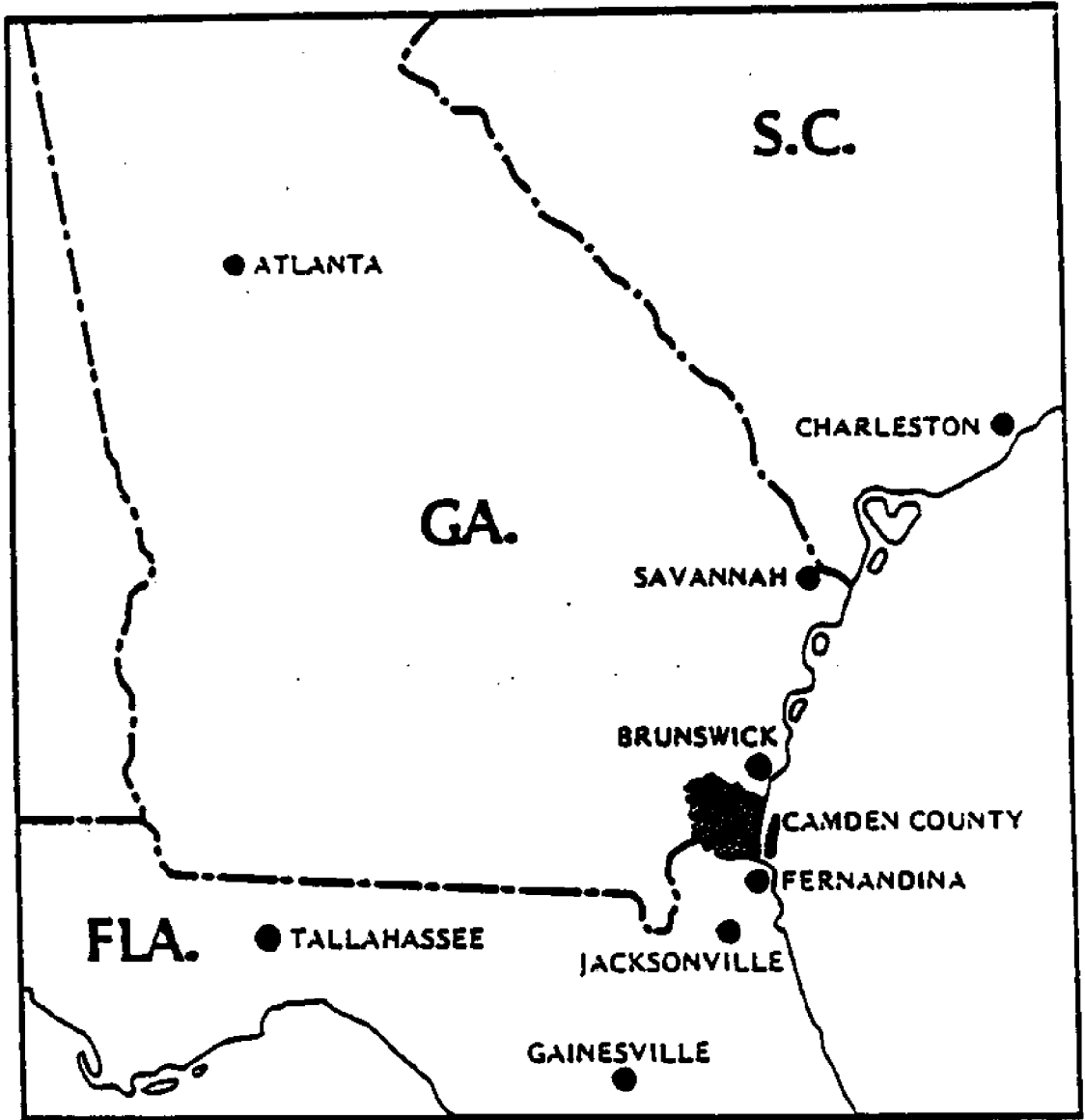


Figure 1. Location map of Camden County, Georgia

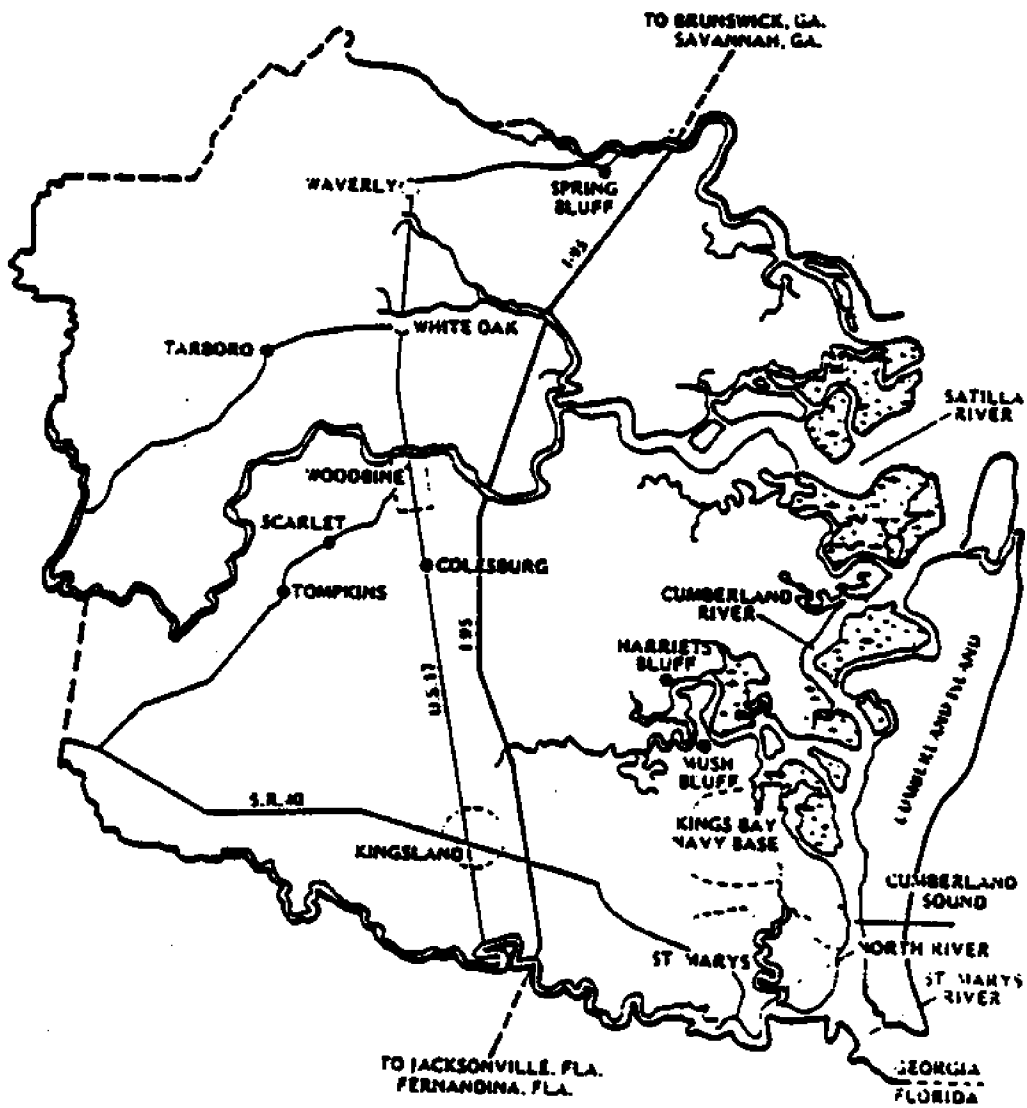


Figure 2. Map of Camden County showing the principal towns, Kings Bay Naval Base, and the Cumberland Sound estuary

Charleston are the only significant cities and these are associated with the developed resort islands of Amelia, St. Simons, Jekyll and Hilton Head. The barrier islands themselves have historically been controlled by a few large landholders since the late 1700s. Throughout the 1800-1900s, entire islands were owned by wealthy families. Cumberland Island, the barrier island situated off the Camden County mainland, was owned by Nathaniel Greene in the 1800s and was later purchased by the industrialist Andrew Carnegie in 1881.

In the 20th century, the barrier islands that had been controlled by single-family estates were gradually transferred to state or federal control. There were exceptions to this pattern, for example, on St. Simons Island, the large estates were dismantled during Reconstruction. The island was divided into smaller holdings which were more easily acquired by post-World War II developers.

Also diagnostic of the Barrier Island Region is a common economic base. The forest industries, with associated pulp and paper mills, dominate the regional economy. In the mainland towns of Fernandina, St. Marys, Brunswick, Savannah and Charleston, there are one or more paper mills situated on adjacent rivers. The pulpwood and paper mill operations provide the majority of industrial employment in the Barrier Island Region. In Camden County, for instance, the Gilman Paper Company as of 1978 employed 70 percent of the county work force (CAPDC 1978: 6).

The second traditional source of employment in the region is the fishing industry. The primary fisheries are shrimp, crab and finfish. Fishing firms tend to be family-owned, particularly in the smaller towns. Fishing is pursued by both blacks and whites, and is the preferred employment by those who value the independence of self-employment. For commercial fisherman in the Barrier Island Region, fishing is synonymous with shrimping. The increasing value of shrimp on the market since 1920 has induced most commercial fishermen to pursue shrimp exclusively. This has resulted in a lack of diversity for coastal fishermen.

The rural nature of the Barrier Island Region reveals similar social characteristics. The church is the most important social institution, with residents' social activities revolving around church-related functions. Residents are strongly oriented to marriage and family. Extensive kinship ties among the residents impart a highly personalistic atmosphere to community life in the region.

The final characteristic defining the Barrier Island Region is historical. This was the "debtful land", contested by Spain and Britain throughout the late 1600s and early 1700s (Bolton and Ross 1968). The strategic significance of the region was evident from the beginning of Spanish and British colonization and continues to the present. The area figured prominently in military campaigns in the American Revolution and the Civil War.

Today the region is the site of the U.S. Navy installations at Charleston, St. Marys and Jacksonville, and a U.S. Army base near Savannah. During the past several decades, other military installations were established in the region including a World War II pilot training base at Harris Neck in McIntosh County, Georgia; a naval air station at Brunswick in the 1960s; and an Army loading dock facility at Kings Bay during the 1950s. (Overbey 1982).

Land Use Patterns

The low-lying coastal region is marked by an extensive salt marsh system and is cross-cut by rivers, inlets and estuaries that provide a productive environment for commercial and noncommercial finfish and shellfish species. "Estuary" by definition refers to "...a semi-enclosed coastal body of water having a free connection with the open sea and within which the sea water is measurably diluted with fresh water deriving from land drainage." (Smith 1964: vii). The "estuarine zone" refers to those transitional areas surrounding the estuary. Along the Barrier Island Region, the estuarine zone encompasses that area of the waters lying between the barrier islands and the mainland. For Camden County, "estuary" will refer to the estuarine zone and be termed the Cumberland Sound estuarine complex.

In Camden County, the estuary and associated wetlands comprise 19 percent of the county's land area. Only 15 percent of the county is developed, and, as of 1979, Camden County's population of 12,500 resided here among three small towns and the rural area. The remaining 56 percent of the land area is controlled by private industry and state and federal agencies. Forty-four percent of the 56 percent is owned by five pulp and paper companies, and 12 percent is held by the Department of Defense (Department of the Navy), the Department of the Interior (National Park Service), and the State of Georgia (Figure 3.). As a result, the residents of Camden County have little control over local land use and are limited in their ability to initiate development.

The economic activities on the Cumberland Sound estuarine complex, and therefore particularly susceptible to disruption by base development, are the commercial and noncommercial fisheries of Camden County. The estuary is a fertile, productive system that supports and spawns a chain of marine life that is vital to the commercial and noncommercial fisheries (Johnson et al. 1974). "At least 65 percent of our nation's commercial fish and shellfish and marine sport species inhabit the estuarine environment during all or part of their life cycle" (Smith 1964: vii). The estuary and associated marine life maintain a delicate balance which can be upset by dredging, dredge spoil disposal, oil spills and other pollutants (Georgia Department of Natural Resources 1975) as well as overexploitation by incoming populations--all impacts associated with naval base development of Kings Bay (Overbey 1982).

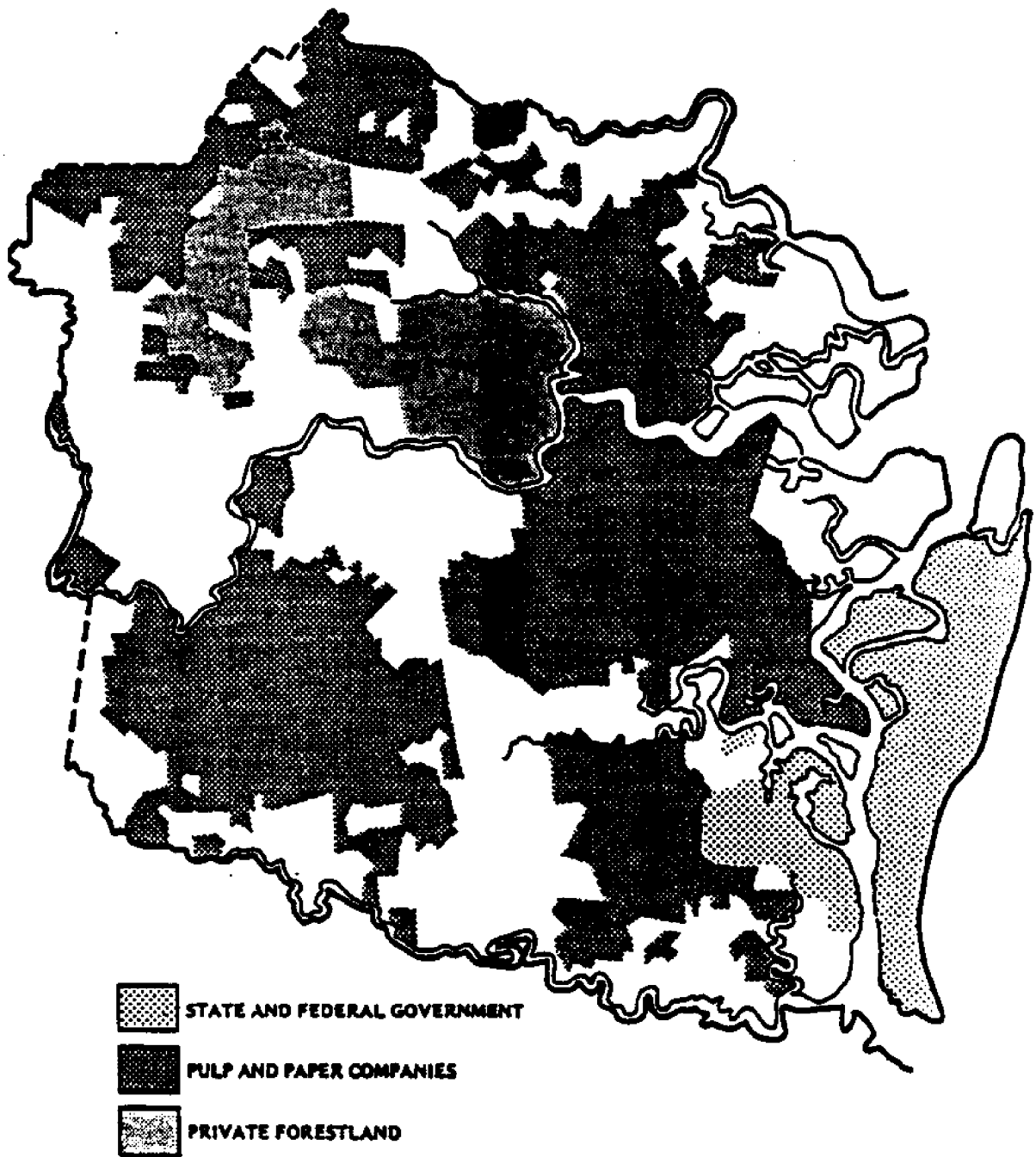


Figure 3. Land ownership map indicating the limited extent of land available for immediate development. Not illustrated is the amount of freshwater swamps. Adapted from Kings Bay Steering Committee (1979: Map 5).

Commercial Fishing

Commercial fishing along the Georgia coast is dominated by the pursuit of shrimp. While the fishery includes the harvesting of blue crab as well as finfish such as shad, whiting, flounder, grouper, spot, seabass, seatrout, red snapper, and croaker, these species are considered incidental to shrimp. The dependence on shrimp is influenced by the value it yields. For instance, in 1978 shrimp comprised only 33 percent of the total landings but accounted for 81 percent of the total value (Department of Commerce 1978).

This emphasis on shrimp is also evident in Camden County. One shrimper, for instance, referred to finfish and some crab that are brought up with the shrimp in the nets as "trash fish", inedible species that are considered to be of little or no economic value. These trash fish include small croaker, weakfish, and some crab. Landings of shrimp in Camden County in 1979 comprised only 36 percent of the total pounds, but accounted for 86 percent of the total value (Department of Commerce 1979).

Commercial fishing in Camden County can be described as a small-scale fishing activity. Work units are small; boats are less than 80 feet; fishing is usually pursued in inshore waters and trips last less than a week; harbors are small; boats are owned individually or jointly; fishermen feel attached to their community; and much of the fishing venture is based on family relations and personal ties (Baks and Postel-Coster 1977: 24). The fishing industry in Camden County consists of family-based firms with docking and packaging facilities located on the St. Marys River in downtown St. Marys and the Satilla River in Woodbine, as well as a number of independent shrimpers who own their own boats and often use these local docks. In 1979, commercial shrimp boats numbered 47 and commercial shrimpers numbered 134 (Department of Commerce 1979).

Camden County shrimpers are well integrated into the community and are not the marginal individuals depicted by many maritime studies (Smith 1977). The close ties that shrimpers maintain with their community are evident in their preference for short-term shrimping trips and their involvement in community activities. One black shrimper also was a pastor of the Church of God. Another shrimper was elected city councilman in St. Marys, and his son, also a shrimper, was elected mayor of St. Marys. Interviews with community residents and observation by the author suggest a reason for the relatively high standing of shrimpers in the community: they exemplify the community ideals of independence, hard work and self-sufficiency (Overbey 1982).

Noncommercial Fishing

The lifestyle of local residents reflects the rural and coastal nature of Camden County. Common outdoor activities

include fishing, hunting and gardening. Field investigation revealed the significance of these activities. The pervasiveness of fishing, hunting and gardening was first indicated by the presence of freezers in almost every household for storing fish, meat, fruits and vegetables. Interviews with a systematic sample of county households in the summers of 1979 and 1980 revealed the nature and extent of these activities as well as the impact of base development on these activities during the first year of base operations. Of concern here is the fishing activity.

Analysis of the interview data from the 1979 survey reveals that 68 percent of the residents fish; and of those, 97 percent fish in salt water, 57 percent in fresh water, and 53 percent in salt and fresh water. As expected in an estuarine system, the distinction between salt water fishing and fresh water fishing is somewhat blurred. Thus the salt and fresh water category was a common response.

Species most commonly caught are shrimp, mullet and crab. The most common techniques employed are cast nets and crab traps or pots. Some species such as seatrout are caught by hook and line.

Ninety-four percent of the fishermen fish within the county. Popular fishing areas include the Satilla, Crooked and St. Marys Rivers, Cumberland Sound, and the south jetties of Cumberland Island. Kings Bay, now closed to fishing for local residents, was formerly a favorite fishing spot.

The majority of residents fish for home consumption. Ninety-seven percent of the fishermen eat their catch or share it with others. Surplus fish are distributed directly to relatives, friends and "those in need". Large catches are often shared with friends through fish fries.

The intensity of fishing by residents is revealed by the amount of time expended in its pursuit. Forty-one percent of the fishermen fish at least every two weeks or more often. Twenty-four percent fish once a month, and 27 percent fish between once a year and four times a year.

The noncommercial fishing activity of Camden County residents appear to be a supplemental subsistence activity rather than merely a recreational activity. Fishing is pursued for the purpose of obtaining food for home consumption and excess fish is shared with other households so that there is no waste. Since fishing does not constitute the sole source of a household's income, it is a supplemental subsistence activity that supplements the income and diet needs of the household.

There is an historic precedent to pursuing the activities of fishing, hunting and gardening to supplement the household diet and income. One elderly resident of St. Marys recalled that traditionally each household in town raised its own vegetables,

kept its own chickens for meat and eggs, cows for milk, and pigs for pork. Photographs taken in the early 1900s and presently available at the Georgia Department of Archive and history depict cows and chickens racing freely in the streets of St. Marys (Overbey 1982) When the economy was depressed, households would exchange items or sell excess foodstuffs. In the early 1900s, this resident harvested and sold oysters for 10 cents a quart or 5 to 6 cents a pint, and made cast nets to catch shrimp to sell for 10 cents a quart or three quarts for a quarter to contribute to the family's income. (Overbey 1982).

The Impact of Base Development

A study with striking parallels to Camden County is Baks and Postel-Coster's (1977) analysis of the impact of industrial development associated with offshore oil drilling on traditional fishing communities on the Scottish east coast. Development of the oil industry along the coast, begun in the 1960s and 1970s with the encouragement of the government, was expected to bring employment and wealth to Scotland directly and to stimulate further economic growth with its operational demands for secondary service industries. The fishing industry was expected to decline as fishermen sought jobs with the oil companies. This prediction proved erroneous, however, as the fishermen continued to fish (Baks and Postel-Coster 1977).

The operation and expansion of the oil industry along the Scottish east coast, however, has produced concern among fishermen. Access to developed fishing harbors, congested by oil tankers, may be restricted for the smaller fishing boats. Offshore drilling debris left on the sea floor can damage fishing nets. Pollution resulting from oil spills or other operational accidents can endanger the fishing grounds (Baks and Postel-Coster 1977).

Befu (1980) reports a similar situation for the fishing villages along the Inland Sea of Japan. Originally, the Inland Sea coast was a string of fishing communities, a "maritime treasure...as well as the most scenic area of Japan" (Befu 1980) Extensive industrial development of the Inland Sea coast, encouraged by the government since World War II, has disrupted the fishing habitats, restricted the fishing territories of local fishermen, and polluted the waters, rendering the fish inedible (Befu 1980).

The major impact of naval base development at Kings Bay on the commercial and noncommercial fisheries of Camden County will result from the dredging of the channels and the disposal of dredged materials or spoil to allow submarines and other naval craft ocean access and maneuverability. The channels to be dredged are the St. Marys Entrance, interior channels located between the Entrance and Cumberland Sound. The Kings Bay basin will also be dredged.

The St. Marys Entrance will be dredge cut 11 feet and widened 100 feet; the interior-channels will be dredge cut 10 feet and widened 100 feet; Cumberland Sound will be dredge cut 10 feet and widened 200 feet; and the Kings Bay basin will be dredge cut 10 feet and widened accordingly (Department of the Navy 1977a, 1980a). The dredging associated with the T-1 phase of development has disrupted 1103 acres of estuarine bottom, removed 6.7 acres of marsh, and produced 13.5 million cubic yards of spoil (Department of the Navy 1977a). The dredging associated with the A-1 phase of development will disrupt an additional 333 acres of bottom, 49 acres of tidal wetlands, and will produce 20.5 million cubic yards of spoil (Department of the Navy 1980a).

Further, base operation requires continued maintenance dredging due to the high sedimentation rates of the basin and channels (Department of the Navy 1977b; 1980b). Maintenance dredging will be necessary to keep the channels and basin clear for submarine traffic. Although no estimates are given for the amount of estuarine bottom to be affected by T-1 maintenance dredging, the amount estimated for A-1 maintenance dredging is 500,000 cubic yards per year (Department of the Navy 1980a). The dredge spoil from base development and operation has been deposited in three areas: diked upland areas located on the naval base; along beaches as a part of beach "nourishment" programs; and in open water at an offshore dumping site.

The dredging and dredge spoil disposal will diminish the productivity of the Cumberland Sound estuarine complex and disrupt the habitat and life cycle of species upon which the commercial and noncommercial fisheries depend. While limited dredging can release nutrients and stimulate productivity of the estuary, the nature of the dredging associated with construction and operation of Kings Bay naval base will not have this beneficial effect (Department of the Navy 1977b).

Dredging of navigation channels increases the amount of sea water entering the estuary, affects circulation patterns and exchange rates of ocean, estuarine and fresh waters, and changes the estuarine temperature (Kutkuhn 1964). Dredging can interrupt the normal pathways of energy flow. Channeling of tidal currents changes the mechanism whereby incoming food sources from the ocean and outgoing food sources from fresh water streams and rivers are transported in the estuary (Copeland and Dickens 1974).

The dredging changes the bottom sediments to a soft tecture, destroys marine plant and animal life within the dredged area, creates turbidity and siltation, releases toxic substances from disturbed sediments (in this case largely pulp mill wastes), and produces a low dissolved oxygen level in the estuary. While the estuarine plant and animal life would normally reestablish itself once the construction dredging was completed and the bottom sediments resettled, thus mitigating adverse effects, the maintenance

dredging and submarine traffic will continuously disturb the bottom rendering the area uninhabitable for marine life on a long-term basis. Submarine traffic would effectively "re-dredge" the estuary with each passage (Department of the Navy 1977b).

The dredge spoil deposited in the diked upland areas on the naval base is susceptible to erosion and runoff which can result in dredge spoil effluent. Spoil effluent increases oxygen demand and may produce fish kills in Kings Bay. Toxic materials such as heavy metals and pulp mill pollutants that are present in the bottom sediments of Kings Bay may reenter the bay as part of the dredge spoil effluent and affect the chain of marine life. (Department of the Navy 1977b).

Other aspects of naval base development affecting the estuary and commercial and noncommercial fish and shellfish species are the potential for oil spills and other pollutants and nuclear contamination. Oil contamination is regarded as an inevitable consequence of the restricted channel and increased submarine traffic (Department of the Navy 1977b). While the Navy maintains an emergency plan for controlling oil spills, the severity of the spill will be governed by the location of the spill, the amount and type of oil involved, and the tidal level. In the event of a spill, the effects on estuarine plant and animal life would be detrimental (Warren 1971). Other estuarine pollutants include increased oil, grease, and metals from storm-water runoff in the base support area, copper used in paints and other toxic substances from waterfront operations, and pesticides for the control of mosquitoes and other biting insects from runoff or drift (Department of the Navy 1980b).

The potential for nuclear contamination of the estuary is dismissed by the Navy due to the construction and design of the submarines and missiles and the safety precautions practiced by naval personnel (Department of the Navy 1977a). In fact, the nuclear aspect of base development is only briefly addressed in the 1977 Draft Environmental Impact Statement under the topic of "Operation Impacts" (Department of the Navy 1977b). There are, however, three potential sources of radiation: shipboard reactors, nuclear warheads and nuclear waste (Overbey 1982).

The Navy conducts environmental monitoring and notes that the total amount of nuclear radiation released into harbors and seas within 12 miles of shore at which nuclear submarines and ships visited, ported and based from 1972 to 1976 has been less than 0.002 curie each year (Department of the Navy 1977a). Some authorities, however, argue that even very low levels of radiation can have subtle adverse effects on marine life (Wolfe 1974; Rice and Baptist 1974; Wilber 1969). According to Wolfe (1974), the introduction of radioactive wastes into estuaries could alter the environment in four ways: "(1) somatic damage (including death) of estuarine biota; (2) increase in genetic mutation rates of population; (3) increase in growth rate and maximum size of organisms; (and) (4) reorientation of human uses of estuaries".

Low levels of radiation may disrupt human use of the estuary, particularly fishing and recreational activities, such as swimming, boating and water skiing (Rice and Baptist 1974; Wilber 1969). Sources of radiation may disrupt human exploitation of the estuary out of proportion to the actual levels of contamination if the local population perceives a health hazard. One Camden County resident who fished locally in 1979 stated a year later that he only fished outside the county. The resident, a Navy veteran, expressed concern about possible nuclear contamination: "I hope tha Navy doesn't poison the area with nuclear waste" (Overbey 1982).

The Implications for Commercial Fishing

Can commercial fishermen adapt to the changes wrought by naval base development? An important consideration in this respect is the historic adaptation of shrimpers to the disruption of the estuary posed by the operation of the pulp and paper mill along the North River in St. Marys. From 1941, when pulp and paper production began, until 1972, when a filtering system was completed, the mill dumped untreated wastes into the North River. By 1955, shrimpers complained that the mill's pollution had destroyed their inshore-based business and that fish tasted like kerosene or turpentine (Fallows 1971). Shrimpers adapted by extending their range of shrimping to areas north and south of Camden County along the Atlantic Coast and to the Gulf of Mexico, while maintaining their local base of operations. This migration was aided by technological innovations: boats became larger (from 20 feet to 60 feet in length); refrigeration for storing shrimp for longer periods of time and electronic equipment for locating shrimp became common (Overbey 1982).

Shrimpers are flexible and could adapt to the impacts of base development in two different ways: (1) by abandoning Camden County as their home port and moving elsewhere; or (2) by remaining in Camden County but concentrating on long-distance shrimping. Abandoning Camden County would be the most disruptive move for shrimpers because it would sever their ties to the community. Shrimpers are well integrated into the community and retain historical family ties. Even in the most adverse conditions, shrimpers have maintained Camden County as their home port because it is "home" (Overbey 1982).

Shrimpers would most likely remain in Camden County and extend the range of their shrimping. This would continue the pattern of shrimping adopted in the 1950s. If the local situation were particularly difficult, shrimpers would again establish temporary ports from which to operate as they had previously. The difficulties inherent in this approach are predictable, stemming from problems already familiar to shrimpers. The costs of shrimping fuel, boats, equipment and taxes, have so increased as to make long-distance shrimping practically infeasible.

The increasing costs of shrimping will require shrimpers to remain closer to home port. There are limitations to shrimping nearby, however. As of 1978, Georgia's Department of Natural Resources indefinitely closed the sounds to commercial shrimping with the hope of increasing the yield of shrimp in the ocean by allowing a maximum number to develop in the estuary.

The closure, although designed to benefit commercial shrimpers, is widely perceived as more directly benefiting bait shrimpers and local resident fishermen since bait shrimping is legal in the sounds. Commercial shrimpers claim that many bait shrimpers catch more shrimp than the amount allowed by state law and sell their catch at a reduced price from door to door. Illegal bait shrimping and peddling are the reasons that one shrimper gave for not operating a retail outlet from his business. Illegal peddlers were able to sell their shrimp for \$1.00 a pound, undercutting his retail price of \$3.00 a pound (Overbey 1982).

Another factor limiting the ability of commercial shrimpers to shrimp locally is a restriction on beach trawling intended to protect spawning shrimp. Presently, shrimpers can trawl the beaches of the Georgia barrier island only during the season, approximately June through December. At other times of the year, trawling within one mile of the beaches is illegal.

Camden County shrimpers rely heavily on the in-season trawling along Cumberland Island. An attempt by the National Park Service in 1980 to acquire additional land on and around Cumberland Island, however, threatened to eliminate the "good shrimping grounds" along Cumberland Island's beaches. The acquisition plan included 4,000 acres of private land, 700 acres of federally owned land and 14,000 acres of state-owned beach, marsh, and tidal creeks (Respass 1980, Southeast Georgian 1980). Local opposition to this move was strong because residents feared the loss of rights to utilize these areas for fishing, boating and recreation.

The Implications for Noncommercial Fishing

Local noncommercial fishermen, who are more directly dependent on the productivity of the estuary than the far-ranging commercial fishermen, will suffer the greatest impact from base development. Local competition for estuarine resources already exists between noncommercial and commercial fishermen in Camden County, with commercial fishermen concerned that noncommercial fishermen are taking smaller shrimp that would normally grow and migrate to trawable waters outside the sound. The situation will be exacerbated by diminished estuarine resources and the addition of a new faction, those noncommercial fishermen among the incoming population of naval personnel.

A small sample of 26 naval personnel who resided in Camden County were interviewed in the summer of 1980 at Kings Bay naval

base, with the permission of the Navy. Sixty-six percent of the sample said they fish, and of these, 67 percent fish within Camden County. Fifty-two percent fish every two weeks or more often. While 83 percent of the naval personnel who fish eat their catch, 17 percent throw back the fish they catch. None of the naval personnel give away or share their catch with others. Among naval personnel, fishing is pursued mainly for pleasure (Overbey 1982).

Heavy participation of naval personnel in fishing activities suggests potential conflicts for scarce and diminishing estuarine resources in the future, particularly if the level of fishing evident in the sample is representative of the incoming naval population as a whole. Sixty-six percent of the 25,000 additional naval personnel practicing recreational fishing locally signals dire consequences for the commercial and noncommercial fisheries.

Changes in the noncommercial fishing behavior of Camden County residents were evident within the first year of base operation. The proportion of respondents that fish declined from 68 percent in 1979 to 56 percent in 1980. This change in fishing practices was analyzed with the McNemar Test for Correlated Proportions (Mendenhall, et al 1974) to determine the probability of such a decline occurring by chance alone. The McNemar test is a variation of the chisquare test designed specifically for panel surveys. Because the same households interviewed in 1979 were interviewed again in 1980, the responses recorded in the two surveys are not independent; the respondents' behavior in the second survey is logically related to the behavior recorded the year before. The McNemar test assesses the significance of change between such dependent variables (Mendenhall, et al 1974; Thomas 1976). The result was significant at a probability level of .01, indicating that a significant, nonrandom decrease in fishing occurred during the first year of base operation (Overbey 1982).

The intensity of fishing and the consumption patterns remained the same, with 44 percent of the fishermen fishing every two weeks or more often, and 92 percent sharing their catch with others. One woman complained, however, that the fishing was worse in 1980 now that more residents were posting their property. This concern over trespassers and the posting of land is a recent phenomenon that appears to be related to the influx of naval personnel.

Concluding Remarks

As we have seen, in order to fully assess the impact of large-scale development projects on coastal communities, established human use patterns associated with the marine environment, the significance of these activities to the economy and community life, and the potential effects of development on the environment that supports the resources on which these activities rely must

be considered. The case of Camden County serves to illustrate these points.

The development of the nuclear submarine base in Camden County will have an adverse impact on the commercial and noncommercial fisheries due to its disruption of the Cumberland Sound estuarine complex. The potential conflict of interests resides in the competing uses of the estuary. Commercial and noncommercial fishermen of the county rely on the productivity of the estuary to provide them with shellfish and finfish species that meet their economic needs, while naval personnel utilize the estuary to meet recreational needs, and the U.S. Navy uses the estuary to promote national defense. Conflicting interests and adverse impacts should be addressed in the environmental impact assessments associated with development projects in coastal communities and weighed carefully in the decisionmaking processes of state and federal agencies, developers and the public.

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AN OVERVIEW OF THE CONDITIONAL OPENING OF GEORGIA'S SOUNDS TO COMMERCIAL SHRIMPING

Susan Shipman, Andre C. Kvaternik, Virginia Baisden
James Music, Duane Harris

Introduction

The penaeid shrimp fishery of Georgia has perennially been the foundation of Georgia's commercial fishing industry. It plays a vital role in the coastal Georgia economy, contributing up to 25 percent of the employment in some of the six coastal counties (Carley 1968). Penaeid shrimp harvests annually account for approximately 80 percent of the total value of all commercial fishery landings. (McKenzie 1981; Georgia Department of Natural Resources 1984). The white shrimp, Penaeus setiferus, is the focus of the shrimp harvest in Georgia, producing about 30 percent of the annual shrimp harvest (McKenzie 1981).

The geography of coastal Georgia is dominated by nine sounds which are variable in open water area, with St. Andrew Sound the largest at 77,000 m², and Altamaha Sound the smallest at 19,000 m² (Mathews et al. 1980). Georgia's sounds are small compared to those in other South Atlantic states. Due to the estuarine nature of the sounds, they serve as important staging areas for adult and subadult shrimp during their seaward emigration. These areas have been important to the shrimp fishery because of their high shrimp concentrations and favorable fishing conditions as compared to off-shore trawling.

Throughout the existence of Georgia's trawl fishery for shrimp, there has been controversy concerning the effects of opening Georgia's sounds to fishing on the long term viability of Georgia's shrimp resources. The historical nature of this debate is reflected in the criteria by which these waters have been opened to commercial food shrimping. These area openings have historically been dictated by statutory calendar dates, political referenda, and more recently, according to sound principles of wildlife management established in law (Table 1).

Although the mechanism has existed in Georgia statutes to open six of Georgia's nine sounds, these waters remained closed from 1977 until the fall of 1983, when these six sounds were opened to commercial shrimping on a conditional basis. Following the severe January 1977 freeze and resultant decimation of the spring spawning stock, internal waters remained closed to commercial food shrimping during 1977 in an attempt to restore shrimp

Table 1. History of area openings for Georgia sounds from 1920's through the present.

Period	Criteria/Area Opened
Early 1920's-1930's	All sounds closed from March through July.
Early 1950's	Sounds opened from mid-March through December by county referendum held every two years in respective counties.
Early to mid-1960's	Doboy and Altamaha closed, St. Andrew and Cumberland open from mid-March through mid-April and from June through December.
Late 1960's	All sounds could be opened in January, May and from October through December if heads-on shrimp count* < 55 per lb and from June through September if ≤ 45 per lb.
Early 1970's	Director of Georgia Game and Fish Commission authorized to open sounds from September through December if shrimp count < 55 per lb; shrimping limited to daylight hours.
Mid-1970's	Commissioner of Natural Resources authorized to open all but St. Catherines, Doboy, and Altamaha Sounds from September through December if shrimp count < 45 per lb.
1979 to present	Commisioner of Natural Resources authorized to open all but St. Catherines, Doboy, and Altamaha Sounds after evaluation of eleven biological, environmental, and socioeconomic criteria as specified in O.C.G.A. Section 27-4-130 according to sound principles of wildlife management, if shrimp count < 45 per lb.

*References heads-on shrimp count throughout table.

populations to near normal levels (Music 1979). Severe environmental conditions prevailed again during the subsequent winter and as a result all sounds remained close during fall of 1978. Fall production in 1977 and 1978 returned to near normal levels and was followed by a record harvest in 1979 (Table 2). Much of the fall harvest from these three years consisted of the larger market size of adult shrimp. Resource managers concluded the closure of the sounds was the cause of the increased harvests and the high percentage of larger shrimp. This conclusion was statistically evaluated only after several years of data collection.

Prior to fall 1983, CRD Fisheries and Data Management Sections personnel initiated statistical analyses to discern the effects of the sound closure. A comparison was conducted between the size of shrimp surveyed during CRD's regular inshore fall monitoring in years prior to and after 1977 utilizing Duncan's multiple range test (Miller 1981). Significant differences (<0.001) were observed in the size of shrimp during falls when the sounds were open as compared to years when they remained closed. (Figure 1). Additionally, the largest shrimp observed during years of sound closure occurred during falls following major winter freezes. This suggested that factors additional to management strategy may have influenced size at emigration.

Due to the interjurisdictional nature of the controversy concerning Georgia's sound closure, count sizes of commercial white shrimp were compared between South Atlantic states (Figure 2). Included were years during which South Carolina and Georgia exercised different management strategies regarding inside waters. Shrimping was allowed in South Carolina sounds and bays during the fall for all years considered, while Georgia sounds were open through 1976. Only in 1980 was there a significant difference between fall count sizes for Georgia and South Carolina production. A linear regression using Georgia and South Carolina weighted fall commercial count sizes indicated a strong correlation ($r^2 = 0.88$, <0.001) between shrimp sizes for the two states' fall production during years prior to and following 1977.

Given this strong correlation between commercial count sizes for two states with opposing management strategies and that the largest count sizes were observed following severe freezes and resultant low recruitment, CRD biologists concurred with the suggestion of other investigators that size at emigration is a function of inshore shrimp density and resultant interspecific competition (St. Amant et al 1966; Parker 1970; Whitaker 1981; Shipman 1983a; Whitaker 1984) rather than solely a result of the sounds closure.

During the period of the sounds closure, biologists documented altered shrimp behavior due to anomalous fall environmental conditions. The drought which devastated south Georgia agriculture during 1980 resulted in abnormally high salinities in Georgia's inside waters. The drought coupled with an usually

Table 2... Georgia white shrimp landings (heads-off) September through December from 1957 through 1983.

Year	Pounds	Year	Pounds
1957	2,775,890	1971	3,864,182
1958	2,492,374	1972	2,223,238
1959	2,758,469	1973	3,591,969
1960	4,015,625	1974	2,685,802
1961	3,000,956	1975	3,097,336
1962	2,819,502	1976	2,650,856
1963	1,973,868	1977	1,855,193
1964	2,283,193	1978	2,356,416
1965	3,114,572	1979	3,944,082
1966	2,382,934	1980	2,585,124
1967	2,826,517	1981	2,326,586
1968	4,345,330	1982	2,247,301
1969	4,263,041	1983	2,217,585
1970	2,921,824		

GEORGIA SEPTEMBER-DECEMBER INSHORE ASSESSMENT COUNT SIZES (HEADS-ON)

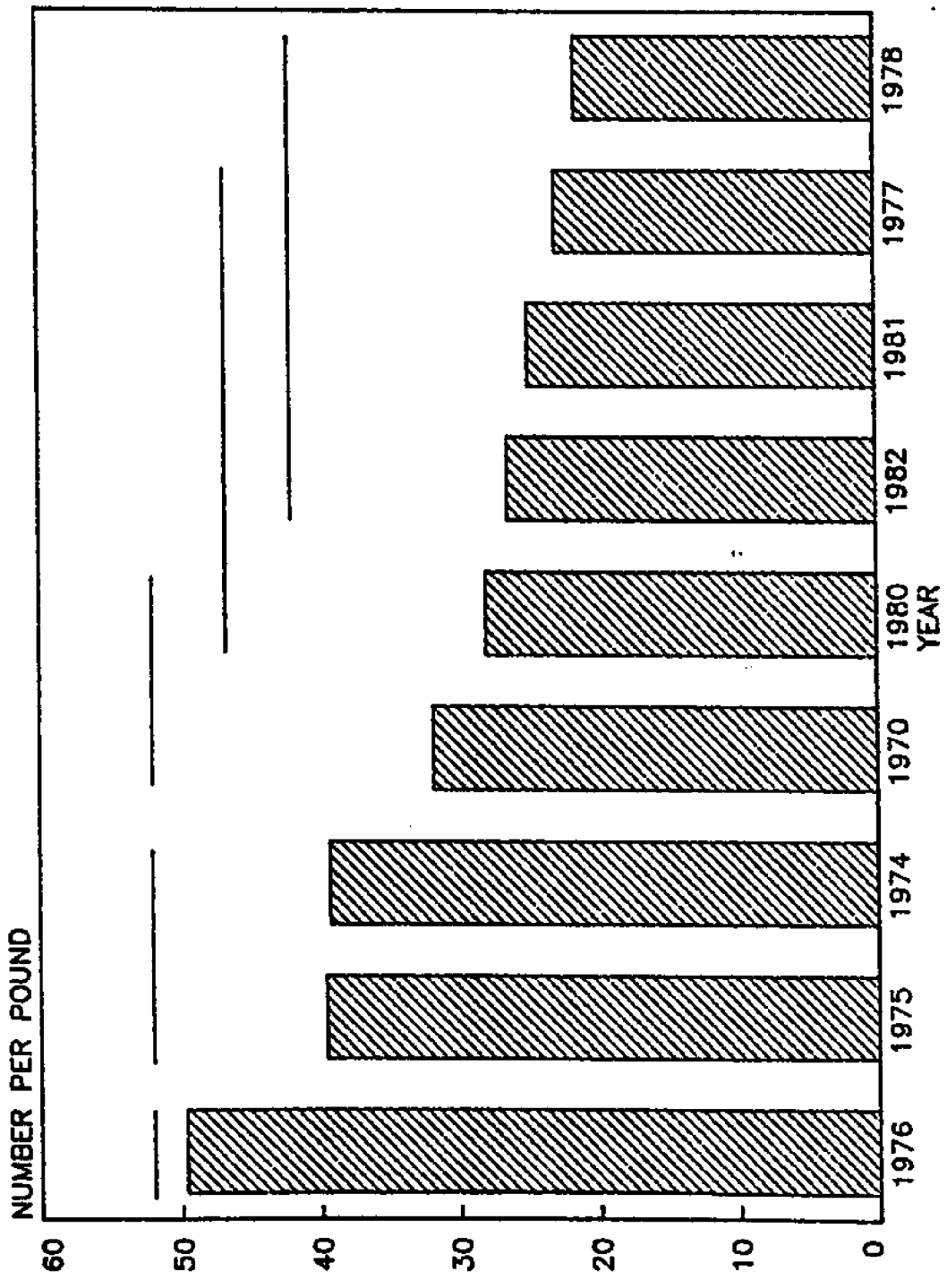


Figure 1. Comparison of shrimp count size (heads-on) observed during inshore fall (September - December) assessment trawling in years in which Georgia's sounds were opened and years in which they remained closed. Non-overlapping horizontal bars indicate significant differences ($\alpha < 0.001$; Duncan's multiple range test).

SOUTH ATLANTIC COMMERCIAL COUNT SIZES (HEADS-ON) SEPTEMBER-DECEMBER AVERAGE

SOUTH CAROLINA
GEORGIA
FLORIDA

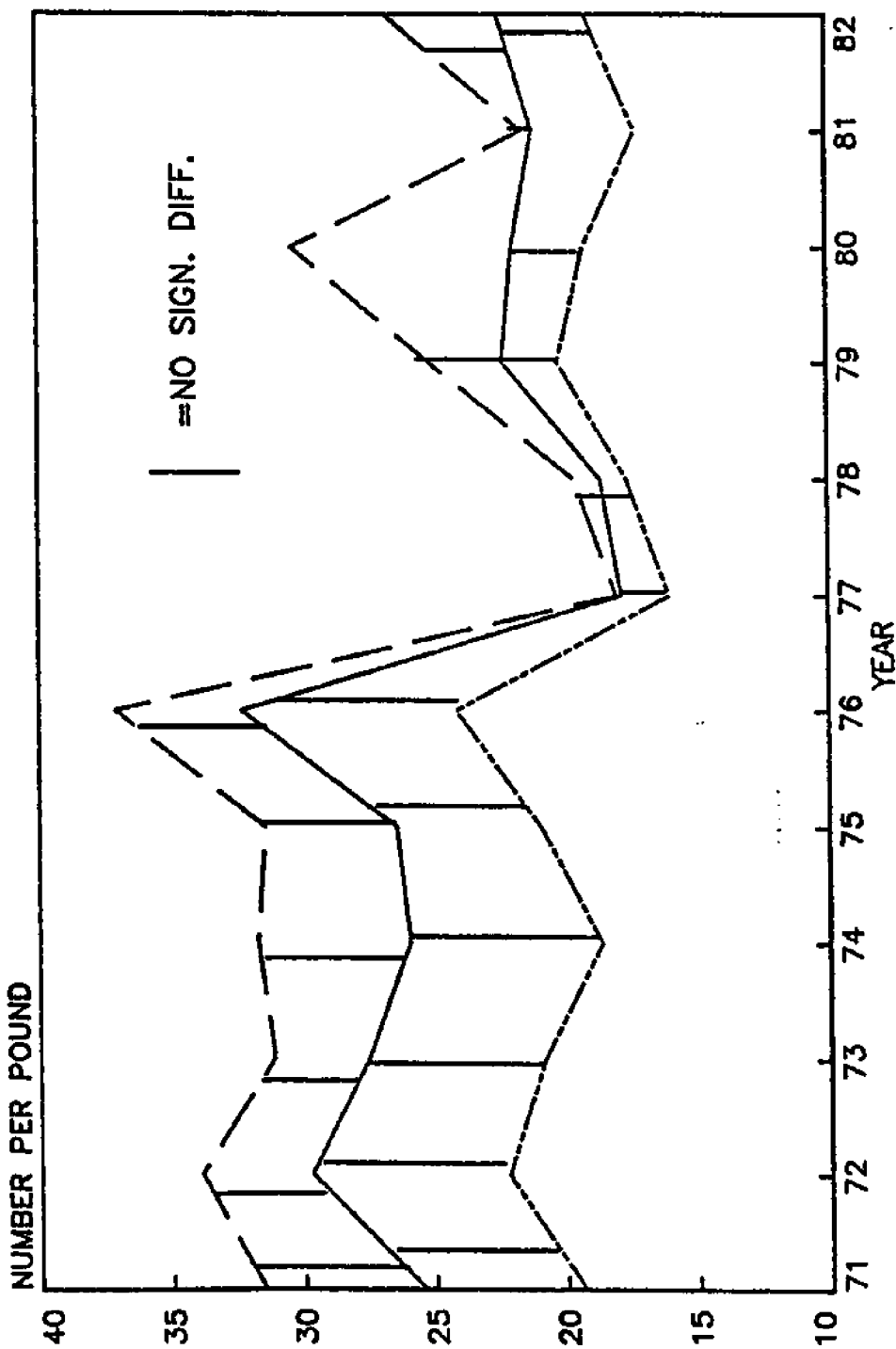


Figure 2. Comparison of average count size (heads-on) observed in annual fall (September - December) commercial white shrimp landings in South Atlantic* states from 1971-1982. Vertical bar indicates no significant difference ($\alpha < 0.001$; Duncan's multiple range test) between count sizes. *Excludes North Carolina.

warm fall interrupted the natural fall emigration of large shrimp from the sounds to offshore waters. Mark-recapture data indicated a greater proportion of tagged white shrimp migrated to Florida and adjacent FCZ waters during that fall and winter than during preceding years (Figure 3). Pulses of movement occurred in late November and December following amplified tidal exchanges due to spring tides and northeasters (Figure 4). The large numbers of marked shrimp recovered off Florida in the weeks following the storm events suggested the turbulent seas accompanying those storms precluded maximum harvest of Georgia's emigrating stocks by the local fishing fleet (Shipman 1983b). This aroused a storm of protest from resident commercial fisherman because they believed those shrimp could have been harvested in Georgia waters if the sounds had been open.

The fall of 1983 was characterized by extremely warm and dry weather conditions. The persistence of environmental extremes such as prevailed during 1980-1981 fall and winter alarmed CRD fisheries managers. These conditions and the conclusions regarding the effect of the sound closure on overall fall production warranted a consideration of a shift in management strategy so as to avoid interjurisdictional loss and to maximize yield. Thus, biological, environmental, and socioeconomic criteria (Appendix A) were evaluated as mandated in O.C.G.A. 27-4-130.

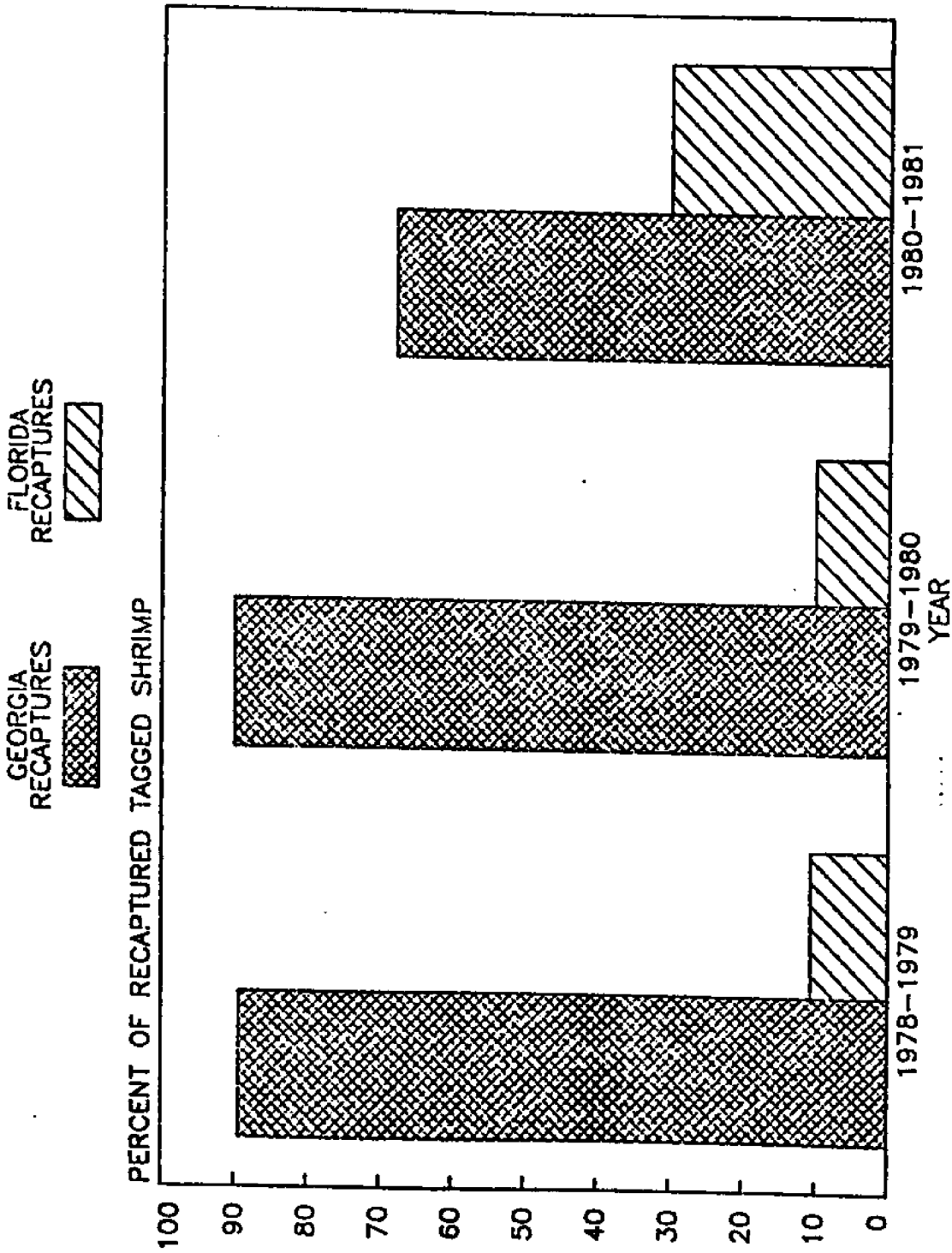


Figure 3. Percent of all fall and winter* recaptures of tagged white shrimp caught off Georgia and off Florida by year for white shrimp tagged and released in Georgia estuaries from June 1978 - December 1981. *Fall: 23 September - 21 December; Winter: 21 December - 20 March.

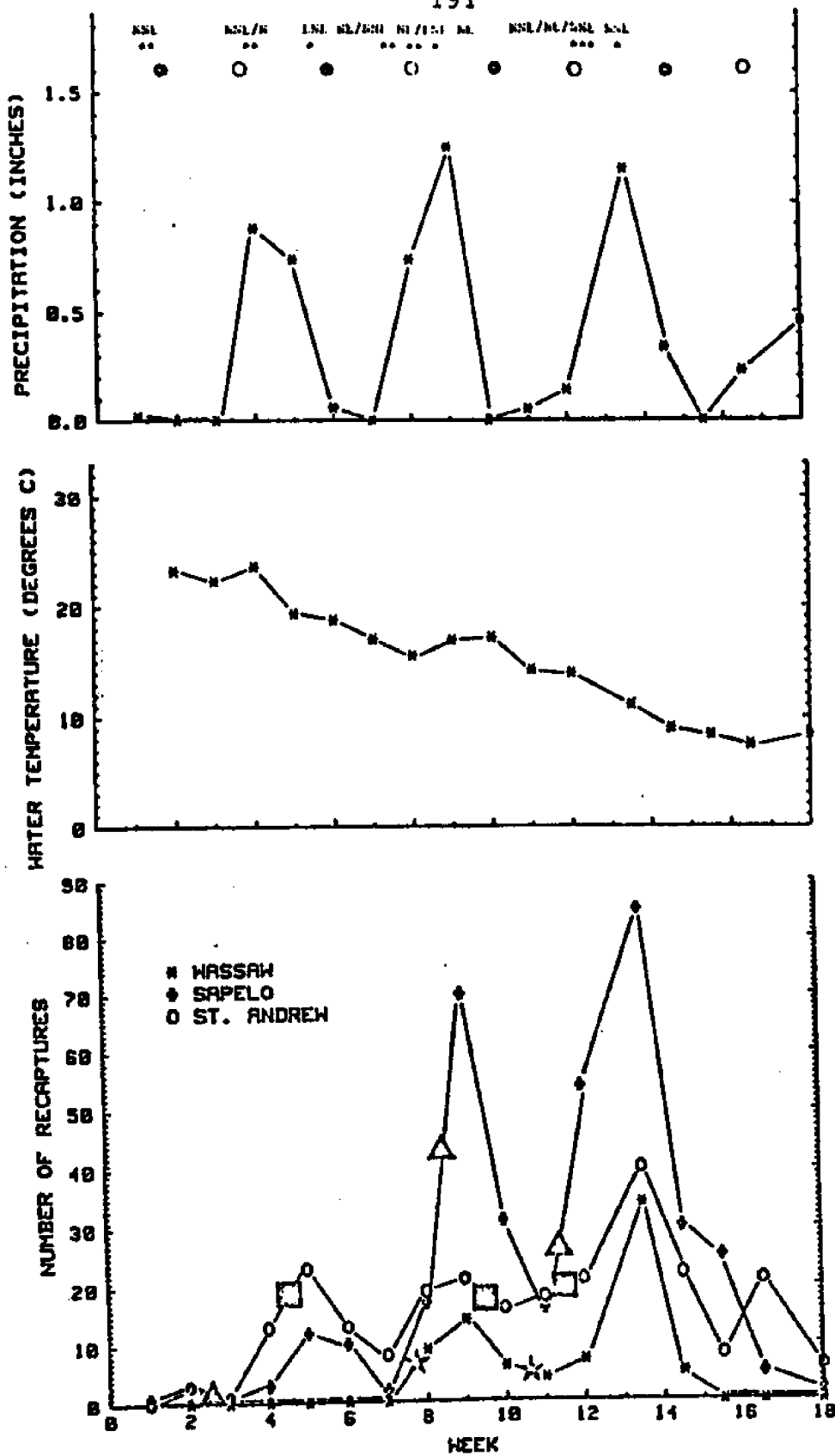


Figure 4. Correlation between environmental influences of wind¹, spring tides², precipitation¹, water temperature³, and number of tagged shrimp recovered weekly from 27 September 1980-31 January 1981. NOTE: Week 1 corresponds to week ending 27 September 1980, with following weeks corresponding to successive 7 day increments; * -new moon; ◯ -full moon; * indicates daily prevailing winds of north-easterly component (NE, northeast; NNE, north northeast; ENE, east north-east); * , A , and [] represent release events in Vassaw, Sapeco, and St. Andrew estuaries.

¹U.S. Department of Commerce. NOAA. Environmental Data and Information Service. Local Climatological Data. Various issues.

²U.S. Department of Commerce. NOAA. National Ocean Survey. Tide Tables-east coast of North and South America including Greenland. Various issues.

³J.L. 88-309 Project 2-319-R assessment, juvenile (Kulden, 1983; Shiffman, 1983), and mark-recapture data.

EVALUATION OF O.C.G.A. and 27-4-130 CRITERIA

The abundance and size of the seafood species in question.

A comparison of October 1983 coastwide assessment averages (Table 3) compared with those for the same time period in previous years indicated sufficient stocks of commercial size white shrimp inhabited Georgia's sounds in late October to support commercial trawling efforts. The most abundant size shrimp in the sounds during October 1983 were larger than those observed during October monitoring in previous years when the sounds were opened. Since large adult shrimp prefer high salinity areas such as those present in the sounds during fall of 1983, larger, higher value shrimp were expected to predominate production from these areas more than in years when normal salinities prevailed.

Creek sector catches (Table 3) indicated that abundant stocks of harvestable size shrimp were congregated in the lower creeks and rivers. Assuming estuarine sectors have a finite carrying capacity, a continued delay in emigration from Georgia's sounds was expected to delay emigration of creek stocks into the sounds. It was believed the reduction of existing sounds stocks through harvest would trigger emigration of large shrimp from the lower creeks and rivers.

An anomalous distribution of juvenile and subadult shrimp was also observed. Mid-October juvenile trawl sampling yielded greater numbers of bait-sized (generally 75 to 115 mm) shrimp in upper headwaters not routinely sampled as compared to abundances at regular stations. Bait shrimpers and recreational cast netters confirmed the absence of shrimp in areas normally frequented by bait fishermen and the unusually high shrimp abundance in upper estuarine areas. Biologists concluded sufficient overwintering juvenile and subadult stocks inhabited areas prohibited to trawling such that spring roe shrimp stocks would not be adversely impacted by opening the sounds to trawling.

The number of persons licensed to take seafood.

Through 9 November 1983, 885 commercial trawler licenses were sold. Residents comprised 84 percent of this fleet, with the remaining 16 percent divided as follows: South Carolina - six percent; Florida - six percent; and North Carolina - four percent. Non-South Atlantic vessels accounted for less than one percent of the sales.

Whereas 78 percent of the 1976 licensed fleet was composed of craft 18 feet or less in length, an average of only 34 percent of trawlers from 1979 to 1982 were 18 feet or less. A shift in size composition toward larger vessels followed the closure of Georgia's sounds (Figure 5). Realizing the competitive advantages to smaller trawlers in fishing the inshore waters, managers favored a conditional opening so as to minimize socioeconomic impacts on the major component of the fishery. Allowing fishing

Table 3. Average temperature, salinity, catch and size (heads-on) of white shrimp caught during October assessment.

Area	1974 ¹	1975 ¹	1976 ¹	1977 ²	1978 ²	1981 ²	1983 ²
<u>Mean Pound/Hour</u>							
Creek	35.0	54.0	49.4	102.6	85.4	25.6	34.3
Sound	51.2	16.9	9.9	51.6	83.7	29.2	47.4
Offshore	3.0	4.5	2.9	3.3	6.0	8.2	4.9
Average	29.7	25.1	20.7	52.5	58.4	21.0	28.9
<u>Mean Number/Pound - Heads-On</u>							
Creek	32.9	37.0	36.0	25.0	25.1	22.7	29.7
Sound	34.0	41.4	36.2	23.1	21.5	21.6	24.9
Offshore	17.4	13.3	18.6	14.0	19.9	21.7	22.3
Average	28.1	30.5	30.2	20.7	22.1	22.1	25.6
<u>Mean Salinity (ppt)</u>							
Creek	22.0	24.0	21.0	24.1	24.9	31.3	27.0
Sound	25.0	25.0	22.0	25.2	26.9	31.1	29.8
Offshore	30.0	31.0	28.0	31.7	30.5	32.6	31.2
Average	26.0	27.0	24.0	27.0	27.4	31.8	29.0
<u>Mean Water Temperature (°C)</u>							
Creek	20.0	22.0	17.0	21.6	20.0	20.0	23.1
Sound	20.0	22.0	17.0	21.6	20.5	19.7	23.2
Offshore	20.0	22.0	16.0	20.9	18.8	20.6	23.2
Average	20.0	22.0	17.0	21.4	19.8	20.1	23.2

¹ Includes weighted data for Wassaw, Sapelo, St. Simons and St. Andrew.

² Based on assessment data and includes the following estuaries: Wassaw, Sapelo, Altamaha, St. Simons, St. Andrew and Cumberland.

GEORGIA LICENSED TRAWLERS BY SIZE GROUP

18 FT OR LESS OVER 18 FT

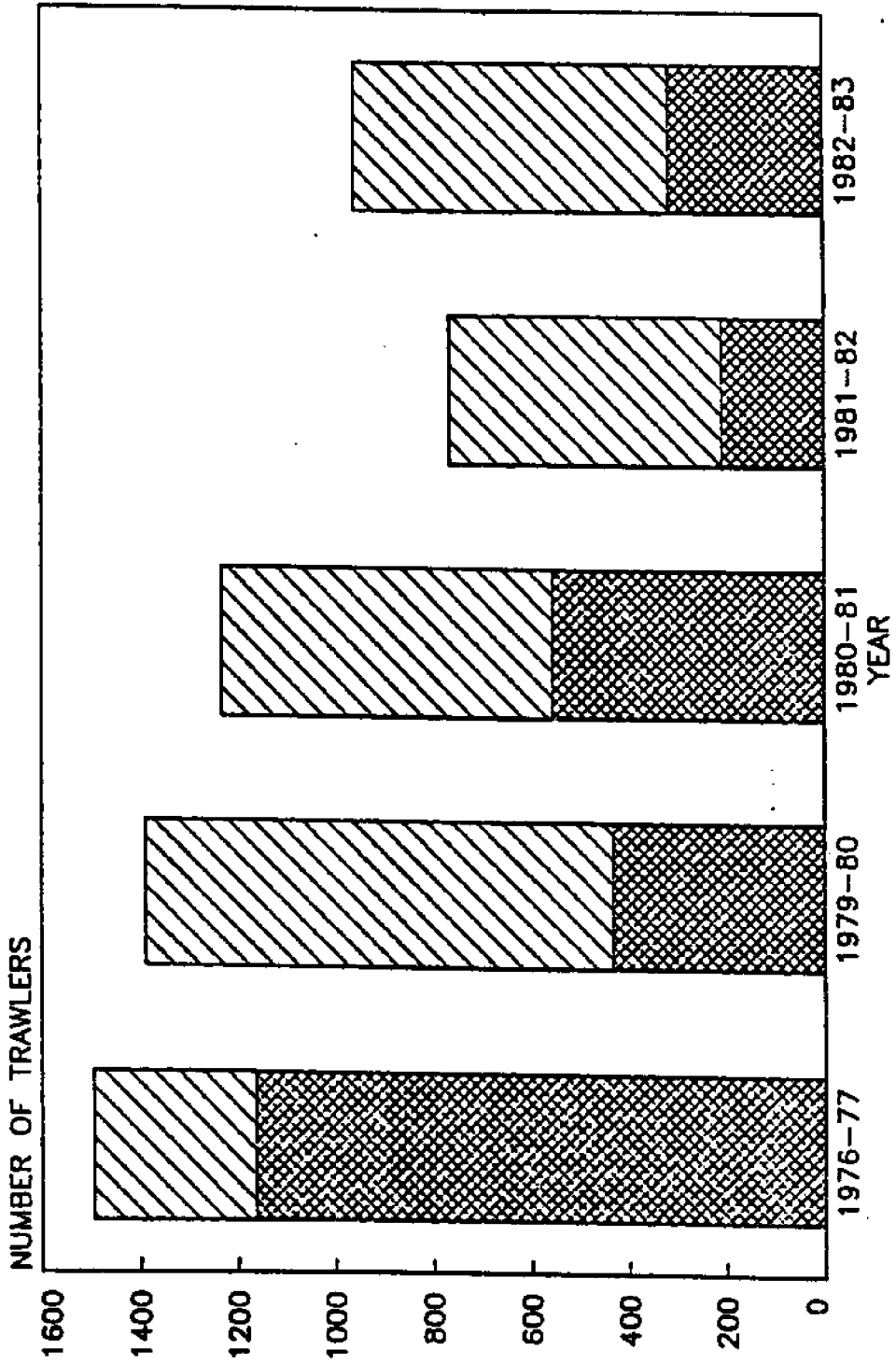



Figure 5. Size composition of trawlers licenses* in Georgia for 1976-1983. *License year is 1 April - 31 March.

on two non-consecutive weekdays would also maximize participation by the full-time commercial fisherman. Moreover, a conditional strategy would minimize new entrants into the fishery which could otherwise create additional safety concerns due to trawling in a limited geographical area. Recognizing the controversial nature of the sound issue, managers believed that limiting fishing to only two days a week would appease many persons opposed to opening the sounds in general.

The Department's forecast for commercial catches.

September 1983 white shrimp landings in Georgia totaled only 521,377 lb, 36 percent below the preceding ten-year average. Monthly landings of 327,000 lb through mid-October were 60 percent below the ten-year October average. Based on a continuation of delayed emigration and production 40 to 60 percent below average, September through December landings were expected to range from 1.1 to 1.6 million pounds.

Of the 99,553 lb landed in Georgia during the first week of October, 49,784 lb (50 percent) were caught in South Carolina sounds in 53 cumulative days fished while 49,767 (50 percent) were caught in Georgia waters in 133 cumulative days fished. Thus, an equivalent amount of shrimp was caught in South Carolina sounds in 1.0 days as was caught in Georgia offshore waters in 2.5 days. With landings reported for approximately one day trips in each state, South Carolina inshore waters production exceeded that of Georgia's outside waters by approximately 700 lb/landing. Opening the sounds to commercial trawling appeared to be the mechanism to maximize biological as well as economic yield.

The quantity in terms of pounds, and the value, in terms of dollars of anticipated commercial landings.

Ex-vessel prices of many shrimp sizes, particularly 21/25's and 26/30's (heads-off) were depressed during fall 1983 due to increased white shrimp production in the Gulf of Mexico and increased foreign imports of medium and large shrimp. Market sources predicted a further decline in prices of large count white shrimp generally predominating offshore fall production and predicted prices for mid-sizes would stabilize (Chauvin, 1983). With 36/40 (heads-off) being the modal size in inshore assessment catches (Table 3), the harvest in the sounds of large quantities of shrimp commanding a strong, stable price appeared to be the best method to maximize economic yield as compared to below average offshore harvest of large shrimp for which the price was predicted to decrease. Based on late October marker prices averaging \$4.23 per lb for 36/40's (head-off) and \$3.99 per lb for 41/45's (heads-off), and assuming fall production would approach the ten year average of 2.7 million pounds, while being comprised of large quantities of medium sizes as a result of opening the sounds, the fall catch was expected to approach \$12.8 million in value.

The available climatological and meteorological data and influence on water temperature.

The environmental parameters of water temperature and salinity are primary influences on adult shrimp emigration (Anderson and Lindner 1956; Pullen and Trent 1969; Schwartz 1977; Farmer and Whitaker, 1978; Whitaker 1982; Shipman 1983b). As previously discussed, environmental conditions during fall 1983 were similar to the unusually warm dry fall of 1980, during which normal offshore emigration of large adult white shrimp was interrupted (Whitaker 1981; Shipman 1983a). The combined influence of abnormally high salinity and warm water temperature (Table 3) prevailed over the influence of spring tidal exchange to further delay emigration, as evidenced by dismal offshore production concurrent with October new moon spring tides. The influence of drought conditions on shrimp distribution was further illustrated by the relatively high salinities (14 ppt) recorded in association with high abundance of juvenile and subadult white shrimp trawled in estuarine headwaters.

The National Weather Service (1983) predicted a continuation of above average temperature through Mid-November. Normal rainfall of approximately two inches predicted for the period would not alleviate drought conditions, and estuarine salinities were expected to remain high. The probability for an en masse offshore emigration triggered by severe environmental influences increased with the progression of fall and onset of winter, and the potential for interjurisdictional loss of these emigrating stocks consequently increased. Given the abnormal environmental parameters characterizing the 1983 fall, it appeared in the best interests of Georgia's shrimp fishery to conditionally open the sounds to commercial trawling.

The life history of each seafood species in question; the coastal ecological features directly related to the life history of each species.

Microscopic shrimp spawned offshore in the spring and early summer immigrate into Georgia's estuaries as post-larvae and move to the upper reaches of creeks and rivers characterized by low salinity. After metamorphosing to the juvenile stage, they experience rapid growth with rapidly warming water temperatures and move seaward throughout the summer. With the onset of fall and winter environmental conditions, including increased rainfall, decreasing water temperatures, and large tidal exchanges accompanying spring tides, adult white shrimp emigrate from the sounds to oceanic waters (Anderson and Linder 1956; Joyce 1965; Pullen and Trent 1969; Whitaker 1982; Shipman 1983b, Shipman and Stevens 1984). Shrimp not attaining a size large enough to emigrate remain in deeper waters of the rivers and sounds where they overwinter. These overwintering shrimp as well as those escaping harvest offshore become next spring's spawners.

A typical environmental conditions during fall 1983 significantly altered the size and stock distribution of the various life history stages. It appeared necessary to modify harvest areas so as to maximize economic and biological yield. Accommodations were made regarding the concern of many resource users who believed the previously defined sound/river limits were located too far inshore. Sound/river limits were redefined to favor optimum growth and survival of juvenile penaeids. Legal trawling limits were defined in nautical terms so as to clarify interpretation by the resource users as well as DNR law enforcement officers.

Anticipated amount and location of the demand for a seafood species

The demand exists for substantially more shrimp than are available from Georgia landings. Georgia processors meet only 12 percent of their raw shrimp supply needs from resident sources during an average production year (Cato and Prochaska 1980). It was estimated Georgia processors would possibly meet 92 to 95 percent of their fall shrimp needs with out-of-state production if below average production persisted. Insomuch as primary Georgia wholesalers needed considerably more shrimp than was being landed by Georgia shrimpers, managers believed opening the sounds for trawling would enable shrimpers to meet some of this demand. Moreover, the revenues generated by the increased production would be a valuable contribution to the coastal economy, particularly in communities heavily dependent upon the shrimping industry.

The resources which influence or are influenced by the abundance, spatial, and temporal variations in seafood species.

CRD fisheries managers formulated a conditional management strategy so as to minimize any adverse impacts on commercially or recreationally important fish or shellfish resources and resource users.

Impacts on the bait shrimp resource and users were considered. Restriction of commercial harvest to the sounds sector would target adult white shrimp, generally of a size less desirable for bait. The continued restriction of bait shrimping to designated zones would eliminate spatial competition between commercial food shrimpers and bait shrimpers.

A major concern of opening the sounds to commercial trawling was the potential impact on Georgia's blue crab fishery. During the sounds closure, crab landings approached the high levels of production during the late 1950's and early 1960's (Table 4), during which time the sounds were open. During the six years (1977-1982) the sounds remained closed to commercial shrimp trawling a greater percentage of crab landings were attributed to pot fishermen (Table 4). A dramatic increase in potting effort was observed. Whereas 9,745 pots were fished in 1976, in excess

Table 4. Annual landings* and percent contribution of hard blue crabs by gear, Georgia, 1950-1982.**

Year	Pot	%	Trot Line	%	Trawl	%	Dip Net	%	Total
1950	1,320.0	26.3	2,662.6	53.0	1,045.0	20.8			5,027.6
1951	1,055.0	16.2	3,936.4	60.3	1,535.0	23.5			6,526.4
1952	1,987.7	21.0	3,060.1	32.4	4,410.4	46.6			9,458.2
1953	5,962.8	62.9	1,538.0	16.2	1,985.0	20.9			9,485.8
1954	6,289.0	59.1	2,091.5	19.7	2,259.4	21.2			10,639.9
1955	4,767.8	44.4	3,965.0	36.9	2,012.5	18.7			10,745.3
1956	5,293.7	62.0	875.7	10.3	2,140.8	25.1	232.1	2.7	8,542.3
1957	6,088.8	67.9	659.5	7.4	2,067.7	23.1	151.8	1.7	8,967.8
1958	5,655.5	55.5	598.8	5.9	3,658.3	35.9	272.3	2.7	10,184.9
1959	7,908.2	62.4	283.5	2.2	4,192.6	33.1	298.2	2.4	12,682.5
1960	10,111.7	64.1	174.2	1.1	5,107.4	32.4	372.7	2.4	15,766.0
1961	7,653.8	62.2	148.6	1.2	3,965.3	32.2	544.5	4.4	12,312.2
1962	7,517.9	61.1	110.0	0.9	4,095.3	33.3	580.0	4.7	12,303.2
1963	8,022.3	55.3	221.3	1.5	4,286.0	36.5	970.4	6.7	14,500.0
1964	2,859.4	24.8	100.8	0.9	8,484.5	73.6	87.2	0.8	11,531.9
1965	2,964.7	28.9	73.3	0.7	7,089.7	69.1	131.3	1.3	10,259.0
1966	4,102.3	47.9			4,409.3	51.5	44.1	0.5	8,555.7
1967	4,140.4	48.7			4,356.1	51.3			8,496.5
1968	2,229.1	60.8			1,439.8	39.2			3,668.9
1969	3,469.9	67.4			1,647.2	32.0	29.7	0.6	5,146.8
1970	4,386.5	61.8			2,705.7	38.2			7,092.2
1971	5,224.1	61.9			3,211.4	38.1			8,435.5
1972	6,145.7	67.8			2,913.9	32.2			9,058.6
1973	5,515.6	69.1			2,468.6	30.9			7,984.2
1974	8,087.4	79.8			2,043.6	20.2			10,131.0
1975	7,398.4	83.5			1,466.8	16.5			8,865.2
1976	5,289.0	90.1			583.6	9.9			5,872.6
1977	7,390.3	95.7			331.2	4.3			7,721.5
1978	10,550.3	99.3			78.0	0.7			10,628.3
1979	11,337.5	100.0			0.0	0.0			11,337.5
1980	10,013.8	99.5			46.3	0.5			10,060.1
1981	12,950.4	100.0			6.4	0.0			12,956.7
1982	12,327.9	99.7			42.1	0.3			12,370.0

*Landings in thousands of pounds.

**1950-1977 from Sholar (1982).
1978-1982 from Flowers (pers. comm.).

AVERAGE GEORGIA HARD BLUE CRAB LANDINGS
BY MONTH, SEPTEMBER-DECEMBER

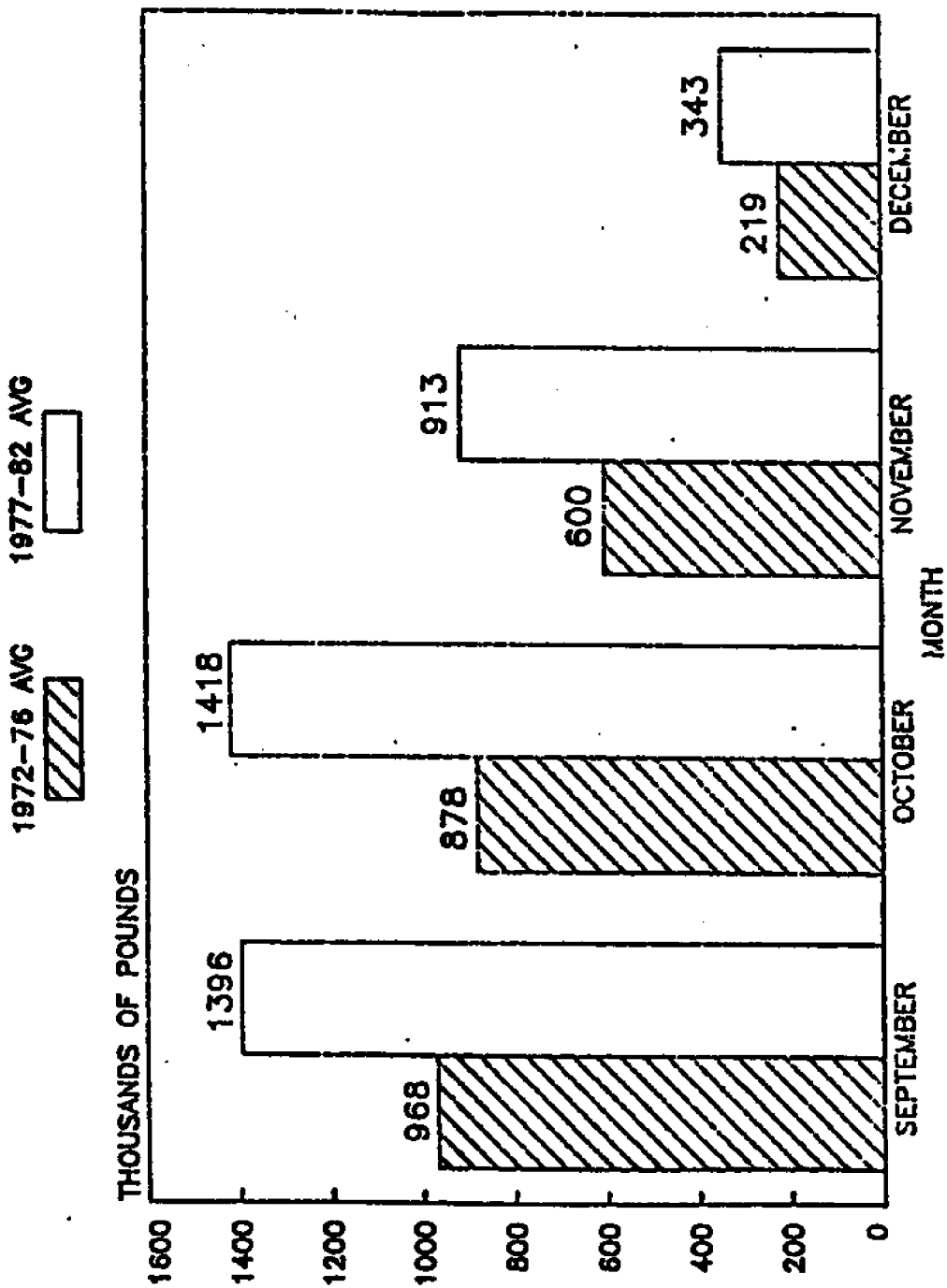


Figure 6. Average Georgia fall (September - December) blue crab landings by month.

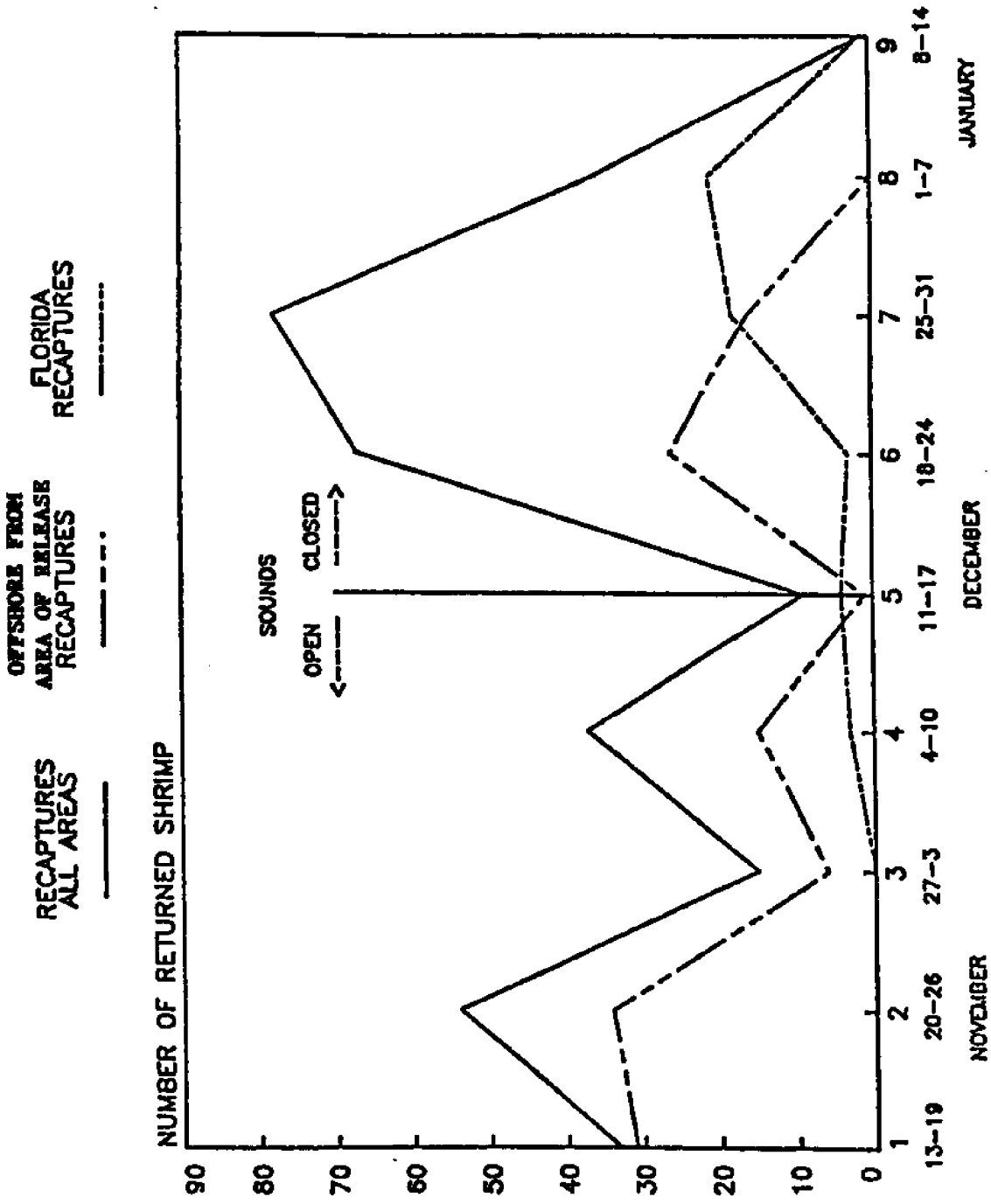


Figure 7. Recaptures of tagged shrimp before and after the opening of Georgia sounds to commercial shrimp trawling.

of 23,000 pots were fished annually since 1978 (National Marine Fisheries Service, 1983). Although the number of full time crabbers was similar for the peak production periods prior to and following the sounds closure, part-time participation increased following 1977 (National Marine Fisheries Service, 1983). Part of this increase was attributable to entry into the fishery by shrimp fishermen during years of below average shrimp production.

A brief economic analysis was conducted of the impact of opening Georgia's sounds to commercial shrimp trawling on the blue crab fishery during November and December. Based on 1) the average November and December production periods prior to and following the sounds closure in 1977; 2) the proportion of production attributable to pots and trawls during those two periods; and 3) the mid-October 1983 price for trawl and pot-caught crabs, managers estimated a potential maximum loss of \$134,390 to Georgia's blue crab fishery. It was believed that the negative economic impact would be minimized by opening the sounds in November and December as this corresponded to the time of mature female blue crab emigration to deeper waters to overwinter. Blue crab landings historically decreased in November and were minimal in December, regardless of whether the sounds were opened or closed (Figure 6). Additionally, it was believed the adverse socioeconomic impact would be partially countered by the potential re-entry of part-time crabbers into the shrimp fishery. Moreover, managers believed the projected increased shrimp production would counter the economic loss to the crab fishery and result in a net economic benefit to Georgia's seafood fishery.

With respect to the sport fishery, commercial landings of recreationally important finfishes indicated no beneficial impact of the sounds closure on these species (Table 5). Results of the Division's Recreational Fisheries Program life history study indicated the spotted seatrout (Cynoscion nebulosus) stocks were rebounding after being drastically reduced as a result of the 1977 and 1978 winter freezes (Music and Pafford 1984). Studies conducted previously (Anderson 1968; Knowlton 1972; Mahood et al 1974) revealed minimal harvest by shrimp trawlers of many species important to the recreational fishery. Spotted seatrout and red drum (Sciaenops ocellatus) are an infrequent by-catch in shrimp trawls and the sounds opening would occur during a period in which trawling would have minimal impact on these species. Species such as kingfish (Menticirrhus sp) and flounder (Paralichthys sp) are commonly caught in shrimp trawls and are commonly landed commercially as a result. However, no reliable recreational fisheries statistics existed to confirm or refute the concern among recreational fishermen that flounder resources had benefited from the sounds closure.

Biologists also concluded opening Georgia's sounds during late fall would be unlikely to have any impact on endangered species such as marine mammals and turtles which utilize these areas during other times of the year. Thus, conflicts between environmentalists and commercial shrimpers would be minimized.

Table 3. Commercial landings for Georgia's major inshore recreational fisheries in thousands of pounds and thousands of dollars from 1960 through 1983.

Year	Spotted Seatrout		Weakfish		Zed Drum		Flounder Composite		Black Drum		Sheepshead		Atlantic Croaker		Spot		Kingfish	
	lb.	\$	lb.	\$	lb.	\$	lb.	\$	lb.	\$	lb.	\$	lb.	\$	lb.	\$	lb.	(uniting) lb.
1960	(1)	(1) 1/	-	- 2/	(1)	(1)	39	4	3	(1)	-	-	(1)	(1)	(1)	(1)	282	23
1961	2	1	-	-	1	(1)	37	4	1	(1)	-	-	-	-	(1)	(1)	247	20
1962	1	(1)	-	-	-	-	27	3	-	-	-	-	1	(1)	4	(1)	166	13
1963	5	2	(1)	(1)	-	-	22	3	1	(1)	-	-	1	(1)	4	1	125	11
1964	2	1	-	-	-	-	6	(1)	1	(1)	(1)	(1)	(1)	(1)	3	(1)	91	9
1965	9	3	2	(1)	-	-	51	5	2	(1)	1	(1)	2	(1)	11	1	253	28
1966	3	1	1	(1)	3	(1)	35	6	1	(1)	1	(1)	5	1	5	1	166	19
1967	7	2	(1)	(1)	6	1	22	4	2	(1)	1	(1)	6	(1)	11	1	187	19
1968	2	1	(1)	(1)	6	1	23	5	1	(1)	(1)	(1)	-	-	2	(1)	123	15
1969	3	1	1	(1)	3	1	28	5	(1)	(1)	(1)	(1)	2	(1)	2	(1)	111	13
1970	10	2	(1)	(1)	2	(1)	37	6	7	1	1	(1)	9	(1)	9	1	146	15
1971	16	4	-	-	1	(1)	51	9	(1)	(1)	1	(1)	(1)	(1)	6	1	165	19
1972	26	6	-	-	3	1	63	17	2	(1)	1	(1)	2	(1)	33	3	200	25
1973	27	10	(1)	(1)	4	1	77	18	5	1	5	1	15	1	34	4	217	33
1974	16	6	-	-	3	1	74	16	3	1	7	1	8	1	16	2	190	30
1975	31	13	2	(1)	10	1	90	24	4	1	6	1	4	1	9	1	222	41
1976	30	15	-	-	7	2	113	35	2	1	6	1	14	2	18	3	227	48
1977	16	9	1	(1)	5	2	82	28	1	(1)	(1)	(1)	7	2	7	1	162	38
1978	2	1	(1)	(1)	(1)	(1)	96	41	-	-	-	-	(1)	(1)	(1)	(1)	282	62
1979	5	4	1	(1)	(1)	(1)	112	49	-	-	-	-	19	6	(1)	(1)	171	54
1980	4	3	(1)	(1)	(1)	(1)	76	33	1	(1)	1	(1)	5	1	1	(1)	235	79
1981	(1)	(1)	(1)	(1)	(1)	(1)	56	28	(1)	(1)	(1)	(1)	1	(1)	8	3	202	85
1982	5	5	1	(1)	(1)	(1)	80	34	-	-	(1)	(1)	2	1	(1)	(1)	381	151
1983	6	6	2	2	1	1	109	51	2	1	(1)	(1)	1	(1)	-	-	336	137

1/ Parentheses indicate less than 500 lb. or \$500.

2/ A dash (-) indicates none reported.

The water quality and other biogenic factors which influence sound wildlife research and management.

The water quality characterizing Georgia's sounds during fall 1983 posed no detriment to the harvest or consumption of white shrimp from this area.

Any other factors based on recent scientific and technological advances which could result in a better management of Georgia's seafood resources.

Since Georgia's sounds had not been opened to commercial shrimp trawling since 1976, it was important that the opening in 1983 coincide with the most advantageous conditions. The opening date was selected to correspond to the earliest neap tides in November, as opposed to opening on spring tides, which would likely result in reduced catches as well as increased hazards for vessels competing in a limited geographic area. Additionally, the sounds were opened well into daylight (8:00 a.m.) as opposed to dawn.

Results

Wassaw, Ossabaw, Sapelo, St. Simons, St. Andrew and Cumberland Sounds were opened to commercial food shrimp trawling on 11 November 1983 by Administrative Order of the Commissioner of Natural Resources. Trawling was allowed only on Tuesday and Friday of each week thereafter through 16 December.

During November 1983, a total of 142,222 lb white shrimp valued at \$669,119 were harvested from six of Georgia's sounds (Table 6). Opening day harvest comprised over 60 percent of the November sounds catch. Premium large shrimp (26/30 count heads-on and larger) comprised 67 percent of that harvest. Whereas September and October catches were 36 and 27 percent below the ten-year average, November catches of 594,399 lb slightly exceeded the ten year average of 571,074 lb. Sound catches in December totaled only 36,343 lb valued at \$145,300. Although the sounds were open during the first half of December, total landings for the month fell below the ten-year monthly average. It is probable the November landings would have been below average had the sounds remained closed. The steady decline of catches from inside waters plus the influx of smaller shrimp into the sounds signaled the need for the 16 December closure of Georgia's sounds to commercial shrimping. Eleven days of harvest yielded 178,565 total pounds of shrimp averaging \$4.56/lb for a total value of \$0.8 million.

CRD's shrimp mark-recapture results indicated the sounds opening strategy was successful in minimizing interjurisdictional loss of production. White shrimp were tagged in November in two of the sounds which remained closed to trawling by law. Tag returns from the area offshore of the release estuary indicated

Table 6. Georgia fall (November - December) inside catch* by sounds. *Preliminary, excludes white shrimp caught in Georgia waters and landed at out-of-state ports.

Sound	White Shrimp Landings					
	November		December		Total	
	Lb.	% Of Total	Lb.	% Of Total	Lb.	% Of Total
Wassaw	7,951	5.6	163	0.4	8,114	4.5
Ossabaw	16,284	11.5	-	-	16,284	9.1
Sapelo	53,261	37.4	13,851	38.1	67,112	37.6
St. Simons	21,677	15.2	7,638	21.0	29,315	16.4
St. Andrew	34,384	24.2	13,401	36.9	47,785	26.8
Cumberland	8,665	6.1	1,290	3.6	9,955	5.6
Total	142,222	79.6	36,343	20.4	178,565	100.0
Value	\$669,119	82.2	\$145,300	17.8	\$814,419	100.0
	<u>Total Landings</u>		<u>Lb.</u>	<u>\$ Value</u>		
	Sounds		178,565	814,419		
	0 - 3 miles		<u>893,983</u>	<u>3,866,068</u>		
			1,072,548	4,680,487		

Table 7. November and December spotted seatrout landings in Georgia by year for 1973-1983.

Year	November Landings		December Landings		Yearly Total	
	Pounds	\$ Value	Pounds	\$ Value	Pounds	\$ Value
1973	2,163	818	1,927	709	26,783	9,800
1974	3,045	2,355	5,298	1,856	16,135	5,790
1975	6,170	4,217	6,460	2,978	30,774	12,861
1976	8,169	2,668	3,665	1,904	29,922	15,189
1977	4,839	49	1,092	589	15,906	8,517
1978	65	265	407	265	2,470	1,513
1979	308	957	1,009	868	4,987	4,199
1980	1,276	171	495	297	4,250	3,358
1981	198	1,721	198	171	629	566
1982	1,874	171	557	606	4,994	4,754
1983	2,032	2,130	671	738	5,722	5,781
Total Average	2,739	1,411	1,980	998	12,961	6,575

NOTE: Reported landings caught primarily by hook and line.

some migration occurred from these closed areas during the period the sounds were opened. However, the greatest movement occurred during the period of severe cold weather which occurred after the sounds closure. Tag returns from waters offshore from the release area declined in the days following the Christmas 1983 freeze while the number recaptured in Florida waters dramatically increased (Figure 7). If the sounds had remained closed during fall 1983, a significant portion of Georgia's fall crop might again have been lost to the Florida fishery as happened following the December 1980 cold front.

CRD assessment trawls conducted from 3-9 January indicated the record Christmas freeze caused widespread shrimp mortality in Georgia. Surface water temperature dropped from 15.5°C to 4°C in only four days. During the coastal monitoring north of the Altamaha River, 40 percent of the white shrimp caught in assessment trawls were dead. Southern sampling yielded 20 percent mortality of the shrimp trawled. The size of shrimp most severely impacted were large. Thus, had the sounds not been opened to trawling such that many large shrimp still inhabited these areas, the cold front could have caused mortality of the premium shrimp, resulting in economic loss to Georgia's shrimp fishing industry.

The conditional opening strategy was successful with respect to minimizing socioeconomic conflicts between commercial food shrimpers. As previously mentioned, there was a shift in size composition of Georgia's fleet toward larger trawlers during the sounds closure. Even in 1983 when the sounds were opened, only 33% of licensed trawlers were less than 20 feet. The timing and short term nature of the opening apparently effected little overall size redistribution of trawlers in the Georgia fishery. However, of the 160 new licenses sold following the opening, over two-thirds were sold to smaller trawlers, and opening the sounds increased participation in the fishery for a limited period by more diverse user groups. Of the trawlers licensed after 10 November, 37 (54 percent) were sold to Georgia residents. Georgians accounted for 80% of the total 1983 license sales as compared to 83% in both 1981 and 1982. The conditional sounds opening had little impact on trawler license residency pattern.

At the hour of official opening of Georgia's sounds to shrimping on 11 November, 430 trawlers were observed by over-flight in the six sounds opened to trawling. These trawlers included both vessels (five net tons or greater, typically greater than 32 feet in length) and boats (less than five net tons, typically 32 feet or less in length). By early afternoon, 17 percent of the observed fleet was fishing offshore waters. One week later, on the third day of shrimping in the sounds, 27 percent of the trawlers were in offshore waters. Thus, following the initial opening hours, trawlers were shrimping in both inside and outside waters.

The lowered blue crab production and economic hardship reported by a few individual potters as a result of the sounds

opening was not realized throughout the industry. November 1983 blue crab production of 1,055,264 lb exceeded the ten-year average (789,848) by 32 percent. December landings of 488,980 lb were 70 percent above the 286,917 ten-year average. Based on an average \$.16/lb, landings in excess of the ten-year November-December average were valued at \$74,797.

CRD observers participated in commercial trawling operations on 11 November so as to evaluate the by-catch of trawling in Georgia's sounds. As expected, biologists observed negligible impact on recreationally important finfish. After 7.5 hours of trawling in St. Simons Sounds, the CAPTAIN DAVE netted a total catch of 2,615 lb of fish, shellfish, and trash. Gamefish (categorized to include: weakfish, flounder species, spotted seatrout, whiting, bluefish, croaker, spot, red drum, black drum, and sheepshead) comprised only 5 percent of this total. Shrimp comprised 50 percent of the total catch while scrap fish and debris accounted for 45 percent. By-catch of Georgia's most popular recreational species, spotted seatrout and red drum, was negligible. These species are fast swimmers and prefer the rarely trawled oyster reefs, thus easily avoiding capture in trawl nets. Additionally, there was no appreciable increase in commercial landings of spotted seatrout in November and December of 1983 (Table 7) which presumably would have resulted from increased trawl catches as a result of the sounds opening.

Only 13 lb (11 percent) of the gamefish caught were flounder. Results of recent life history studies conducted by DNR biologists on recreationally important finfish suggest creel size summer flounder (two years and older) generally emigrate from Georgia's estuaries. Also, tagging results from this study suggest southern flounder (Paralichthys lethostigma) are probably underharvested by recreational anglers in Georgia (Music and Pafford 1984).

Results of the K-Mart/Brunswick Jaycees First Annual Spotted Seatrout Tournament held on 12-13 November following the sounds opening on the 11 November further suggest the negligible impact of trawling in the sounds on recreationally important finfish species.

Although 78 anglers entered, it was not known exactly how many participants succeeded and caught fish as many anglers opted not to weigh in their catches if their creel would not exceed the totals already posted. This was evidenced by the lack of second-day entries in the largest fish category. Outstanding catches of 152.25 lb and 125.75 lb were made by angler teams on the first and second day. With the trout entered averaging approximately one pound, the tournament total of 632.8 lb represented approximately 600 fish. Excellent catches of red drum ranging in size from one to nine pounds were also observed and photographed at the weigh station. Other fish caught during the tournament included black drum and sheepshead.

Impacts of the sounds opening on environmentally sensitive species were also negligible. No sea turtles or marine mammals were reported by DNR Law Enforcement personnel patrolling the waters or by observers on trawlers in three heavily fished sounds. Unconfirmed reports of incidental capture of several Ridley sea turtles (Richardson, pers. comm.) were attributed to the success of the Florida Headstart Program which has released large numbers of year-old turtles.

Discussion

The objective of Georgia's marine fishery management program is to regulate the use of common property fishery resources to provide maximum benefit to all resource users within the state while insuring the viability of future stocks. State laws mandating consideration of biology, population dynamics, environmental conditions, social and economic considerations, and impacts on other resources are imperative to accomplishing this objective. Flexibility such as is currently provided by Georgia statutes is necessary for responsible management of marine species such as shrimp, whose stock abundance and behavior are environmentally regulated.

Perhaps the best example of the application of flexible fisheries management of Georgia's marine fishery resources in recent years was the decision to open the sounds to commercial shrimp trawling on a limited basis during November and December. During this period of environmental extremes, maximum yield in weight and value was approached through inshore harvest of premium value shrimp inhabiting Georgia's sounds. The conditional strategy minimized adverse impacts on users of the shrimp resource as well as other resources. Opening of Georgia's sounds occurred during the period when crabbing normally declines in the sound, when the most important recreational finfish, spotted seatrout, inhabit the creeks and rivers, and when environmentally sensitive species (e.g., sea turtles) do not inhabit the sounds. Conditional harvest on two non-consecutive weekdays minimized any potential conflict between recreational and commercial fishermen. Former sound limits were realigned to target harvest of predominately larger, adult shrimp while ensuring the protection of subadult and juvenile shrimp and other resources inhabiting the creeks and rivers. Although controversial, the decision to open Georgia's sounds on a limited basis to commercial shrimp trawling during portions of November and December 1983 effected prudent, responsible management of the state's valuable shrimp fishery.

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Appendix A

ARTICLE 4
SEAFOOD
PART I
GENERAL PROVISIONS

27-4-130. Factors governing decision to open or close salt waters; of opening or closing of water.

(a) When this article provides that a determination to open or close any of the salt waters of this state, or to allow or disallow the use of certain equipment, is to be made in accordance with current, sound principles of wildlife research and management, such determination shall be made only after a consideration of the following:

- (1) The abundance and size of the seafood species in question;
- (2) The number of persons licensed to take seafood;
- (3) The department's forecast for commercial catches;
- (4) The quantity, in terms of pounds, and the value, in terms of dollars, of anticipated commercial landings;
- (5) The available climatological and meteorological data and influence of water temperature;
- (6) The life history of each seafood species in question;
- (7) The coastal ecological features directly related to the life history of such species;
- (8) Anticipated amount and location of the demand for a seafood species;
- (9) The resources which influence or are influenced by the abundance of and the spatial and temporal variations in seafood species;
- (10) The water quality and other biogenic factors which influence sound wildlife research and management; and
- (11) Any other factors based on recent scientific and technological advances which could result in a better management of Georgia's seafood resources.

THE RELATIONSHIP OF FISH CONSUMPTION AND MERCURY
CONTAMINATION IN THE ST. JOHNS RIVER

Lori L. Beason, Walter Honour,
Kim I. Miller, A. Quinton White

INTRODUCTION

Mercury contamination of aquatic environments is a widespread problem. Much of the mercury in water can be attributed to industrial wastes from pre-1975 chloralkali operations and pre-1972 paper pulping operations (May and McKinney 1977). It is estimated that up to 230 metric tons of mercury are released annually into water by weathering processes including erosion of rocks and sediments. Coal combustion may release as much as 3,000 metric tons of mercury and mercury compounds per year which can also contaminate the aquatic environment through atmospheric deposition (F.D.E.R., 1984).

Mercury contamination of the environment has declined sharply since the 1960's when the adverse health impacts of mercury became widely known. Contaminated sediments are still a prominent mercury source (May and McKinney 1977). High concentrations of mercury were found in sediments over 100 miles downstream from a synthetic fiber plant which had discontinued mercury use 27 years earlier (May and McKinney 1977).

Swedish scientists found that microorganisms could transform relatively harmless elemental mercury and inorganic mercury salts into the highly toxic methyl mercury (Miller 1975).

Aryl organic mercury, $C_6H_5Hg^+$ and $(C_6H_5)_2Hg$, is moderately toxic and exhibits a short retention time in tissue, but it is rapidly transformed by the body, or in the environment, into inorganic mercury, Hg and Hg^{+2} . Inorganic mercury also exhibits moderate toxicity and a short retention time in the body (Miller 1975). The threat of mercury poisoning begins when inorganic mercury salts are converted by microorganisms into aryl organic mercury. These methyl and dimethyl compounds are highly toxic and are readily concentrated within the food web (Miller 1975).

Symptoms of mercury poisoning in humans include headaches, fatigue, irritability, and tumors along with other nervous disorders. These symptoms may surface weeks or months after initial exposure to toxic levels of mercury. Inorganic mercury damages the kidneys, liver and brain by concentrating in these organs (Ehrlich et al. 1977). Methyl mercury also concentrates in the membranes of red blood cells and the nervous system. Biological

half-life in humans is approximately 70 days (Berlin in Ehrlich et al. 1977).

Accumulation of methyl mercury within the food web is influenced by many factors. Mobility characteristics of an organism may limit the amount of time spent in a contaminated region. The temperature of the water in a contaminated zone will influence the amount of time the organism spends in that area. The extent of mercury contamination of the area is another essential element, as is the size and life stage of the organism. Species trophically higher in the food web are likely to have higher concentrations of mercury.

The current Florida Department of Environmental Regulation (F.D.E.R.) maximum standard for total mercury in the marine environment is 0.10 ug/l (Table 1). While inorganic mercury compounds have been proven to cause mortality in fish larvae at levels of 0.10 ppb, methyl mercury at 0.06 ppb inhibits reproductive capacities (Anonymous 1984).

Table 1. Water quality criteria for mercury as established by the Florida Department of Environmental Regulations, Chapter 17, Paragraph 3.

MERCURY		
CLASS I	Potable Water	0.20 ug/l
CLASS II	Shellfish Harvesting	0.10 ug/l
CLASS III	Recreational Waters	
	Marine	0.10 ug/l
	Fresh	0.20 ug/l

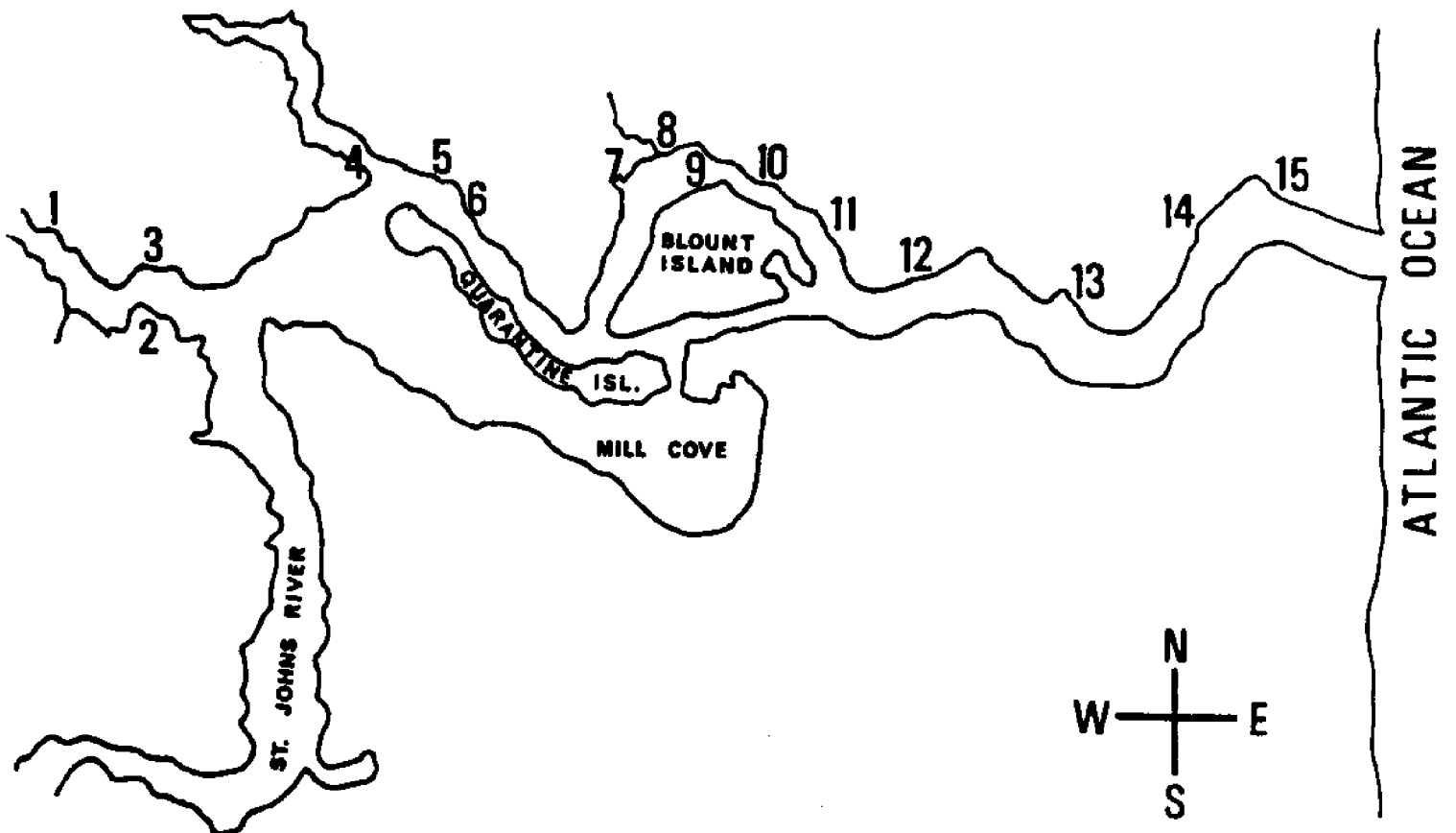
Public susceptibility to mercury contamination is largely determined by their fish consumption patterns. Fish consumption is a function of the seasonality of a species and the dominance of one species over another. Weather and water conditions influence the extent of fishing and the amount of available fish. Dietary or economic restrictions of individuals could also increase the rate of fish consumption by excluding other sources of protein from the diet.

In this study, the high-risk population is defined as those individuals who use fish from the St. Johns River as a primary source of protein. In some instances, the target population purchases fresh fish from local vendors. In most cases, however, the high-risk individuals fish regularly and consume their own catch. Therefore, the individuals at highest risk are those who consume the greatest quantities of fish from the St. Johns.

Methods

To determine the high-risk population, interviews of local fishermen were conducted from September 1983 through May 1984 at 15 sites along the lower St. Johns River (Figure 1). The main objective of the survey was to determine the number of pounds of fresh fish, by species, that were consumed per person per week in a given household. Other objectives included determination of the extent of fishing in a given region, the distance traveled to

Figure 1. Map of the St. Johns River showing the 15 interview sites.



Location

- | | |
|-------------------------------|-----------------------------|
| 1. Bert Maxwell Park | 9. Blount Island Old Bridge |
| 2. South Main Street | 10. Browns Creek Bridge |
| 3. North Main Street | 11. Clapboard Creek Bridge |
| 4. Broward River Bridge | 12. Milton Drive |
| 5. Dunns Creek Bridge | 13. Sisters Creek Bridge |
| 6. Dunns Creek Bulkhead | 14. Haulover Creek Bridge |
| 7. JEA Northside Gen. Station | 15. Huguenot Park |
| 8. San Carlos Creek Bridge | |

the survey site, occupation and age bracket of the individual, and the uses of the fish caught. Collections of organisms were taken from the river for analysis of mercury levels in their edible portions. The species targeted for sampling are listed in Table 2.

Table 2. Species sampled for mercury contamination and criteria for selection of each species.

<u>SPECIES</u>	<u>REASON FOR SELECTION</u>
<u>Cynoscion nebulosus</u> (Spotted Sea Trout)	8th highest commercial tonnage; Carnivore - feeds on smaller fish and shrimp; potentially high bioaccumulation; significant human consumption.
<u>Mugil cephalus</u> (Striped Mullet)	Highest commercial tonnage; Omnivore - feeds on detritus and deposits; significant human consumption.
<u>Micropogon undulatus</u> (Croaker) <u>Leiostomus xanthurus</u> (Spot)	20% of spring harvest; Carnivores - feed on small fish and shrimp; use estuary as nursery; pool dwellers; significant human consumption.
<u>Callinectes sapidus</u> (Blue Crab)	Year round resident crustacean; Omnivore - scavenger - feeds on plant and animal material; significant human consumption from commercial and recreational sources.

Each sample consisted of approximately 20 to 30 relatively mature individuals of each species. Immediately after capture, each individual was wrapped in aluminum foil, placed on ice, and later frozen in the laboratory until they could be processed for analysis. The samples were sent to the U.S. Geological Survey (U.S.G.S.) Central Laboratory where the edible portions of each organism were removed and homogenized into bulk samples for mercury determination.

Results

A total of 807 interviews were conducted at the 15 sites on the north side of the St. Johns River. The participant profile shown in Table 3 summarizes the results of the interviews. The

distribution of meals per week is shown in the histogram in Figure 2. Meals ranged from one per month to one per day.

The interview analysis in Table 4 shows for each location: the number of trips made to that site, the number of interviews conducted, the number of fishermen present and the number of repeat interviews. These data were used in estimating the total fishing population of 7,162 for the study sites. This calculated total fishing population value was based on capture-recapture principles. The initial capture is represented by all of the fishermen interviewed less those questioned during the last sample since those individuals cannot be reinterviewed (807-26). The recapture effect is seen in the total number of fishermen which were interviewed an additional time (88). The fishermen reinterviewed represent the dilution factor in the population, hence, the number interviewed less the last sample multiplied by the total number interviewed divided by the number of repeat interviews (807/88) represents the total fishing population (Figure 3.)

An analysis of fish caught (Table 5) shows the distribution, by species, at each site. The dominant fish reported was croaker (Micropogon undulatus), with catfish (Ictalurus sp.), spot (Leiostomus xanthurus) and spotted seatrout (Cynoscion nebulosus) also being taken in relatively large numbers.

Mercury analysis (Tables 6 and 7) showed a worst-case of 1.00 ug/g in catfish. The reported worst-case for water quality in the St. Johns River was 0.50 ug/l (U.S.G.S. data).

Table 3. Profile of individuals interviewed, and meals per week at which river fish/shellfish were consumed.

PARTICIPANT PROFILE				
	Average		Median	Range
Age	40.20	\pm 12.20	36.00	12.00 - 79.00
Family Size	3.40	\pm 1.50	3.00	1.00 - 10.00
No. of Meals/Week	1.40	\pm 0.69	1.00	0.25 - 7.00

Figure 2. A comparison of the population interviewed and the number of meals of fish consumed per week.

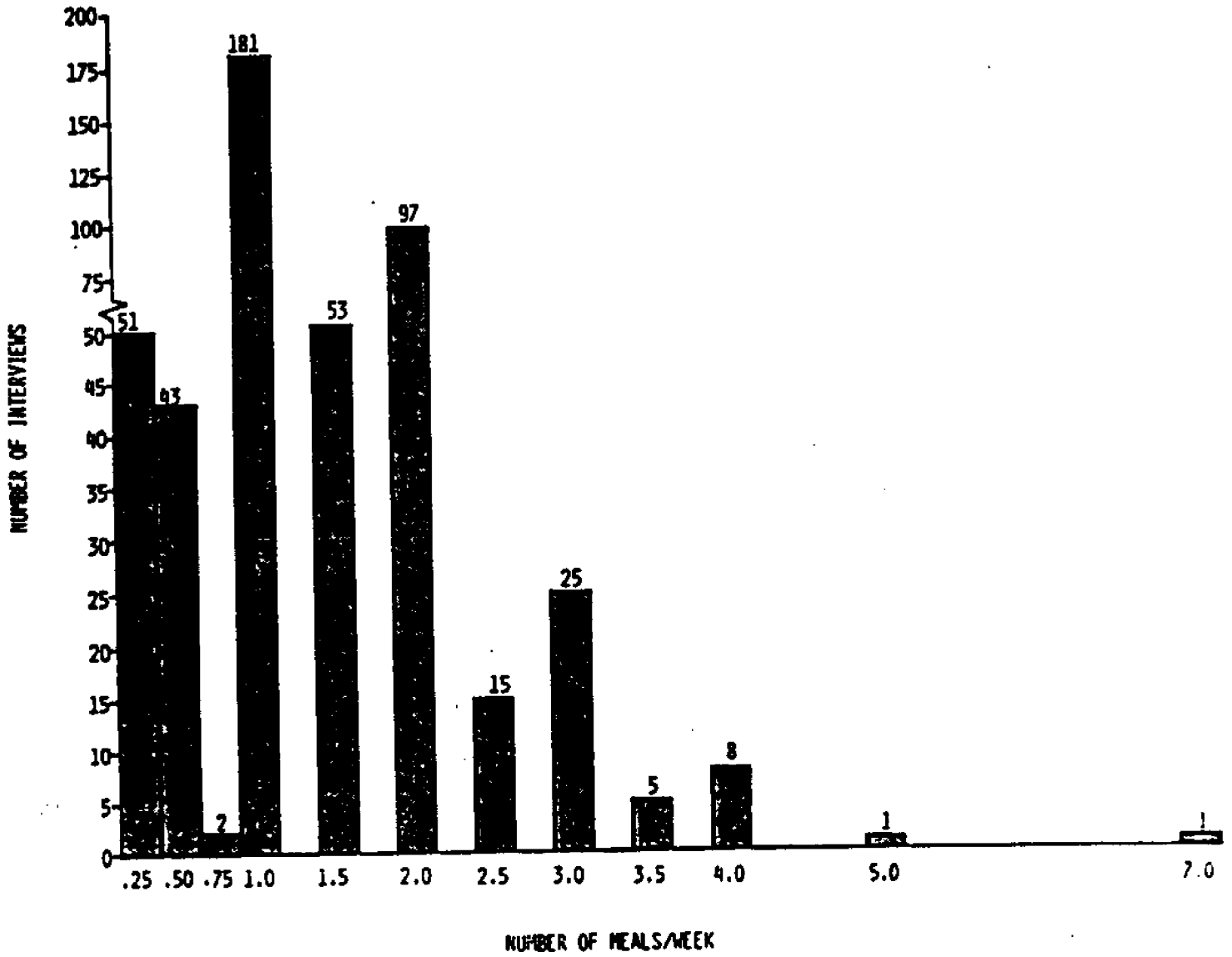


Table 4. Distribution analysis of interview information.

INTERVIEW ANALYSIS				
Location	No. of Trips	No. of Interviews	No. of Fishermen	No. of Repeat Interviews
1. Bert Maxwell Park	20	42	60	2
2. S. Main Street	27	14	68	0
3. N. Main Street	29	108	125	19
4. Broward River Bridge	35	28	46	2
5. Dunns Creek Bridge	34	48	65	2
6. Dunns Creek Bulkhead	16	8	28	0
7. JEA Northside Generating Station	18	7	31	0
8. San Carlos Creek Bridge	28	7	22	1
9. Blount Island Old Bridge	46	305	444	36
10. Browns Creek Bridge	36	121	141	20
11. Clapboard Creek Bridge	29	45	64	5
12. Milton Drive	7	7	22	0
13. Sisters Creek Bridge	26	51	73	0
14. Haulover Creek Bridge	20	8	6	1
15. Huguenot Park	8	8	8	0
TOTAL	379	807	1,203	88

Figure 3. Fishing population estimate.

$$\begin{aligned} \text{Population} &= \frac{(\text{No. Interviewed}) (\text{No. Interviewed-last Sample})}{(\text{No. of Repeat Interviews})} \\ &= \left(\frac{807}{88} \right) (807-26) \\ &= 7,162 \end{aligned}$$

Table 5. The distribution of species caught at each of the 15 interview sites.

CATCH ANALYSIS																
Organism	Site															TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Bass	31	0	103	26	38	7	1	2	110	143	28	35	12	16	10	562
Blue	4	0	6	0	9	0	0	0	44	80	6	2	17	11	2	181
Brim	5	0	61	12	6	0	0	0	65	58	60	0	0	0	0	267
Catfish	46	25	204	74	77	10	5	8	988	241	86	5	172	17	10	1,968
Croaker	165	44	665	95	183	16	10	7	2518	941	367	0	192	0	0	23,320
Drum	4	3	33	10	16	7	0	0	98	60	13	5	20	1	0	270
Flounder	13	1	44	0	9	1	100	0	23	40	8	22	0	1	4	266
Mullett	0	12	0	13	1	0	0	0	7	0	0	0	0	0	0	33
Sheepshead	1	1	82	4	3	0	0	0	41	97	7	2	3	0	0	241
Spot	8	18	98	19	85	10	1	0	676	562	219	0	139	0	0	1,835
Spotted Trout	16	2	69	30	75	1	0	8	151	359	75	30	23	26	54	1,705
Whiting	0	3	121	1	11	0	0	0	245	37	30	2	36	0	0	486
Yellow Mouth Trt.	9	3	55	16	6	6	0	1	72	31	18	20	19	0	0	256
Yellow Tail	0	6	81	16	31	15	0	4	90	97	79	0	309	0	0	728
Crabs	98	6	155	12	35	0	88	0	243	150	14	0	15	15	0	831
Unidentified Spp.	2	4	144	25	19	4	8	7	75	76	20	18	20	1	1	424

Table 6. 1983 Mercury concentrations in prominent species.

MERCURY CONCENTRATIONS IN ST. JOHNS RIVER FISH - 1983			
	No.	Maximum Concentration (ug/g)	Average Concentration (ug/g)
Croaker	4	<0.01	<0.01
Spot	51	<0.01	<0.01
Yellow Trout	11	0.14	0.06
Spotted Trout	5	<0.01	<0.01
Crab	11	0.03	0.02

Table 7. 1984 Mercury concentrations in prominent species.

MERCURY CONCENTRATIONS IN ST. JOHNS RIVER FISH - 1984

	No.	Maximum Concentration (ug/g)	Average Concentration (ug/g)
Blue Crab	116	0.23	0.12
Jacks	17	0.76	0.46
Yellow Trout	19	0.37	0.17
Spotted Trout	13	0.23	0.13
Catfish	20	1.00	0.52
Bluefish	3	0.57	0.50
Flounder	2	0.10	0.09
Spot	83	0.36	0.10
Red Bass	2	0.24	0.19
Mullet	27	0.31	0.21

Discussion

Mercury poisoning in humans may result from ingestion of contaminated aquatic organisms. The maximum safe limit of total mercury in water from which aquatic organisms are caught and eaten was determined to be 0.10 ug/l (Sittig 1980). Mercury levels of 0.50 ug/l were found in water samples from the St. Johns River. The U.S. Food and Drug Administration (U.S.F.D.A.) standard for mercury in fish flesh is 1.00 ug/g (Sittig 1980); the St. Johns fish have reached this level with a maximum concentration of 1.00 ug/g in catfish and an average concentration of 0.18 ug/g for all species analyzed.

The worst-case contamination, calculated from test and interview results, was ingestion of 200 ug Hg/day (Figure 4.C). This figure is based on the highest mercury content found in collected fish and the maximum amount of fish consumed per person per day as determined by interviews. The potential worst-case is based on water contamination, potential bioaccumulation, and maximum fish consumption per day which results in a value of 620 ug/day (Figure 4.D). The documented Lowest Observable Effect Level (LOEL) ranges from 200 to 500 ug/day (Sittig 1980).

Although the mercury concentration in some areas of the St. Johns exceeds the Florida D.E.R. limit of 0.10 ug/l, only one species of the fish tested has met the F.D.A. standard of 1.00 ug/g. Yet, the observed worst-case contamination of 200 ug Hg/day for individuals in this study is within the LOEL range. The possibility also exists for an individual to regularly consume 620 ug of Hg/day based on the potential bioaccumulation factor of 6,200 and water quality data (maximum of 0.50 ugHg/l) (Figure 4.D). These levels of consumption introduce the potential for adverse health effects in humans.

The current mercury levels in the St. Johns suggest complications for individuals consuming fish from the river; therefore monitoring should continue. This point may be illustrated by the apparent increase in mercury concentrations in the fish from 1983 to 1984 (Tables 6 and 7). The possibility of the mercury levels dissipating over time exists only if no further contamination occurs. This is unlikely because of natural weathering processes and industrial activities. Continual efforts should be made to avoid additional mercury contamination of the river.

Figure 4. Bioaccumulation and contamination calculations based on the 1984 experimental data.

$$\begin{aligned}
 \text{A. Observed Bioaccumulation Factor} &= \frac{\text{Mercury Concentration in Fish}}{\text{Mercury Concentration in Water}} \\
 &= \frac{1.00 \text{ ug/g}}{0.5 \text{ ug/l}} \\
 &= \frac{1,000 \text{ ug/kg}}{0.5 \text{ ug/l}} \\
 &= 2,000
 \end{aligned}$$

B. Potential Bioaccumulation Factor:

$$\begin{aligned}
 \text{Published Range} &= 900 - 63,000 \text{ (Sittig 1980)} \\
 \text{Adopted Average} &= 6,200^*
 \end{aligned}$$

$$\begin{aligned}
 \text{C. Observed Worst-Case Contamination} &= (\text{Highest Mercury Concentration in Fish}) (\text{Highest Fish Consumption/day}) \\
 &= (1.00 \text{ ug/g}) (200 \text{ g/day}) \\
 &= 200 \text{ ug/day}
 \end{aligned}$$

$$\begin{aligned}
 \text{D. Potential Worst Case Contamination} &= \text{Water Concentration (Potential Bioaccumulation Factor X Highest Fish Consumption/day)} \\
 &= 0.5 \text{ ug/l (6,200 X 0.2kg/day)} \\
 &= 620 \text{ ug/day}
 \end{aligned}$$

*The bioaccumulation factor for fish and shellfish has an estimated value of 6,200 (Sittig 1980).

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COLONIZATION AND UTILIZATION OF A CONCRETE ARTIFICIAL REEF
OFF THE GEORGIA COAST BY INVERTEBRATES AND FISHES

Matthew R. Gilligan

Introduction

The efficacy of using artificial reefs to attract fish and as a fishery management tool is well known (Bohnsack and Sutherland 1985), especially in Japan where they are intensively and extensively used in commercial fisheries (Vik 1982). In the United States, they have been developed by all levels of government and private organizations principally to enhance recreational and sport fishing (Steimle and Stone 1973, Artificial Reef Development Center 1985). Artificial reefs have been used as a mitigation measure to offset the loss of marine habitats by coastal development (Bair and Feigenbaum 1984), and methods to measure the economic value of artificial reefs in the U.S. have been proposed (Sport Fishing Institute 1985).

Artificial reefs serve to attract and concentrate fishes by 1) functioning as orienting devices for adult midwater and migratory schooling fishes (e.g. jacks, mackerels, barracudas, Atlantic spadefish, cobia), 2) providing sites for colonization of the planktonic larvae for reef fishes (e.g. snappers, groupers, tropicals) and, 3) providing habitats for resident reef fishes. The spatial heterogeneity of reefs in general and reef height diversity in particular (Molles 1978) seem to contribute to higher reef-fish species diversity while higher productivity of some target reef fish species (e.g. black sea bass) seems to be a result of low reef profile and wide spatial distribution of reefs (Feigenbaum 1984). Floating structures suspended in the water column (Fish Attracting Devices or FADs) attract baitfish schools and larger pelagic fishes offshore, but improvement of fishing nearshore (near fishing piers) has not been unequivocally shown (Murray et al. 1985).

It is evident to both researchers and fishermen that artificial reefs increase finfish productivity when placed in reef-poor localities. In 1983, no less than seven Georgia saltwater gamefish records were fishes taken at artificial reefs in Georgia (Savannah Sport Fishing Club 1984). It has not been shown, however, that artificial reefs actually increase the net production of the shelf. In other words, would the primary productivity which ends up as reef fish biomass have ended up as just as much fish biomasses in a benthic or pelagic ecosystem? If it does, then it would be improper to say that artificial reefs increase shelf production. Davis et al. (1982) showed that artificial reefs can change the composition and density of

adjacent benthic communities up to 200 m away. Testing a shelf-wide hypothesis may be nearly impossible.

It is also difficult to compare the production of fishes on natural reefs to that of artificial reefs. Natural reefs show wide geographically and topographically-related variation in fish community structure (Hiatt and Strasburg 1960, Jones and Chase 1975, Gilligan 1980, Thomson and Gilligan 1983). Comparisons of artificial to natural reefs have been made and, in general, artificial reefs seem to attract higher densities of fish than natural reefs. However, most of these studies (see Bohnsack and Sutherland 1985) have not standardized, quantified, or replicated, reef structural complexity and distribution, factors that may significantly effect their utilization by fishes and have not addressed questions of production, productivity, and reef fish community structure.

For the most part, Georgia's broad sandy shelf is reef-poor. The only significant natural reefs (also called live bottoms) are located 35 miles offshore in the 30-40 m isobath range (e.g. Snapper Banks) and 18 miles offshore in the 18-21 m isobath range (e.g. Gray's Reef National Marine Sanctuary). Since 1970, the Coastal Resources Division of the Georgia Department of Natural Resources and local sport fishing organizations have undertaken the deployment of artificial reefs in the near-shelf zone (<20 m depth) to enhance recreational and sport fishing resources of the coast. To date, the effort totals 130,000 scrap automobile tires and 14 surplus vessels ranging in length from 33 to 444 feet at eight buoy-marked locations along the coast. The selection of materials to be used in these reefs was usually based upon material and transport availability (donations), and considerations regarding the persistence of the material once in place (will it move or break up causing a hazard/nuisance to shipping or commercial fishing?; Ansley, pers. comm. 1983).

On March 31, 1983 through efforts of the Savannah Sport Fishing Club, Inc. and other contributing organization and individuals, 407 tons of surplus precast concrete culvert and pipe material comprizing 249 pieces was offloaded from a barge in the area of an already established artificial reef (reef 'L'; buoy at 31° 45.4 N., 80° 36.5 W.) establishing Georgia's first concrete reef. The purpose of the effort was to enhance recreational and sport fishing.

In view of 1) increasing coastal populations and demand for fishing resources, 2) the increasing role of private sport fishing groups in artificial reef development and 3) recent federal legislation designed to make it easier for private organizations to build fishing reefs, there is a need for information on artificial reef type effectiveness and persistence in the South Atlantic Bight. This report summarizes an effort to develop techniques for monitoring the colonization of the reef by invertebrates and fishes.

Methods

The concrete material used for the reef consisted of 249 commercial, iron-reinforced precast culvert and pipe sections. The cylindrical and box-like structures were up to 2.4 m in longest dimension with one or two open sides and smaller openings. Some smaller pieces and rubble were created incidental to the loading and dumping process.

The material was unloaded from an unanchored barge over an area of approximately 100 by 200 meters (depth 18-20 m) in the vicinity (100 m at 120-130 degrees magnetic from the maintenance buoy) of the Georgia Department of Natural Resources artificial reef 'L' which is located 20 nmi (nautical miles) ESE of Wassaw Island, Georgia (Figure 1). Materials already at the site, which was established in March 1977, include two steel barges, 2,000 tire units and a 150-foot dredge.

Monthly sampling, visual observation and photography programs were conducted for five months after the material was dumped (table 1). Each month, during one 50-minute SCUBA dive at the reef site (depth 18-20m), small, loose pieces of exposed concrete with marine growth were collected, a rapid visual assessment of fishes was done, and close-up underwater photographs of concrete surfaces were taken. Following the five monthly visits, close-up photography and visual assessment was done three times over the next 13 months.

Concrete samples were returned to the laboratory where they were analyzed for the size, density and diversity of encrusting growth. Each rapid visual assessment of fishes was done near at least three large concrete pieces and recorded on water-resistant paper and underwater clipboard. No predetermined swimming pattern, transect, or search pattern was followed for the visual assessment. Each species seen on or around the concrete and estimates of the average sizes of individuals were recorded. Underwater close-up photography of outside, inside and edges of concrete structures was done using a Nikonos IV-A 35 mm camera, SB-101 electronic flash, 1:3 close-up extension tube, 35 mm lens and either Kodachrome 64 or Ektachrome 64 (ASA 64) transparency film. Water temperature, salinity and an estimate of water clarity (visibility) were also noted during each trip to the reef.

Results

Invertebrates

Colonization of the concrete surfaces by barnacles, bryozoan colonies, serpulid worms, hydroid colonies, algae, ascidian colonies, anemones and sponges was rapid. Barnacle settlement and growth was most dramatic during the first five months. Underwater photographs showed nearly 100 percent cover of concrete surfaces by barnacles on some concrete surfaces after only

one month. Densities and barnacle sizes are given in Table 1. Maximum barnacle densities were observed on outside concrete surfaces particularly near upper edges of the structures while inside surfaces remained relatively clean (<0.01 barnacles/cm²).

After the first month, hydroid colonies had grown to 1 cm in height, and the calcareous tubes of serpulid worms were detected on concrete surfaces. After the second month, the serpulid worms were well established and two kinds of byozoans (flat colonies in calcified radiating rows and branched stalk colonies) were established. After the third month, some of the flat bryozoan colonies had overgrown serpulids and barnacles or met other colonies in a stand-off, ascidian colonies had become established, and many surfaces were still dominated by barnacles. After the fourth and fifth months, the increasingly complex encrusted surfaces had acquired anemones, filamentous red algae, crustaceans (amphipods and decapods), gastropod mollusks, sponges, octocorals, and asteroidean echinoderms.

Fishes

Results of the visual observations of fishes are summarized in Table 2. All 20 of the fish species seen on or near the concrete during the study are common near natural and artificial reefs of the inner and midshelf of the South Atlantic Bight (Gilligan ms).

Adult black sea bass were common in and around the concrete after only one month. Most of the fishes utilizing the reef during the study period were adults of resident reef species that have planktonic (drifting) eggs and larvae rather than those that deposit their eggs on the reef (e.g. blennies, gobies, damselfishes). Small juveniles of the black and rock sea bass,, sand perch, scup, gray triggerfish, squirrelfish, and whitespotted soapfish were observed at the reef indicating that not all colonization was by the migration of adults from nearby established reefs. Pelagic fishes (e.g. jacks, mackerals, cobia) were not easily observable due to poor visibility (<8 m) during most of the visits.

Characteristic of inner and midshelf reefs of the Georgia Coast, the density and diversity of fishes decreased dramatically during the winter months (data not included).

Discussion

Higher densities and growth of barnacles on the outer surfaces and edges of the concrete structures suggests that either the rate of planktonic propagule (egg or larva) arrival is higher in these areas or that, once settled, feeding rates, hence growth rates were higher in these areas. Since this area of the shelf is characterized by significant currents and since propagule and food-bearing water currents near exposed surfaces would likely be higher than near protected inner reef surfaces, this might

explain both higher immigration and faster growth on exposed surfaces. The barnacle data shows that colonization is a constant process since small size barnacles (newer colonists) were present in all areas throughout the study. Growth inhibition is not suspected because mean barnacle size was not significantly lower in high density area.

The physical appearance of the encrusting growth persisted while fish diversity declined during the winter. Close-up underwater-photographs revealed that the growth and colonial proliferation among colonizing sessile species, which began within months of placement, were characterized by inter- and intra-specific competition for space resulting in a mosaic of encrusting growth. More importantly, the added dimensionality and topographic complexity of the reef created by the encrusting growth (e.g. barnacles, bryozoan colonies, serpulid worms, hydroid colonies, ascidian colonies, anemones and sponges) appeared to permit a succession of other organisms to establish themselves on the reef (e.g. small mollusks, crustaceans, annelids, echinoderms and fishes). The resulting wider resource spectrum of the reef. (i.e. food and microhabitats) could, in turn, further increase the species diversity since, in general, a wide resource spectrum in a habitat permits more species to coexist.

Lowered fish diversity and abundance at the reef during the winter is most likely the result of low water temperature. Winter sea temperatures at this site, which is near the inner/midshelf margin, average less than 15° C (Atkinson, pers. comm.). These temperatures are near if not below the lethal thermal minimum of many tropical species which are common on natural and artificial reefs in this area during the summer and fall.

It appeared that the shape of the concrete structures, while large and stable, did not initially provide the smaller holes and interstices necessary as refuge for smaller fishes especially the post larvae and juveniles of reef species. During the first months, juveniles and smaller reef fishes were normally seen only in broken concrete rubble. It appeared that appropriate refuges for juvenile reef fishes were in short supply on most of the structures during this early period. This was particularly evident on occasions during visual observations when juvenile reef fishes (e.g. whitespotted soapfish) were observed lying flat against partially encrusted concrete surfaces--no other cover (e.g. crevice or hole) being available.

Dumping of the 249 concrete units individually from an unanchored barge resulted in a scattered pattern on the bottom, although some aggregations of 8 to 13 units each were found. The inability to survey the entire reef prohibited making overall assessments of fish population at the reef. Poor visibility during visits to the reef necessarily decreases the accuracy/repeatability of visual assessment of fishes. The data from the visual assessment must also be viewed in light of a significant

but unquantified harvest of fishes from the reef by recreational fishermen, divers, and commercial trap fishing. Nonetheless, the methods developed and employed in this study may be useful in future efforts to identify the important structural and ecological factors that determine the productivity of artificial reefs of the South Atlantic Bight.

Biological studies of artificial reefs coupled with oceanographic, hydrographic, and climatological information are necessary to predict and understand the processes that regulate the productivity of both artificial and natural reefs. Improved quantitative assessment of artificial reefs, reef communities and biotic changes that occur on them are necessary to effectively evaluate artificial reef type effectiveness (Bohnsack and Sutherland 1985). The information derived from artificial reef studies will be directly or indirectly useful to those who develop, manage, and use them.

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Table 1. Summary of barnacle growth and density on the concrete artificial reef at the 'L' buoy during the first four months after placement. md = mean barnacle density in individuals per cm² in the most dense areas of barnacle growth, mxd = maximum barnacle density in individuals per cm², ms = mean barnacle size in millimeters (longest basal dimension), mxs = maximum barnacle size, and mns = minimum barnacle size.

Date	md	mxd	ms	mxs	mns
4-29-83	11.0	14	3.23	4.1	2.3
5-29-83	8.7	12	4.89	6.1	1.8
6-25-83	4.9	6	5.13	10.8	1.3
8-09-83	4.3	6	6.84	15.2	1.5

Table 2. Results of visual observations fishes at the concrete artificial reef at 'L' buoy during five monthly visits to the reef after its establishment. j=juveniles, a=adults, () = estimated size or size range of individuals in centimeters.

Species	4/29/83	5/29/83	6/25/83	8/9/83	9/9/83
1. <u>Centropristis striata</u> black sea bass	a(30)		j(4-5)	j(5-6)	a
2. <u>Haemulon Aurolineatum</u> tomtate	a(18)	a	a	a	a
3. <u>Stenotomus caprinus</u> longspine porgy	a(12)	a	j(4-5) a(15-20)	a	
4. <u>Decapterus punctatus</u> round scad	a	a	a		
5. <u>Hemipteronotus novacula</u> pearly razorfish		a	a	a	
6. <u>Centropristis philadelphica</u> rock sea bass		a	j(6-7)	a	
7. <u>Urophycis earli</u> Caolina hake		a	a	a	
8. <u>Chaetodipterus faber</u> Atlantic spadefish		a			a
9. <u>Archosargus probatocephalus</u> sheepshead			a(35)		
10. <u>Balites capriscus</u> gray triggerfish			a(25)		
11. <u>Diplodus holbrooki</u> spottail pinfish			a(15-20)		
12. <u>Rypticus maculatus</u> whitespotted soapfish			(6-7)		
13. <u>Holocentrus sp.</u> squirrelfish			(6)		
14. <u>Calamus leucosteus</u> whitebone porgy			a(30)		
15. <u>Halichoeres bivittatus</u> slippery dick				a	

Table 2 continued:

<u>Species</u>	<u>4/29/83</u>	<u>5/29/83</u>	<u>6/25/83</u>	<u>8/9/83</u>	<u>9/9/83</u>
16. <u>Diplectrum formosum</u> sand perch				a	
17. <u>Stentomus chrysops</u> scup				a	a
18. <u>Hypleurochilus geminatus</u> crested blenny				a	
19. <u>Monocanthus hispidus</u> planehead filefish					j
20. <u>Sphyraena barracuda</u> great barracuda					a

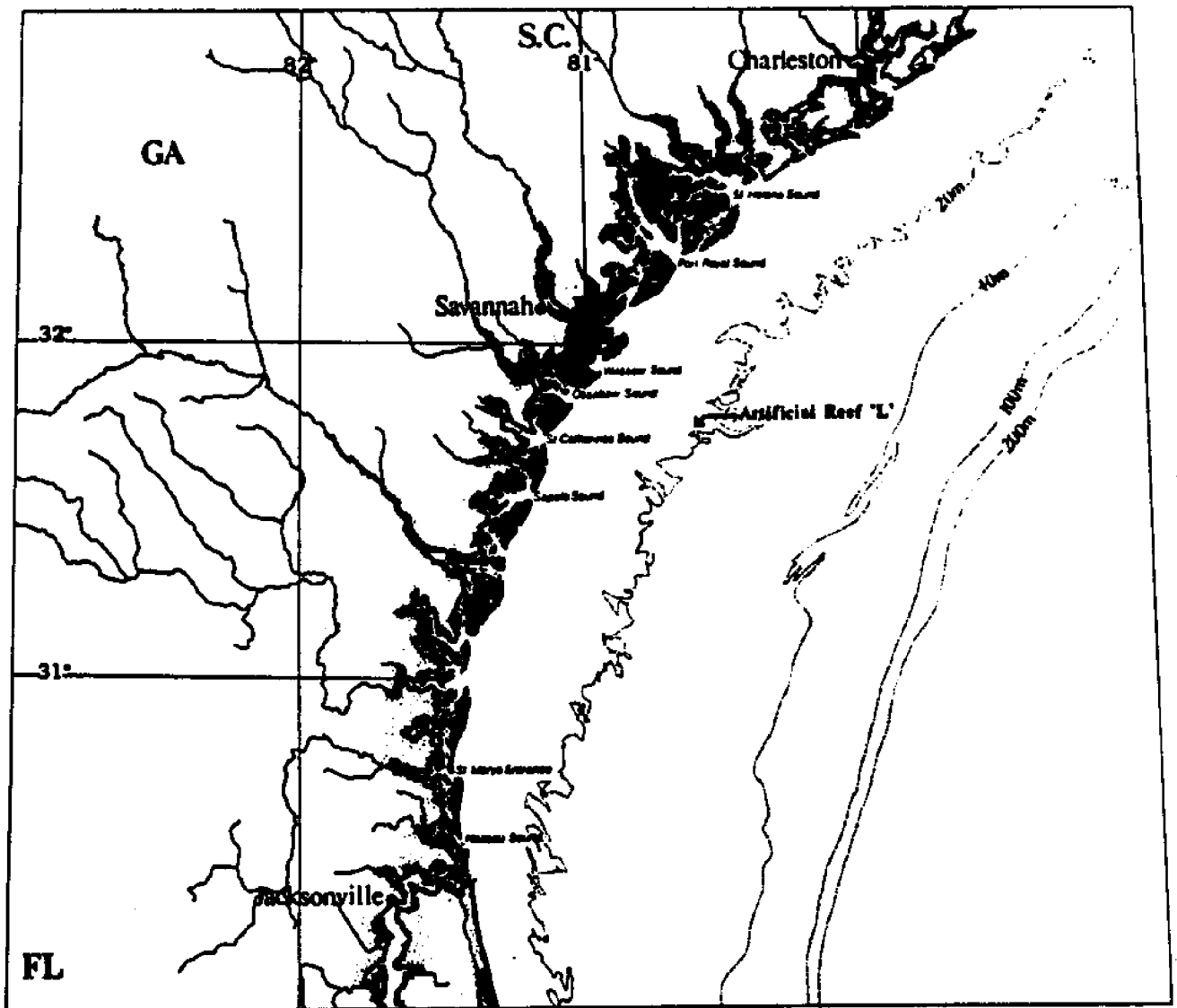
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Figure 1.

Map of the Georgia coast showing the location of Georgia Department of Natural Resources Artificial Reef 'L' at 31 45.4N and 80 36.5 W near the 20m isobath.



ONTOGENETIC AND SEASONAL PATTERNS OF OSMOTIC AND IONIC REGULATION
AND THE ENERGETIC COST OF A VARIABLE SALINITY ENVIRONMENT
IN THE STRIPED MULLET, MUGIL CEPHALUS L.

Frank G. Nordlie

Introductions

No teleost fish group more fully typifies the euryhaline condition than the mullets (family Mugilidae) which are ubiquitous in coastal marine and brackish waters, and frequently in connected fresh waters, throughout temperate, subtropical and tropical zones of the world (Nelson 1976). One of the most abundant of these fishes and the best known in this part of the world is the striped mullet, Mugil cephalus L. The present paper will explore some of the environmental problems facing this species through its life history in coastal waters and salt marshes of southeastern United States.

Based on information contained in reviews of Breder and Rosen (1966), DeSilva (1980), and supported by the extensive work of Kilby (1949, 1955), Mugil cephalus populations spawn offshore in marine waters where the zygotes develop and hatch. The developing larvae/juveniles migrate toward shore, and the successful individuals move into estuarine and tide-marsh channels and some ultimately into the shallow pools of tide marshes. Here they continue to develop for a varying portion of their first year of life, following which they may move to deeper channels of the tidal system, go into fresh water tributaries, or return to sea for varying periods (including spawning migrations after sexual maturation). The factors determining the directions to be taken remain unknown. Obviously a species with such a complex life history faces extreme variability in several key environmental conditions in its life, but especially in ambient salinity and temperature. This paper, while not pretending to be all-inclusive, will explore some aspects of physiological responses to these environmental conditions.

Since the goal of this symposium is to assess potential environmental impacts of coastal development in Northeastern Florida and Southeastern Georgia, Mugil cephalus is certainly a species whose environment stands to be altered by such cultural activities.

Methods

Ontogenesis of Osmotic Regulatory Capacity

Juvenile individuals of Mugil cephalus were obtained by seining in Gulf coast salt marshes near Cedar Key, Florida, through the winter and spring months. They were returned to the laboratory in Gainesville, and subjected, in laboratory acclimations, to a series of experimental salinities ranging from fresh water to full sea water, at an ambient temperature of $22 \pm 2^\circ\text{C}$ and on a photoperiod of 12L:12D. All acclimations were continued for a period of 14 days before individuals were transferred to the next salinity in the acclimation series or until blood sampling was carried out.

Osmotic concentrations were determined using a Wescor model 5100B vapor pressure osmometer on 5 Hl plasma samples. Even so, it was generally necessary to pool plasma from two or three individuals in order to obtain the necessary 5 Hl of plasma. Blood was taken by blind sternal puncture using heparinized (ammonium heparinate) microhematocrit tubes that had been drawn out to fine tips and broken off to the appropriate diameter. The procedures were described by Nordlie et. al. (1982). Lengths are expressed as standard lengths (SL).

Osmotic Regulation as Influenced by Environmental Temperature

Groups of individuals averaging ca. 18 gm in body mass (roughly 10 cm SL) were collected, using a cast net, from salt marshes adjacent to the Matanzas River near the Whitney Marine Laboratory on the Florida east coast. These individuals were returned to the laboratory in Gainesville, and subjected to laboratory acclimations. Groups of individuals were acclimated to a series of ambient temperatures, controlling the ambient salinity ($34.5 \pm 1^\circ/\text{oo}$) and the photoperiod (12L:12D). Again, all acclimations to a given set of conditions extended for a period of 14 days. Plasma samples were taken from individuals of each acclimation group following a 14-day acclimation to the ultimate acclimation temperature (starting from 20°C and working in 5°C alterations upward or downward until the desired acclimation was achieved. Blood was taken from the caudal artery by severing the caudal peduncle and allowing arterial blood to flow into heparinized (ammonium heparinate) collecting tubes. Plasma osmotic concentrations were determined on 200 Hl samples pooled from the several individuals in an acclimation group. Determinations of osmotic concentrations were made on a Precision Systems osmometer. Other aspects of the techniques were described in Nordlie (1976).

Respiratory Demands as Influenced by Variations in Environmental Salinities

Individuals ranging in body mass from 10 to 37 gm were used in these studies and were captured by means of seines and cast

nets from Gulf coast salt marshes near Cedar Key, Florida. They were returned to the laboratory in Gainesville and subjected to controlled acclimations. Ambient temperature was maintained at $25 \pm 1^{\circ}\text{C}$ with a photoperiod of 12L:12D. Individuals were acclimated to the test salinities for a period of 8 days before metabolic determinations were carried out. Rates of oxygen consumption of intact individuals were measured in closed systems, using opaqued Erlenmeyer flasks of appropriate volumes as respiration vessels and following the decrease in O_2 pressures in the vessels. Determinations of O_2 pressure were made using a Radiometer pO_2 electrode. The techniques were applied as described by Nordlie and Leffler (1975).

Individuals utilized in all parts of the work were fed Tetramin R and all statistical procedures utilized followed Sokal and Rohlf (1969).

Results

Osmotic Regulatory Capability as a Function of Body Size

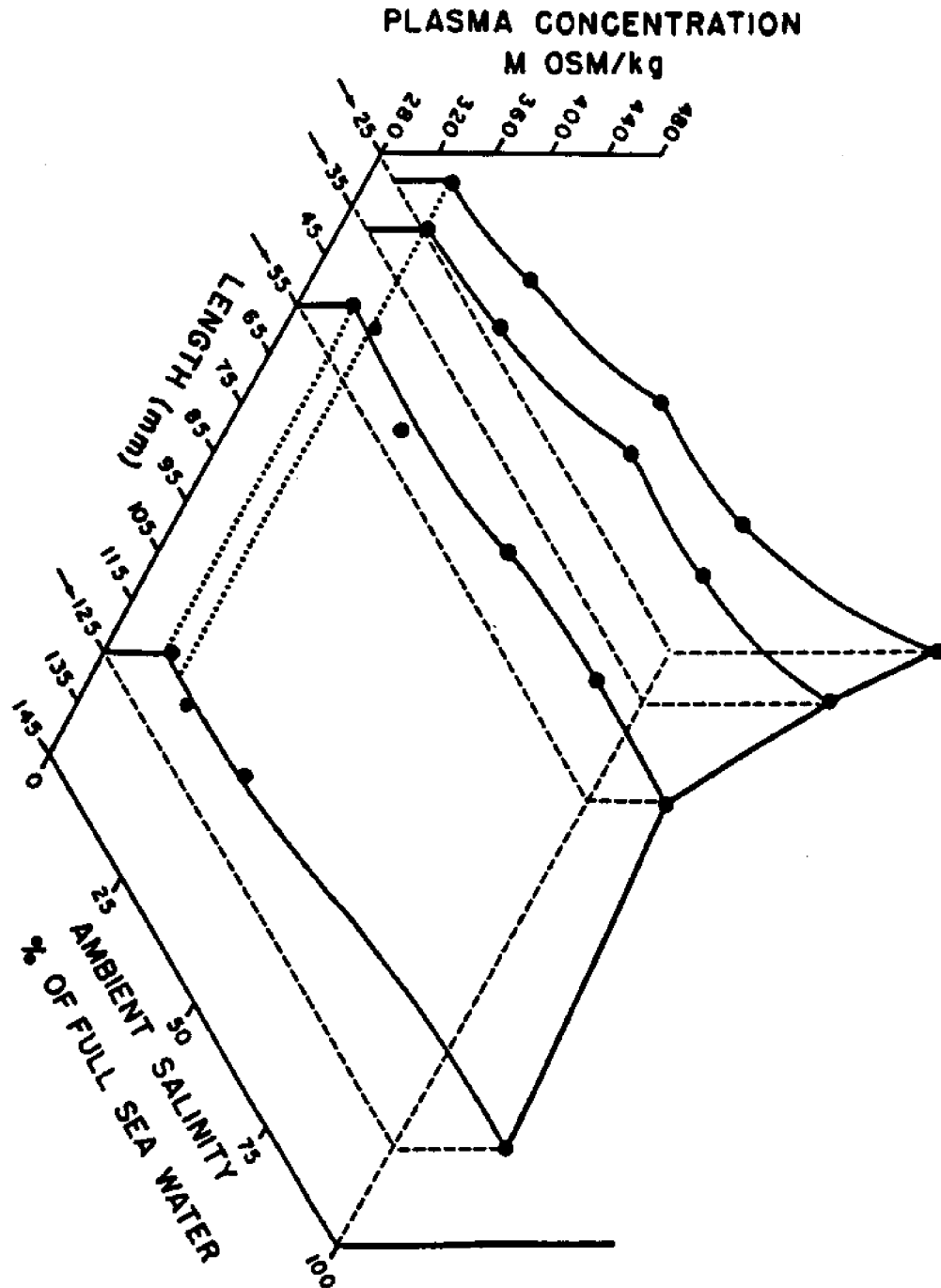
Determinations of osmotic regulatory capacity of juvenile Mugil cephalus were carried out over a range of sizes from 25 mm to 105 mm (SL) after laboratory acclimation to a series of ambient salinities. This study was carried out to determine whether or not the smallest (youngest) individuals found in the salt marshes showed any qualitative differences in osmotic regulatory characteristics from individuals of progressively larger sizes. Also, the salinity tolerances of these individuals were investigated over the ambient range from fresh water to normal sea water (Nordlie et al. 1982). Results of these analyses are represented in Fig. 1 (taken from Nordlie et al., 1982). First, it was found that the smaller juvenile mullet (25 and 35 mm SL groups) did not survive the acclimation to fresh water, so their osmotic regulatory characteristics are represented only for salinities of 5% sea water through 100% sea water. Individuals of larger sizes (55 mm SL and larger) survived acclimation over the entire salinity range from fresh water through full sea water. Second, it was also determined that the overall osmotic regulatory capability gradually improved with development to a length of ca. 55 mm. Beyond this size, the responses at a series of ambient salinities from fresh water to full sea water are roughly those of small (and presumably larger adult individuals of the species (>105mm) (Nordlie et al. 1982).

Osmotic Regulation as Influenced by Environmental Temperature Variations

The range of ambient temperature encountered by individuals of this species among the various habitats potentially occupied by developing individuals or adults in a year's time in coastal waters of this part of the world can easily extend from a low of 10°C to a high of 30°C . The pattern of responses in plasma osmotic concentrations to a series of environmental temperatures

Figure 1.

Plasma osmotic concentrations (mOsm/Kg) as functions of ambient salinities (% of full sea water) for juvenile Mugil cephalus of a series of lengths (SL in mm) (From Nordlie et al., 1982).



within this range in an environment of normal sea water was investigated in laboratory acclimation studies involving juveniles of a relatively uniform size (ca. 18 gm--10 cm SL). Results of this analysis are found in Table 1. It can be seen from these data that there are significant alterations in the plasma osmotic and ionic concentrations with alterations in ambient temperature.

The data in Table 1 show that there were consistent reductions in the concentrations of Na^+ and Cl^- and in the total plasma osmotic concentration as the acclimation temperature was sequentially reduced in 5°C steps from a high of 30°C to a low of 10°C . One can also look at these alterations in the opposite way, following the increases in Na^+ and Cl^- and plasma osmotic concentrations with increases in acclimation temperature. No significant alteration was found in K^+ concentration with alterations in ambient temperature.

Respiratory Demands as Influenced by Variations in Environmental Salinities

As respiratory oxygen demands of organisms are altered through variations in ambient temperatures, they may also be altered by variation in ambient salinities and by temperature x salinity interactions. There have been relatively few studies of any complexity attempted to determine possible implications of a euryhaline mode of existence on respiratory oxygen demands in any teleost species. Some of the host of questions that can be asked about such interactions were posed in reference to Mugil cephalus (Nordlie and Leffler 1975). In that study we assumed that at least one likely pathway by which metabolic demands of the organism might be altered as salinity varied was through the ionic and osmotic regulatory processes. A summary of the thermodynamically minimal energy demands of the ionic transport process is as follows (Lehninger 1971):

$$G^{\circ} = RT \ln \frac{C_2}{C_1}$$

where R is the molar gas constant (1.984 cal/ $^\circ$ -mol), T is the absolute temperature, and C_2 and C_1 are the molar concentrations of a specific ion being transported from compartment 1 to compartment 2.

We hypothesized that in the ideal compensation system this cost would be minimal where environmental and blood concentrations were equal and would rise progressively in more and less dilute environments (that is, where there are progressively greater differences between environmental and blood ionic and/or osmotic concentrations.) This is what we found to be the case in Mugil cephalus with respect to the overall osmotic concentration as can be seen from Figure 2. However, this is by no means a universal pattern of response in respiratory oxygen demands to

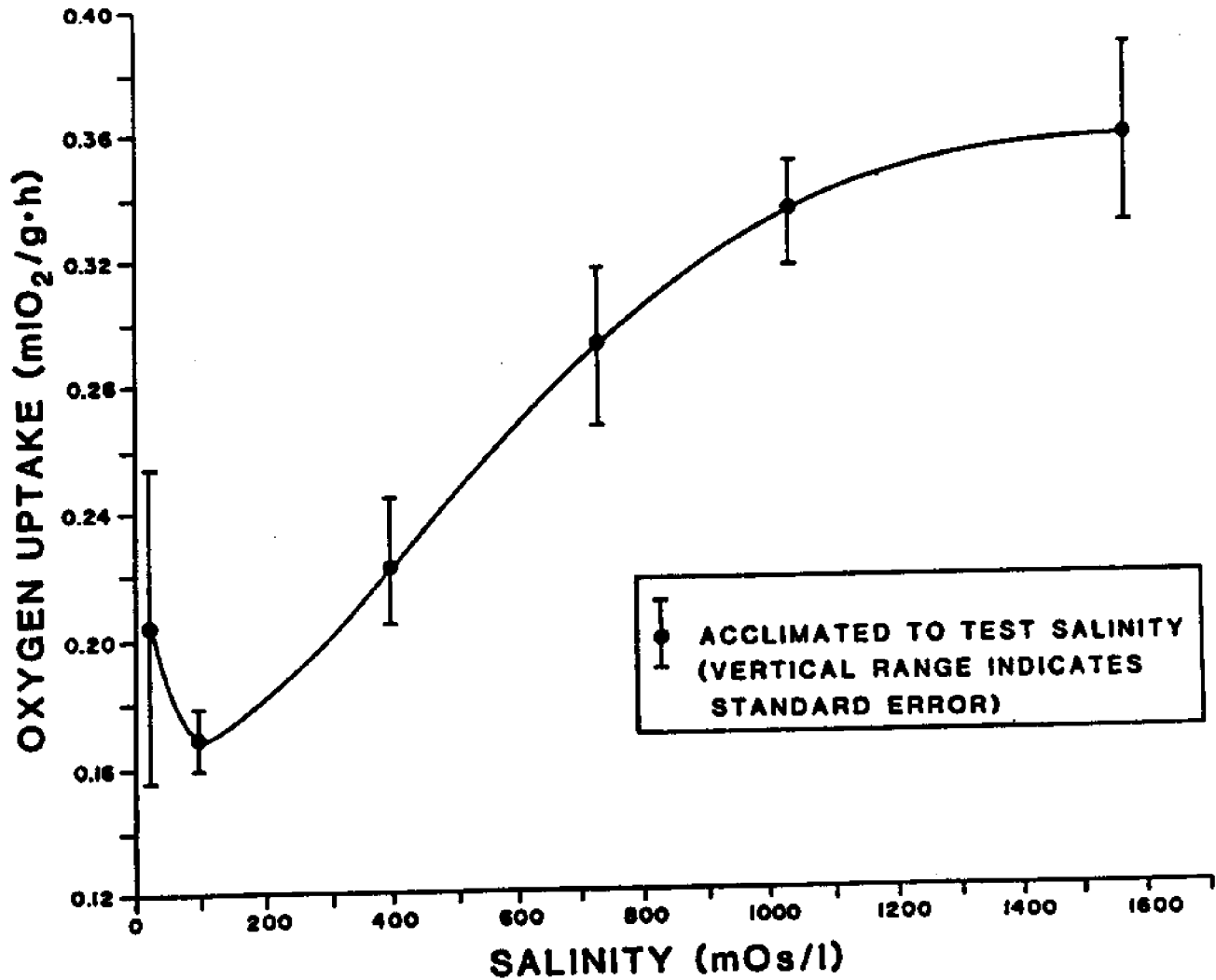
Table 1

Ionic and Osmotic Concentrations of Mullet Plasma as Functions
of Acclimation Temperatures
(From Nordlie, 1976)

Acclimation Temperature (°C)	Plasma Ion Concentrations			Plasma Osmotic Concentration mOsm/kg	
	Na ⁺	K ⁺	Cl ⁻		
	\bar{X}	158.8	10.7	138.8	
10	S.E.	1.1	0.8	0.9	323
	N	12	12	12	
	\bar{X}	164.2	7.7	142.0	
15	S.E.	2.0	0.6	1.6	335
	N	11	11	11	
	\bar{X}	166.9	10.3	144.8	
20	S.E.	1.4	0.3	0.5	341
	N	39	39	39	
	\bar{X}	176.3	6.8	155.1	
25	S.E.	2.2	0.8	1.6	364
	N	23	23	23	
	\bar{X}	178.0	10.5	158.2	
30	S.E.	2.2	0.5	2.1	378
	N	5	5	5	

Figure 2.

Oxygen uptake (ml of O_2 /gram/hour) as functions of ambient salinity (mOsm/l) in juvenile Mugil cephalus acclimated to the test salinities ($25 \pm 1^\circ C$) (redrawn from Nordlie and Leffler, 1975).



altered ambient salinities as was later pointed out by Nordlie (1978). Based on further work and a search through the literature I suggested that there are at least four basic patterns of response in respiratory oxygen demands to variations in ambient salinity as seen in Table 2.

Discussion

Neither the zygotes nor newly-hatched fry of Mugil cephalus are truly euryhaline. Sylvester et al. (1975) demonstrated that the optimal salinity for development of embryos of striped mullet (incubated at 19.5-20.5°C) was 30-32‰, with less than 50% survival at salinities below ca. 29‰. No upper salinity limit was set in that work. Lee and Menu (1981) looked at both ends of the salinity spectrum and demonstrated better than 50% hatching success at salinities ranging from 15 to 55‰. However, the optimal salinity range (22-22.5°C) was found to be from 30 to 40‰ with the peak at 35‰. While there was good hatching success outside of this range, many anatomical anomalies were noted in the developing embryos.

Sylvester et al. (1975) found that the optimal salinity range for the survival of newly-hatched larvae was lower than that for egg development, at 26-28‰. The range of salinities within which there was 50% or greater larval survival was roughly from 25 to 35‰. This was interpreted to indicate an adaptation to an estuarine environment in the larvae.

Obviously salinity tolerances of M. cephalus extend over a wider range (at least toward the more dilute end of the scale) in the older and larger juvenile stages evaluated here (>25 mm SL). Kilby (1949) reported that the smallest juveniles that he took in Gulf shore waters were of lengths of 16 mm, or appreciably smaller than the smallest individuals used in this study. It is not yet known when in the developmental sequence the extensions of salinity tolerances and improvements in osmotic regulatory capacity begin to develop. From the results cited here (from Nordlie et al. 1982), it is obvious that these capacities are at least not in their definitive state by the time the juveniles enter brackish waters. Certainly it appears that individuals of small sizes (<55 mm) are vulnerable to very low salinities. It is suggested here that the juveniles migrating in salt water and newly-arrived in brackish waters are most vulnerable to sudden reductions in salinity and this vulnerability is reduced as the individuals develop. By the time they have reached a length of ca. 55 mm they achieved salinity tolerances and osmotic regulatory capacities (at least under the experimental environmental conditions investigated) roughly similar to those of small adults. Since it is known that larger individuals of this species can tolerate salinities in excess of 2X that of sea water (McFarland 1965; Gunter 1967), and that individuals of ca. 10-15 cm SL are already capable of tolerating salinities of at least 1.6 X sea water (ca. 55‰) (Nordlie and Leffler 1975), this

Table 2

METABOLIC RESPONSES TO ALTERED SALINITY IN TELEOST FISHES

(After Nordlie, 1978)

<u>Response Type</u>	<u>Description</u>
I.	The rate of oxygen consumption is not significantly altered over a wide range of environmental salinities (freshwater to normal sea water).
II.	The rate of oxygen consumption is minimal at an ambient salinity that is isosmotic with the blood. Rates of oxygen consumption increase at lower and higher salinities.
III.	The rate of oxygen consumption is minimal at the optimal salinity for the form and is at other than the isosmotic level. Again, rates of oxygen consumption increase as functions of the osmotic gradient in more and less saline waters.
IV.	Rates of oxygen consumption are maximal at the optimal salinity for the form and rates of oxygen consumption are depressed at salinities higher and lower than the optimal level.

tolerance of hypersaline waters must also develop relatively early. Salinities in excess of those of normal sea water are frequently produced by evaporation in the shallow salt marshes at low tide during hot, dry weather or on a longer term basis in more or less isolated lagoons. Again, we predict that the migrating and newly-arrived juveniles are potentially most vulnerable to the stresses at increased salinities.

A few workers have focused their attention over the years on the influences of environmental temperature on osmotic regulatory capacities of various species of ectotherms. Wikgren (1953) published one of the early classics in this area demonstrating that salinity tolerances were altered as osmotic regulatory ability of a species was influenced by environmental temperature. Prosser, Mackay and Kato (1970) generalized from their, and other, findings that plasma inorganic electrolyte concentrations decrease with increasing ambient temperatures and increase with decreasing ambient temperatures in marine fishes (or in euryhaline fishes in a marine environment). The reciprocal was said to be true of freshwater fishes. The basic assumption here was that at colder temperatures, the ionic/osmotic regulatory systems functioned less well than at higher temperatures and this difference between internal and external concentrations were reduced. We have ignored here the accumulation of organic "anti-freeze" substances in the bloods of fishes that occupy environments reaching subzero temperatures (e.g. Scholander et al., 1957; Umminger, 1969b). Umminger (1971) demonstrated that there was somewhat more variability in total osmotic response patterns, at least of freshwater fishes (or of euryhaline fishes in a freshwater environment) than Prosser, Mackay and Kato (1970) had suggested. However, he agreed that their conclusions with respect to the plasma inorganic electrolytes were generally correct. An unexpected result of the present work was to discover that Mugil cephalus does not respond to temperature in its plasma osmotic concentration and inorganic electrolytes as one would be led to expect of a euryhaline teleost in marine waters. Other euryhaline forms such as Fundulus heteroclitus and F. grandis (Umminger 1969a, 1970) do show expected response patterns both in fresh and in marine waters. Hordlie speculated (Nordlie 1976) that the response pattern observed in M. cephalus might, in fact, represent an adaptation (or stress response), not to reduced, but rather, to increased environmental temperatures. At high environmental temperatures saturation levels of dissolved oxygen are reduced and ambient levels would be expected to be even lower in tide marshes where there is a significant accumulation of suspended and deposited organic material. Under such potentially stressful conditions, a partial relaxation of osmotic and ionic regulation should ease the metabolic burden on the organism and thus reduce the oxygen demands in an oxygen-poor environment. While this hypothesis has not been tested directly, the data and conclusions of Cech and Wohlschlag (1982) provide indirect support. They demonstrated adjustments in respiratory, ventilatory and hematological patterns in Mugil cephalus correlated with the

problems of obtaining respiratory oxygen during the warmest part of the summer and at the onset of the fall spawning migration.

In as yet unpublished work, Hordlie found in a preliminary investigation that ionic and osmotic concentrations in Mugil cephalus acclimated to hard freshwater were not significantly altered at acclimation temperatures ranging from 30°C to 10°C. Tentative conclusions are that, while Mugil cephalus is obviously capable of tolerating a wider range of ambient temperatures than that utilized in the present study (10°C-30°C), it demonstrates a stress response within this range, to increased temperatures in marine waters but not in fresh waters. It seems logical that the ambient temperature ranges from 10°C on down toward 0°C, and from 30 to 35 or 40°C should also be investigated. Whatever additional information these extensions might provide, it is already clear that Mugil cephalus is influenced in its osmotic/ionic regulatory capacity by environmental temperature.

It has been well documented that a contributing cause of death in fishes subjected to rapid change in temperature (upward and/or downward) is the disruptive influence of such temperature changes on the osmotic/ionic regulatory processes of the individuals (Wikgren 1953; Heinicke and Houston 1965; Stanley and Colby 1971). One expects, based on the lesser salinity tolerances of smaller Mugil cephalus that these smaller individuals would be more stressed by abnormal temperatures or salinity temperature combinations than would larger individuals.

There are some data in a study by Carr and Giesel (1975) on effects of high temperature conditions in coastal salt marshes (Jacksonville area) that serve as a nursery area for a number of marine forms, including Mugil cephalus, and also serve as receiving waters for the effluent waters from the cooling systems of a nuclear power plant. They found that while there was an obvious reduction in the utilization, by juveniles of most teleost species, of creeks receiving such heated waters, that juvenile mullets (here M. cephalus and M. curema) remained roughly as abundant as in a control area, an unaffected creek. One expects that it is not such constantly extreme conditions (at least within limits) that seriously disrupt regulatory processes, but rather changes in temperature. However, a shutdown of the cooling systems and thus of warm water discharge during the colder period of the year might have devastating effects on the juvenile fishes inhabiting such affected areas. It would be expected that individuals of M. cephalus would be more vulnerable to the effects of elevated temperatures and less to those of reduced temperatures than would those of M. curema. This conclusion is based on the work of Moore (1976) who concluded that M. cephalus is more of a temperate-subtropical form and M. curema is more of a tropical form based on a comparison of ranges of temperature tolerances and of geographical distributions of the two forms. Moore agreed with the conclusion of Liao, et al. (1972) and Nash and Kuo (1975) that the optimal range of temperature, including for spawning, in M. cephalus was roughly 20 to 24°C. Obviously

the tolerable ranges, for at least some life stages, extend well beyond these limits. However, it is likely that normal development, and especially the development of reproductive readiness and its ultimate success, will occur only within fairly narrow ranges of environmental temperature and salinity and their combinations.

The possible impacts of altered environmental conditions, other than of temperature influences, singly or in concert, on metabolic demands of organisms, have been largely ignored, perhaps mainly because of the difficulty of conducting such studies even in the laboratory. The work summarized here on Mugil cephalus (Nordlie and Leffler 1975) shows this species to have lowest respiratory oxygen demands (and, we assume lowest total metabolic demands) at ambient salinities roughly equivalent to the blood plasma concentration (at 25 ± 1 °C). Metabolic demands then increase in either direction from this salinity. Thus, we suggested that such a species commits least energy to the demands of maintenance of osmotic/ionic concentrations in this ambient zone. This would allow greater energy commitments to growth and reproduction at such salinities. This hypothesis was supported by findings of DeSilva and Perera (1976) who found juvenile Mugil cephalus to have lower food intakes, greater growth rates and higher conversion efficiencies at brackish salinities. However, while food intake was least and conversion efficiency was highest at an ambient salinity of 10‰, highest growth rate in their study was attained at an ambient salinity of 20‰, but only with an unlimited food supply. On a restricted ration only the individuals in an ambient salinity of 10‰ survived. An ambient salinity of 10‰ is roughly equivalent to the average plasma osmotic concentration of this species. The results of a limited investigation by Marais (1978) of the influences of a series of ambient temperatures on the routine metabolic rate of juvenile Mugil cephalus at salinities of 1‰ and 35‰ showed results similar to ours with respect to salinity effects for this limited salinity series. He also showed that metabolic rates increased with temperature increases from 13 to 23°C in both 1‰ and 35‰ media, but at ambient temperatures of 28 and 33°C, metabolic rates were depressed at both environmental salinities. This again suggests that Mugil cephalus, while tolerating high ambient temperatures, shows stress responses at ambient temperatures well below the maximum tolerable levels. These data again support the hypothesis that the increased osmotic/ionic concentrations at elevated temperatures represent an adaptation in Mugil cephalus to reduce metabolic demands at such temperatures.

Speculating on the possible impacts of altered environmental conditions on species (Table 2) showing other types of responses in metabolic rates to altered salinities leads to the conclusion that all forms obviously have limits within which they can respond to salinity alterations and that most species show some response in metabolic demands to salinity alterations. I have

found that these various types of responses are at least correlated with the ionic (and osmotic?) regulatory patterns of the various species studied as they respond to altered salinities. Every species, be it a teleost fish, alga, crustacean, or bacterium, has a set of environmental tolerances for each stage in its life history. In some instances the tolerable ranges of environmental conditions do not vary much over the life-time of the individual. However, for some forms there are dramatic ontogenetic alterations in certain tolerance patterns and thus in the need of predictability of environmental conditions of certain habitats for survival and/or successful completion of a life cycle. Mugil cephalus is a species showing the latter pattern of ontogenetic variations in environmental tolerances accompanying ontogenetic shifts in habitats and thus in requirements for predictable ranges of conditions--here temperature and salinity--in the specific habitats utilized at various times in the developmental sequence. It seems reasonable to conclude from the information now available that the most environmentally sensitive stages in the life cycle of this species are in embryonic and larval development through the time that the juveniles reach a size (or age equivalent) of ca. 55 mm SL. Various workers have also demonstrated that another period of special sensitivity to environmental conditions is that of the development of reproductive readiness. While adult individuals may tolerate wide ranges in salinity and/or temperature conditions, the ranges known to allow the successful development of gametes are very restricted. Also information from the literature suggests that rapid changes in environmental temperature/salinity conditions may be more destructive than more gradual changes (within the tolerable ranges).

While a fair amount is known about environmental requirements of Mugil cephalus, perhaps because of the actual and potential economic importances of this species, much yet remains to be done. Also most species that have little obvious or direct economic value have been largely ignored, despite their possible trophic importance in coastal and/or estuarine ecosystems. We must make a plea to carry out studies of environmental effects of individual species and their ecosystems long before proposals for alterations of specific ecosystems are to be evaluated. Only then can there be time to make systematic and detailed analyses that will provide predictive power, useful in the assessment of possible biological alterations that might be produced by such cultural alterations.

Acknowledgement

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A SURVEY OF THE WEST INDIAN MANATEE,
(TRICHECHUS MANATUS),
ON THE LOWER ST. JOHN'S RIVER

James A. Valade¹, Kim I. Miller², A. Quinton White²

INTRODUCTION

Manatee presence in Northeast Florida has been documented since the late 1940's (Moore 1951). These accounts describe the presence of manatees in the lower St. John's River during the spring, summer and fall seasons. A nationwide distribution, status and conservation survey (Hartman 1974) described similar trends, as well as established the presence of two artificial warm water refugia (power plant effluent) in Duval County where wintering manatees are known to occur.

Recent reports substantiate these findings (Gicca, unpubl. data, 1979; Valade unpubl. data, 1980; Bengston 1981; Rathbun, et al 1983; Kinnaird and Valade 1983). Tentative identifications of individual manatees made during this study document more extensive use of the power plant effluents than previously observed.

METHODS

The study area for this investigation included the J.D. Kennedy Generating Station waterfront (Figure 1). There are two thermal outfalls on this site: the main discharge and the south discharge. Both were monitored from 30 December 1983 to 14 June 1984 on a five day, forty hour week basis.

To a lesser extent, the Southside Generating Station was included in this survey. Observations were made within the discharge canal and at its point of discharge into the river.

To document the number of manatees present within these discharges, manatees were individually identified by means of their distinctive scar patterns (Moore 1956; Hartman 1971; Powell and Waldron 1981). Patterns were recorded by sketching and photographing. While photographing provides the best record of scar patterns (Rathbun et al 1983), water conditions and animal behavior precluded photographing at times, and sketching presented the only viable means of identifying and documenting presence of specific animals.

Discharge and ambient river temperatures were also recorded as a means by which to examine temperature effects on manatee presence and absence.

¹p. O. Box 11635, Jacksonville, Florida 32211

²Department of Biology and Marine Science, Jacksonville University, Jacksonville, Florida 32211

RESULTS

Sightings

A total of 668 manatee sightings were made during this study. Of these, 627 were from the J.D. Kennedy Generating Station and 41 were from the Southside Generating Station. Twenty-five of these sightings were of calves (3.8% of the total number of sightings).

The number of manatees sighted on a daily basis ranged from zero to nine, inclusive of both stations (Figures 2 and 3). Most sightings occurred in January and April.

Manatee Identification and Multiple Sightings

Eighty-four manatees were identified; three were adequately photographed and others were partially photographed. Photographs were to be provided for United States Fish and Wildlife Service Sirenia Project the documentation of individual identities. All identified animals were sketched, but not all were entered into the USFWS Sirenia Catalogue due to their ambiguous nature.

In addition, 40 manatee sightings were made for which identities could not be determined due to poor water conditions, appearance in areas not accessible to critical viewing, surfacing behavior and duration of presence at the discharges.

Of the 44 animals previously identified in Jacksonville (Kinnaird and Valade 1983, two were resighted during this study: manatees JX04 and BC200. Of the 84 manatees identified during this study, 64 were sighted only once (75.3%) (Figure 4). The greatest number of daily sightings for one individual was 31, spanning a period of 77 days (a second individual was sighted on 25 separate days over a period of 55 days). Eighteen other manatees were also resighted during daily observations. The majority of the multiple sightings occurred in January and April (Figure 5).

January resightings spanned greater periods than did those in April. Manatees resighted in January were fewer in the number than those resighted in April, as would be expected.

The greatest number of newly identified individuals occurred in April; numbers were elevated in January, March, and April, with the fewest number of new sightings occurring in February.

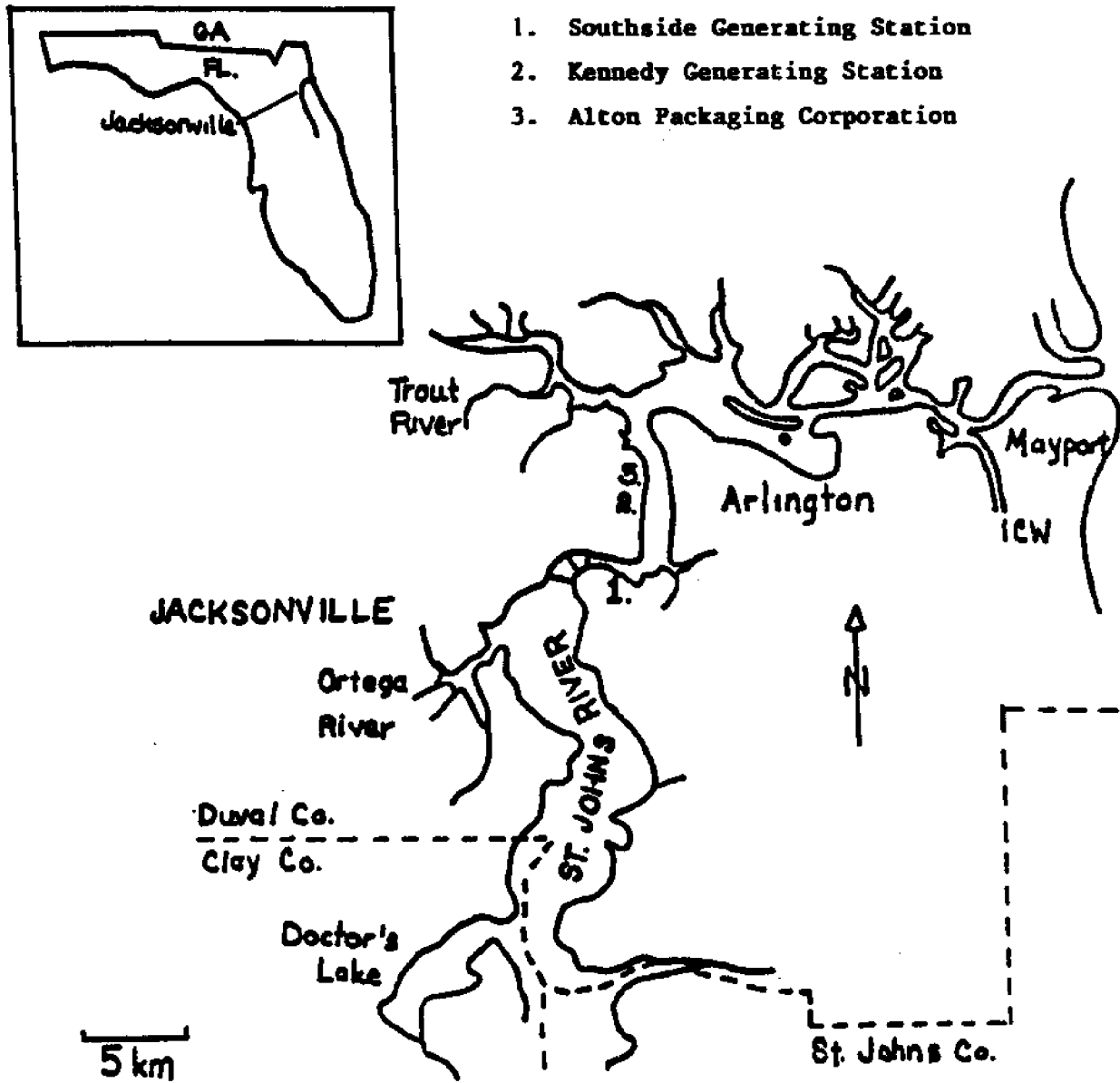


Figure 1.

Figure 2. Number of Manatees Sighted at the Main and South Discharges of the Kennedy Generating Station, 1984

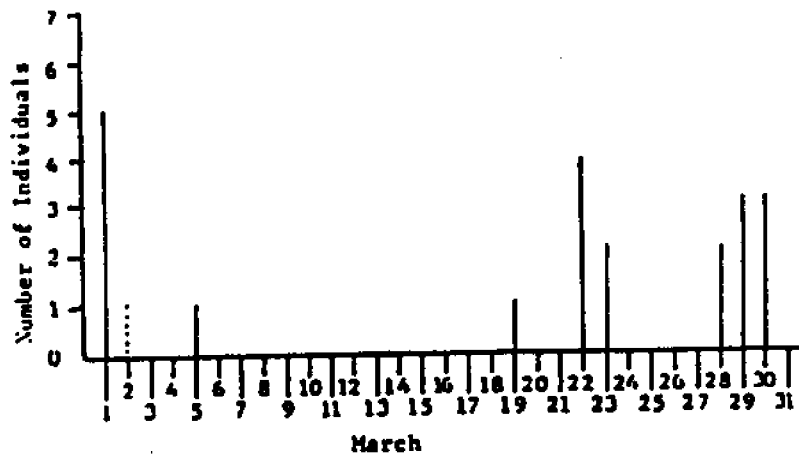
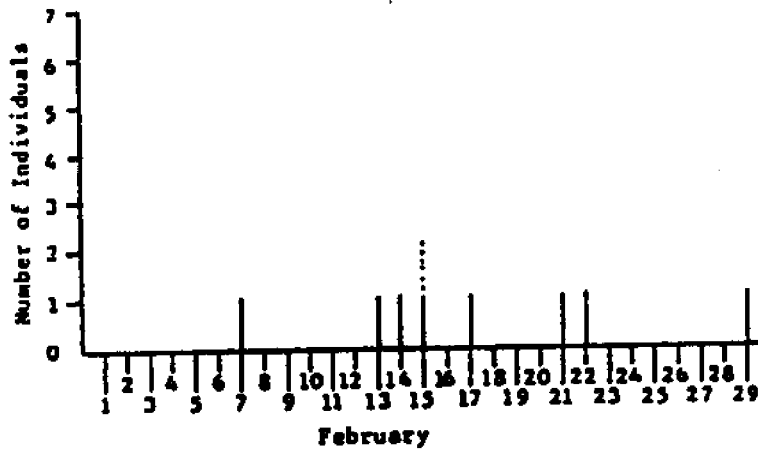
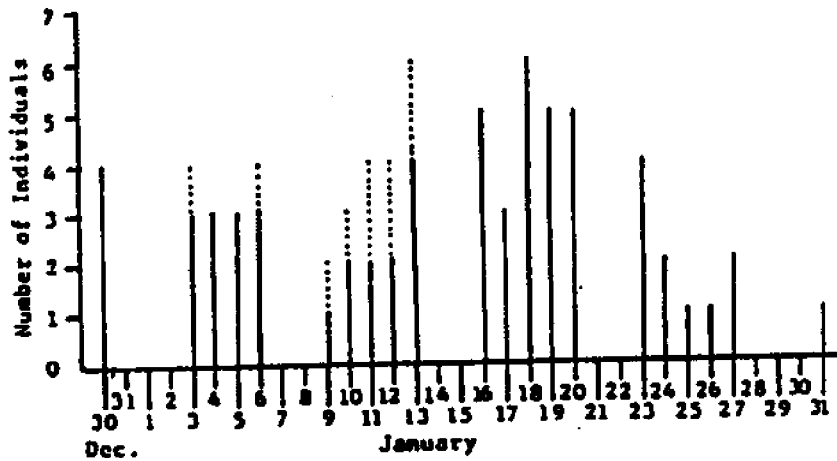


Figure 2. Continued

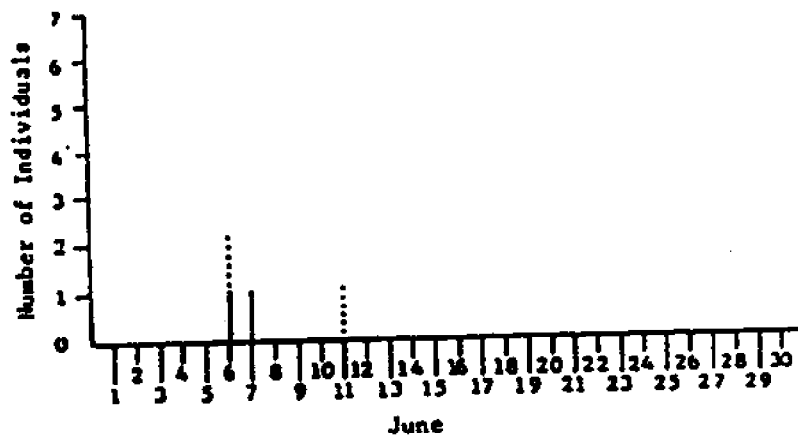
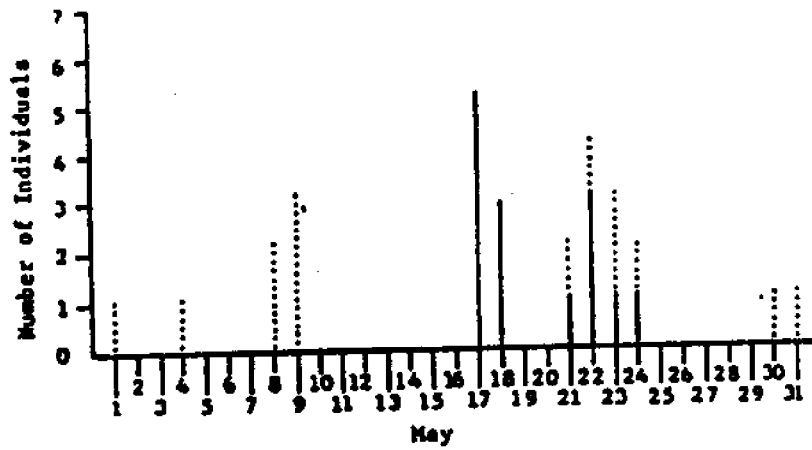
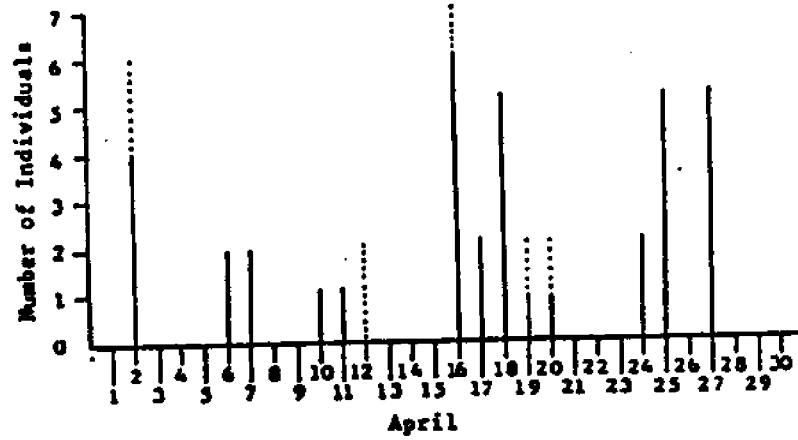
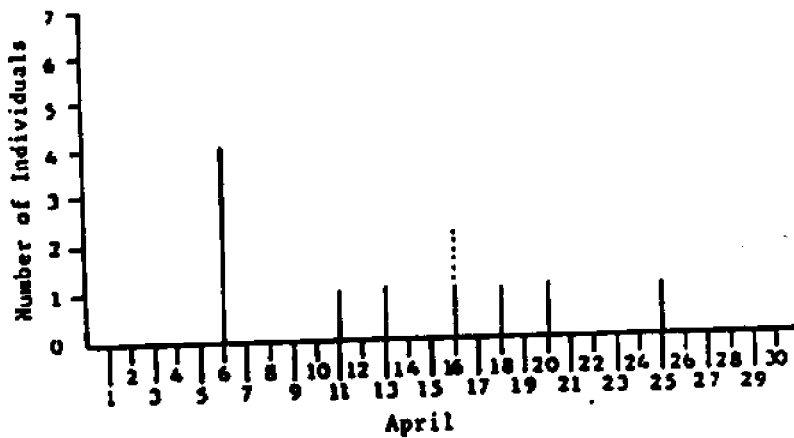
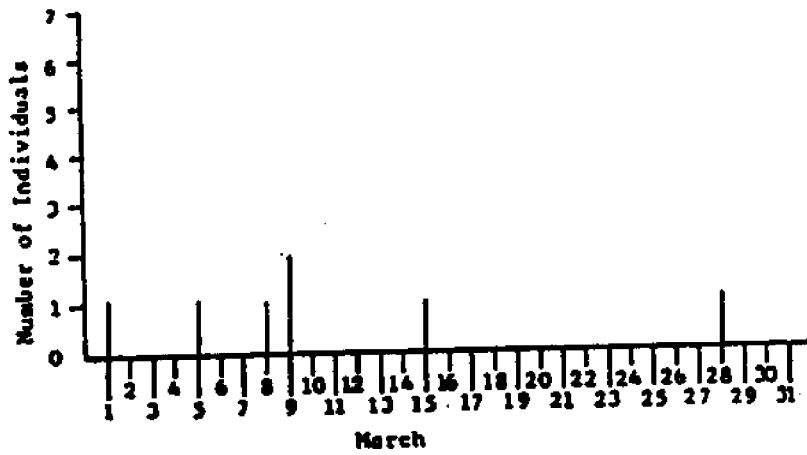
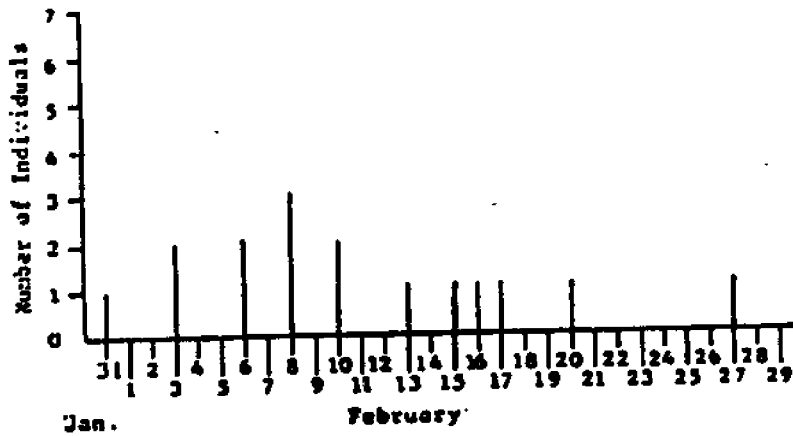


Figure 3. Number of Manatees Sighted at the Southside Generating Station, 1984



———— Identified Individuals
 Unidentified Individuals

Figure 4. Individual Sighting Frequencies for Both Generating Stations

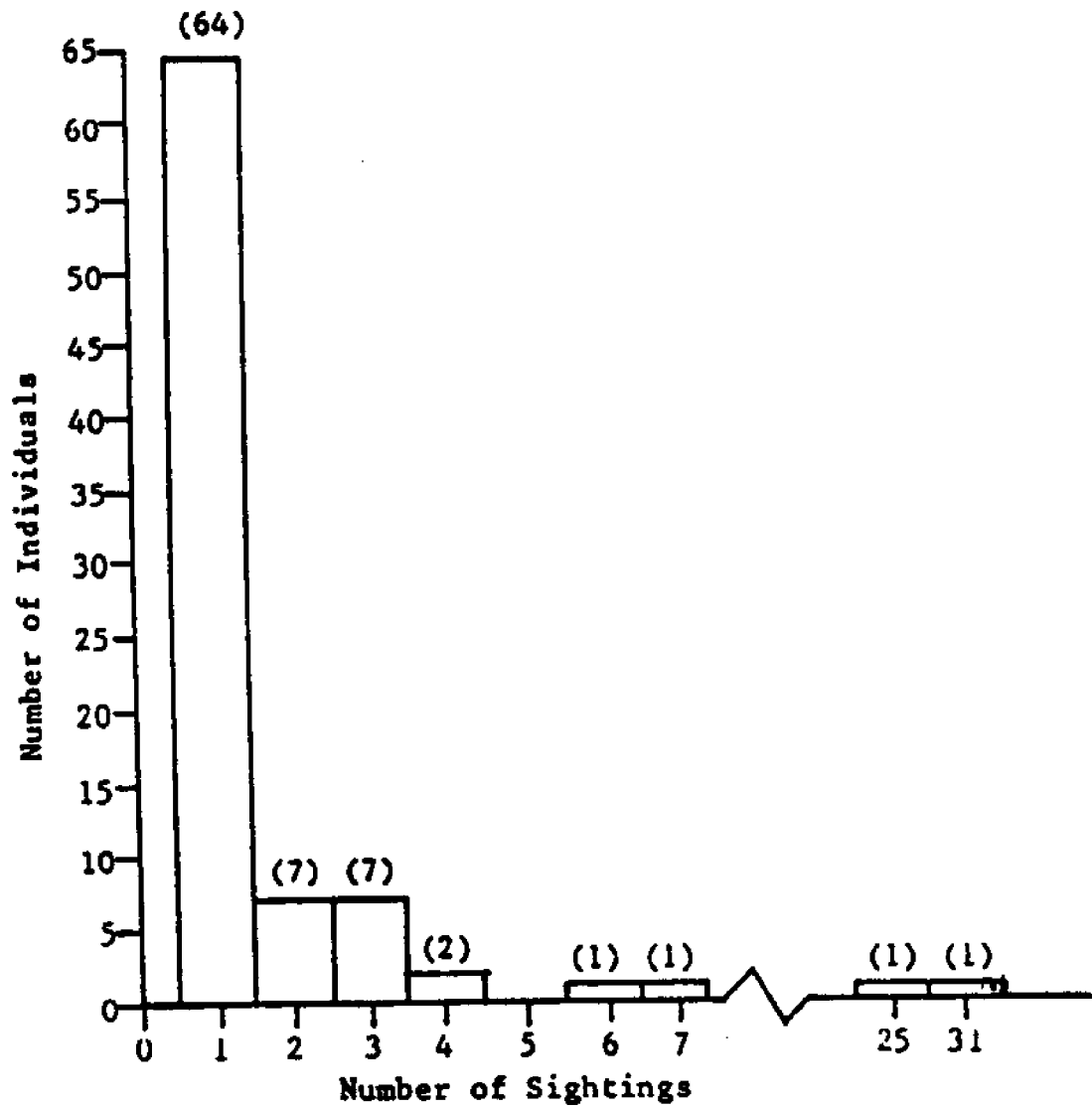
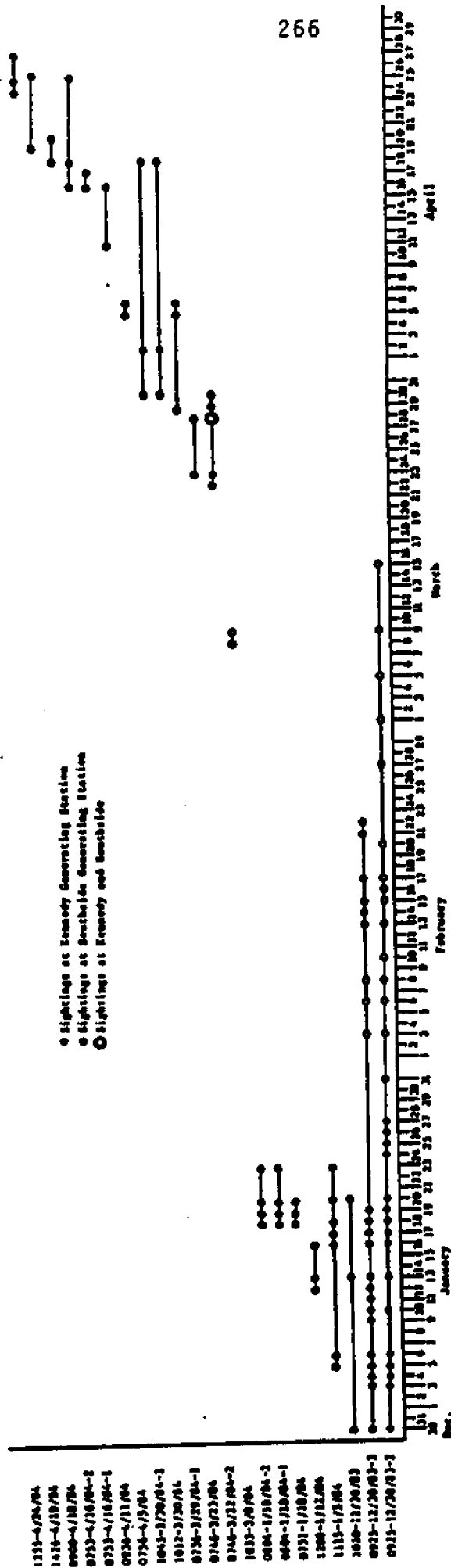


Figure 5. Sightings and Resightings of Individuals - Dates and Location



Movements

Long Distance

Five long distance movements to the Jacksonville generating stations were documented.

Manatees BC110 and BC200 were identified in Brevard County and resighted during this study in Jacksonville. Other movements included manatee PE82 from Port Everglades, manatee RB324 from Riviera Beach, and manatee BS50 from Blue Springs.

Bengston (1981) noted that male manatees appear to travel greater distances than females: manatees PE82 and BS50 appeared in Jacksonville accompanied by calves, demonstrating that long distance migration is not restricted to male manatees.

Local Movements

Four manatees were initially observed in Jacksonville at the Kennedy Generating Station discharges and later at the Southside Generating Station discharge. Three of these animals returned to the Kennedy Generating Station; manatee 0925-12/30/83-2 was sighted at the Kennedy over a one month period and was later sighted over a 60-day period at the Southside Generating Station.

Site Movements

Fourteen manatees sighted at the Kennedy Generating Station were observed to have made 57 movements between the south and main discharges. At the Southside Generating Station, 26 movements to different areas of the discharge canal were noted.

Temperature Effects

Manatees are known to congregate in warm water areas during periods of cold weather (Rathbun *et al* 1983). In the Jacksonville area, manatees seek refuge at local thermal effluents conceivably in response to cold periods (Kinnaird and Valade 1983). By means of multiple regression analyses, correlations between the number of manatees and river and effluent temperatures were made.

Correlations were weak at best; use of temperature differences (discharge temperature minus ambient river temperature) over weekly periods from the Kennedy Generating Station's main discharge produced the highest values. The first and fourth week of January and the fourth week of February² displayed the highest degree of correlation. Respective r^2 values were 0.30, 0.26, and 0.27.

A predicted value technique was also examined; variables were the same as those used in the regression analyses. The average error ranged from 0.24 to 1.09. The largest errors occurred the few times four or five animals were recorded. The regression model substantially underpredicted these actual

sightings of four or five manatees. This appears to be the result of the typically low number of manatees present during the third and fourth weeks of March along with the few high recordings of four or five manatees.

DISCUSSION

Earlier reports describe the use of Jacksonville discharges by as many as 44 animals (Kinnaird and Valade 1983). While numbers in excess of this figure were predicted by Eberhardt (1982), this study documents the first indication that elevated numbers of manatees may be present and that the extent of usage is greater than previously observed.

Eighty-four manatees were tentatively identified at the Jacksonville Electric Authority's J.D. Kennedy and Southside Generating Stations. The number of sightings of these animals peaked in January and April. These peaks parallel those observed by Kinnaird and Valade (1983). The January peak suggests an influx to the discharges by local wintering animals due to extreme cold temperatures experienced during this period. Regression analyses show the highest degree of correlation between lower temperatures and manatee numbers at this time. The large number of manatees present in April may reflect the appearance of northerly migrating animals to their summer ranges; the number of newly identified animals was greatest during this period.

Multiple sightings of individual manatees were also more extensive than previously documented. Twenty individuals were observed at the discharges on at least two separate days, with a maximum number of 31 resightings of one individual over a 77 day period. Kinnaird and Valade (1983) describe twelve individuals being resighted on as many as six occasions over a 65-day period.

Resighted animals also demonstrated greater movement between the two power plants. Kinnaird and Valade (1983) documented eight movements by eight individuals between the two plants. In this study, four manatees were observed to have made seven movements between the two sites, three individuals were initially sighted at Kennedy, then at Southside and subsequently back at the Kennedy Generating Station. While no movements at each plant's waterfronts were previously observed, extensive movements within the discharges and between on-site discharges were noted during this study.

The increased number of sightings, individually identified manatees, and observations of manatee movement over earlier studies were conceivably due to improved observation techniques; the length of time spent on site far surpassed that of any previous study. Colder temperatures may also have led to the greater number of manatees observed.

Table 1 - Cumulative Temperature and Manatee Data

Kennedy Water Temperatures

Amb - 24 hour average
MD - 24 hour average
SD - 3 hour average

Southside Water Temperatures

Z1 - 2 hour average
Z2 - 2 hour average
Z3 - 2 hour average

On-site Water Temperatures (SATMS)

MD - 3 hour average

Air Temperatures

NOAA - 8 hour average
On-site (SATMS) - 3 hour average

Kennedy

Manatee Total - all manatees

Southside

Manatee Total - all manatees

-: indicates data not collected
 O: all zero values indicate a verification

Table A. Cumulative Temperature and Humidity Data

Date	Kennedy				Southside				Onsite				Kennedy Manatees Total	Southside Manatees Total
	Water Temp.		At		Water Temp.		At		Water Temp.		At			
	MD	SD	MD	SD	MD	SD	MD	SD	MD	SD	MD	SD		
1/1/84	51.4	62.7	11.3	-	-	-	-	-	-	-	-	-	39	-
1/2/84	50.6	60.7	10.1	-	-	-	-	-	-	-	-	-	46	-
1/3/84	49.9	62.0	12.1	-	-	-	-	-	-	-	-	-	321	-
1/4/84	49.5	62.0	12.5	-	-	-	-	-	-	-	-	-	3	-
1/5/84	49.3	60.0	10.7	-	-	-	-	-	-	-	-	-	3	-
1/6/84	50.6	60.1	9.5	-	-	-	-	-	-	-	-	-	32	-
1/7/84	51.4	61.9	10.5	-	-	-	-	-	-	-	-	-	50	-
1/8/84	51.5	61.2	9.7	-	-	-	-	-	-	-	-	-	48	-
1/9/84	51.7	61.7	10.0	-	-	-	-	-	-	-	-	-	51	-
1/10/84	53.0	63.2	10.2	15.0	-	-	-	-	-	-	-	-	64	-
1/11/84	53.7	65.2	11.5	16.4	-	-	-	-	-	-	-	-	49	-
1/12/84	54.9	68.0	13.1	5.7	-	-	-	-	-	-	-	-	40	-
1/13/84	53.8	65.5	11.7	4.2	-	-	-	-	-	-	-	-	41	-
1/14/84	53.0	62.7	9.7	-	-	-	-	-	-	-	-	-	44	-
1/15/84	52.3	66.4	14.1	-	-	-	-	-	-	-	-	-	47	-
1/16/84	53.3	67.0	13.7	9.5	-	-	-	-	-	-	-	-	52	-
1/17/84	53.2	62.9	9.7	10.8	-	-	-	-	-	-	-	-	52	-
1/18/84	53.5	67.3	9.8	13.8	-	-	-	-	-	-	-	-	63	-
1/19/84	54.0	63.4	9.4	15.3	-	-	-	-	-	-	-	-	53	-
1/20/84	53.5	69.5	16.0	5.5	-	-	-	-	-	-	-	-	42	-
1/21/84	53.5	68.8	15.3	-	-	-	-	-	-	-	-	-	38	-
1/22/84	51.4	63.9	12.5	-	-	-	-	-	-	-	-	-	42	-
1/23/84	51.5	62.9	11.4	-	-	-	-	-	-	-	-	-	55	-
1/24/84	51.9	61.3	9.8	46.1	-	-	-	-	-	-	-	-	63	-
1/25/84	52.3	62.6	8.4	38.0	-	-	-	-	-	-	-	-	65	-
1/26/84	53.7	62.6	8.9	34.3	-	-	-	-	-	-	-	-	56	-
1/27/84	54.2	63.4	9.2	33.8	-	-	-	-	-	-	-	-	64	-
1/28/84	54.5	61.3	6.8	-	-	-	-	-	-	-	-	-	57	-
1/29/84	55.4	61.8	6.4	-	-	-	-	-	-	-	-	-	55	-
1/30/84	55.7	62.9	7.2	23.4	-	-	-	-	-	-	-	-	54	-
1/31/84	56.3	63.8	7.5	31.7	-	-	-	-	-	-	-	-	44	-
2/1/84	55.3	63.2	7.9	31.4	-	-	-	-	-	-	-	-	45	-
2/2/84	55.3	63.8	8.9	33.7	-	-	-	-	-	-	-	-	49	-
2/3/84	55.1	64.3	9.2	27.9	76.2	79.1	71.5	21.1	24.0	16.4	-	-	60	-
2/4/84	55.8	64.3	8.5	-	-	-	-	-	-	-	-	-	63	-
2/5/84	55.9	65.3	9.4	-	-	-	-	-	-	-	-	-	50	-
2/6/84	55.8	65.6	8.8	33.0	64.2	66.9	62.2	8.4	11.1	6.4	-	-	40	-
2/7/84	55.3	63.9	9.6	27.5	-	-	-	-	-	-	-	-	39	-
2/8/84	54.5	63.0	4.5	30.2	56.9	65.4	63.0	2.4	10.0	8.5	-	-	40	-
2/9/84	53.7	64.1	10.4	34.0	-	-	-	-	-	-	-	-	51	-
2/10/84	54.2	65.6	11.4	40.0	-	-	-	-	-	-	-	-	57	-
2/11/84	55.1	65.7	10.6	-	-	-	-	-	-	-	-	-	60	-
2/12/84	55.9	66.8	10.9	-	-	-	-	-	-	-	-	-	66	-
2/13/84	57.4	69.4	10.2	42.8	-	-	-	-	-	-	-	-	68	-
2/14/84	57.8	67.2	9.4	30.0	-	-	-	-	-	-	-	-	62	-
2/15/84	56.3	70.1	11.8	28.4	76.6	78.8	70.7	18.3	20.5	12.4	-	-	50	-
2/16/84	59.3	69.0	9.7	26.5	76.6	81.1	70.7	17.3	21.8	11.4	-	-	61	-

Table Continued

Date	Kennedy Water Temp		Kennedy At		Southside Water Temp		Southside At		Onsite Water Temp MD	Onsite At	Air Temp		Air At	Kennedy Manatee Total	Southside Manatee Total
	MD	SO	MD	SO	MD	SO	MD	SO			MOAA	Onsite			
4/5/84	67.0	71.7	95.0	6.7	28.0	72.1	+0.4	61.3	67.6	5.3	2	4			
4/6/84	66.1	72.3	89.0	6.2	22.9	72.5	+0.2	65.6	68.2	6.9	2	-			
4/7/84	66.3	71.8	-	5.5	-	-	-	63	-	-	0	-			
4/8/84	66.9	72.0	-	5.1	-	-	-	67	-	-	1	-			
4/9/84	67.6	73.4	-	5.8	-	-	-	72	-	-	1	-			
4/10/84	66.4	73.0	89.7	6.6	23.3	-	-	60	-	-	1	-			
4/11/84	66.4	72.8	93.2	6.4	26.8	73.2	-0.3	65.6	72.5	6.9	2	-			
4/12/84	66.4	73.5	94.3	7.1	27.9	75.2	+1.1	77.3	78.8	1.5	0	-			
4/13/84	67.5	74.1	94.5	6.7	27.1	-	-	74	-	-	-	-			
4/14/84	68.8	74.6	-	5.8	-	-	-	68	-	-	-	-			
4/15/84	69.4	76.9	-	7.5	-	-	-	68	-	-	6	1			
4/16/84	66.5	70.4	80.0	3.9	13.5	76.3	+5.9	82.3	65.5	3.2	2	-			
4/17/84	68.8	73.0	89.7	4.2	20.9	75.4	+2.4	61.3	66.9	5.6	2	-			
4/18/84	67.9	73.7	92.7	5.8	24.8	73.6	-0.1	85.6	71.1	5.5	5	-			
4/19/84	67.8	74.4	84.7	6.6	16.9	78.1	+3.7	68	-	-	1	-			
4/20/84	68.4	78.4	90.8	10.0	22.4	76.5	+1.9	69	-	-	1	-			
4/21/84	69.7	77.1	-	7.4	-	-	-	72	-	-	-	-			
4/22/84	69.4	77.8	-	12.4	-	-	-	77	-	-	-	-			
4/23/84	71.6	78.5	93.3	6.9	21.7	-	-	69	-	-	0	-			
4/24/84	72.0	79.2	88.7	7.2	16.7	-	-	65	-	-	2	-			
4/25/84	72.2	79.6	93.2	7.4	21.8	84.2	+4.6	71.3	81.1	9.8	5	-			
4/26/84	72.4	81.8	93.3	9.0	20.5	78.1	-3.7	74.0	76.8	2.6	0	-			
4/27/84	72.7	80.5	90.8	7.8	18.1	-	-	75	-	-	5	-			
4/28/84	72.8	79.1	-	6.3	-	-	-	77	-	-	-	-			
4/29/84	74.0	80.6	-	6.6	-	-	-	76	-	-	0	-			
4/30/84	74.8	85.3	91.1	10.5	16.3	-	-	76	-	-	0	-			
5/1/84	71.4	81.0	92.2	9.6	20.8	-	-	76	-	-	0	-			
5/2/84	76.4	85.9	93.7	9.5	17.3	84.7	+1.2	77	-	-	0	-			
5/3/84	76.7	85.5	87.6	8.8	10.9	87.3	+1.8	76	-	-	0	-			
5/4/84	77.4	83.8	89.2	6.4	11.8	85.8	+2.0	81	-	-	0	-			
5/5/84	78.3	85.7	-	7.4	-	-	-	76	-	-	-	-			
5/6/84	78.2	87.7	-	9.5	-	-	-	79	-	-	0	-			
5/7/84	78.9	89.9	91.0	11.0	12.1	92.8	+2.9	81	-	-	0	-			
5/8/84	81.3	86.1	88.0	4.8	6.7	86.9	+0.8	80	-	-	2	-			
5/9/84	78.8	86.1	88.0	7.3	9.2	86.0	-0.1	64	-	-	3	-			
5/10/84	77.7	84.5	-	6.8	-	-	-	63	-	-	0	-			
5/11/84	77.3	83.6	-	6.3	-	-	-	64	-	-	0	-			
5/12/84	77.2	84.0	-	6.8	-	-	-	71	-	-	-	-			
5/13/84	78.3	85.8	-	7.5	-	-	-	76	-	-	0	-			
5/14/84	78.4	86.0	-	7.6	-	-	-	79	-	-	0	-			
5/15/84	79.1	85.5	-	6.4	-	-	-	68	-	-	0	-			
5/16/84	77.5	85.5	-	8.0	-	-	-	66	-	-	0	-			
5/17/84	76.8	84.1	-	7.3	-	87.1	+0.9	63	-	-	5	-			
5/18/84	76.1	86.2	90.5	10.1	14.4	-	-	65	-	-	3	-			
5/19/84	76.8	86.7	-	9.9	-	-	-	69	-	-	-	-			
5/20/84	76.8	86.6	-	9.8	-	-	-	74	-	-	1	-			
5/21/84	77.8	86.4	92.2	8.6	14.4	89.6	+3.2	78	-	-	3	-			
5/22/84	79.4	89.0	92.2	9.6	12.8	-	-	81	-	-	3	-			

Table 3. Continued

Date	Kennedy Water Temp		Kennedy At		Southside Water Temp		Southside At		Onsite Water Temp. MD	Onsite At	Air NOAA	Air Onsite	Air At	Kennedy Mantaes Total	Southside Mantaes Total
	MD	SD	MD	SD	MD	SD	MD	SD							
5/23/84	78.6	87.2	8.6	12.9	-	-	-	-	91.8	+8.6	74	-	-	1+2	-
5/24/84	79.3	89.0	9.7	11.5	-	-	-	-	-	-	77	-	-	1+1	-
5/25/84	78.5	87.9	9.5	-	-	-	-	-	-	-	78	-	-	0	-
5/26/84	-	-	-	-	-	-	-	-	-	-	78	-	-	-	-
5/27/84	-	-	-	-	-	-	-	-	-	-	76	-	-	0	-
5/28/84	80.8	87.0	7.0	-	-	-	-	-	-	-	79	-	-	0	-
5/29/84	80.7	89.5	8.8	12.6	-	-	-	-	-	-	79	-	-	0	-
5/30/84	79.7	87.1	7.4	10.8	-	-	-	-	-	-	67	-	-	+1	-
5/31/84	78.3	85.5	7.2	11.0	-	-	-	-	-	-	62	-	-	0	-
6/1/84	76.2	82.1	5.9	13.6	-	-	-	-	-	-	64	-	-	0	-
6/2/84	-	-	-	-	-	-	-	-	-	-	70	-	-	-	-
6/3/84	-	-	-	-	-	-	-	-	-	-	77	-	-	-	-
6/4/84	77.5	88.3	10.8	10.0	-	-	-	-	-	-	79	-	-	0	-
6/5/84	78.1	86.8	8.7	11.1	-	-	-	-	-	-	78	-	-	0	-
6/6/84	78.9	87.3	8.4	12.1	-	-	-	-	-	-	77	-	-	1+1	-
6/7/84	78.5	79.6	1.1	12.1	-	-	-	-	-	-	76	-	-	1	-
6/8/84	81.2	82.7	5.0	3.5	-	-	-	-	-	-	74	-	-	0	-
6/9/84	-	-	-	-	-	-	-	-	-	-	76	-	-	-	-
6/10/84	-	-	-	-	-	-	-	-	-	-	75	-	-	-	-
6/11/84	81.2	88.0	6.8	7.1	-	-	-	-	-	-	75	-	-	+1	-
6/12/84	81.2	91.3	10.1	9.3	-	-	-	-	-	-	76	-	-	0	-
6/13/84	-	-	-	-	-	-	-	-	-	-	75	-	-	0	-
6/14/84	80.7	87.3	6.6	8.3	-	-	-	-	-	-	79	-	-	0	-

Previously observed trends in the Jacksonville area continued to be observed, although the trends were more pronounced due to the greater numbers of manatees, numbers of sightings, and higher degree of use of the Jacksonville power plant effluents.

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A NATIONAL PERSPECTIVE ON COASTAL FISHERY HABITATS

B. J. Copeland

Introduction

AS unique ecosystems of varying mixtures of mud, water and organic material along the shorelines of our oceans and Great Lakes, estuaries represent a very important national resource. The extensive estuarine system of the United States ranges from the steep, tectonically formed estuaries along the northwestern coast to the shallow, wide estuaries of the drowned river valleys in the Southeast.

Estuaries serve several functions that are economically and socially important to this nation. These include:

- 1) They provide habitat for many species of fish invertebrates (almost 70% of our commercial and recreational catch nationwide) that constitutes a significant portion of the economically important commercial fishery and coastal recreational industries.
- 2) They serve as a buffer zone between the oceans or Great Lakes and the land, providing an important ameliorating zone for storms, floods, etc.
- 3) They serve as important sinks for materials that flow from the lands and man's activity, catching these materials before they reach the ocean.
- 4) They serve as important pathways of transportation to connect inland commerce to ocean shipping.
- 5) They are aesthetic mixing pots, attracting people who support a burgeoning recreational and tourism industry.

The southeastern region of the United States has more extensive estuarine systems than anywhere else in the country. Nearly half of the estuarine area lies within the geographic region from Texas to North Carolina. In the Southeast, about 95% of our fisheries catch depends upon estuaries during one time or another of their life history. It is, therefore, not surprising to be reminded that half of the nation's fisheries catch comes from the southeastern region. We are also told that the southeastern region represents one area where fisheries catch could be substantially increased. Are we to conclude, then, that more effective management of our estuarine habitat would pay dividends by increasing our recreational and commercial fisheries?

There is a complex array of pressures being exerted on the estuaries today.

The following are examples:

- 1) Nutrient loading, with its complex interrelationships of form, fate and timing.
- 2) Control and fate of exotic substances such as pesticides, herbicides, heavy metals and organic compounds.
- 3) Impact of urbanization, with the increasing threats of stormwater runoff and sewage disposal.
- 4) Impact of changing land uses, with the accompanying interaction of water drainage and impacts on estuarine productivity.
- 5) Increasing numbers of commercial and recreational fishing efforts vying for a finite number of stock.
- 6) Increasing conflicts of interest in the allocation of resource uses, including arguments over commercial and recreational interests in the same species.
- 7) The overlap of local, state and federal jurisdictions, which are sometimes incompatible for effective allocation of resources.
- 8) Cooperation between users and regulators often fall short in maximizing the benefits of envisioned management programs.
- 9) Education of the public is often inadequate to effectively involve them in a management program.

Research Needed To Manage

Although large data sets exist for many functional aspects of estuaries, there are several serious gaps in information needed to understand the complexities of how most estuaries function. Recently, a symposium was held in Raleigh, North Carolina (Copeland et al. 1984) to develop research strategies needed to manage the nation's estuaries. Several of the nation's most capable researchers peered into the future and, based on the very latest scientific protocol, suggested some research directions necessary to better understand estuarine functions. Assessment of problematic needs resulted in five basic categories of research.

Water Management and Estuarine Productivity

One of the important problems currently facing our nation is the allocation of freshwater resources. As municipal,

commercial, industrial, agricultural and recreational demands for water increase, downstream availability of water to estuaries decreases. Changing land use activities near estuaries and upstream tributaries are affecting the quantity, quality and timing of freshwater inflows. Since estuaries, by definition, involve the inflow and mixing of fresh and salt water, these variances may impose significant changes upon estuarine productivity. The coupling between freshwater inflow and productivity in the estuaries poses a prime research question. We need to know the quantitative relationship between freshwater inflows and fisheries production in individual and regional groups of estuaries. In addition, we need to determine how much fresh water is too much or too little on a seasonal or annual basis.

It is difficult to obtain unifying principles regarding the impact of freshwater flow on estuaries, particularly with the great variability that occurs in the magnitude of flow, the concentration of materials in the water and the seasonal variability of inputs (Nixon 1981). In an attempt to summarize the magnitude of river inputs to various coastal areas of the United States (Figure 1), Nixon (1981) calculated mean annual discharge of major rivers per unit of coastline. If the productivity of estuaries is related to the magnitude of river flow, then, one ought to be able to predict the amount of fisheries yield per unit area of coastline. This simply cannot be done! We lack the necessary fundamental research to quantify the relationship between freshwater inflow and secondary productivity. Large-scale problems here in the Southeast range from not enough fresh water in Texas, to diversion of a major river system in Louisiana, to changes in drainage patterns of the Everglades, to increased localized drainage from land clearing on the coastal plains of North Carolina.

Sediment Management and Estuarine Productivity

Sediment quantity and quality can affect estuarine productivity. Man's activities on the watershed can affect sediment processes such as the rates of accumulation and contaminant absorption. To better understand sediment management, researchers need to examine the rates of accumulation and the transformation of sediment composition between points of entry and accumulation. We also need to categorize the processes controlling the movement, absorption and desorption of contaminants as well as to develop a capability to predict, for a range of environmental conditions, the relationship between sediment accumulation and habitat type.

Although soil erosion rates have been reduced by soil conservation practices, our estuaries are still feeling the effects of the earlier high erosion rates. A large percentage of the sediments eroded from the uplands of the southeastern United States since 1700 is still being released to the estuaries by flooding (Schubel 1984). These waves of sediment inputs to the coastal zone have resulted in vast changes in some of our estua-

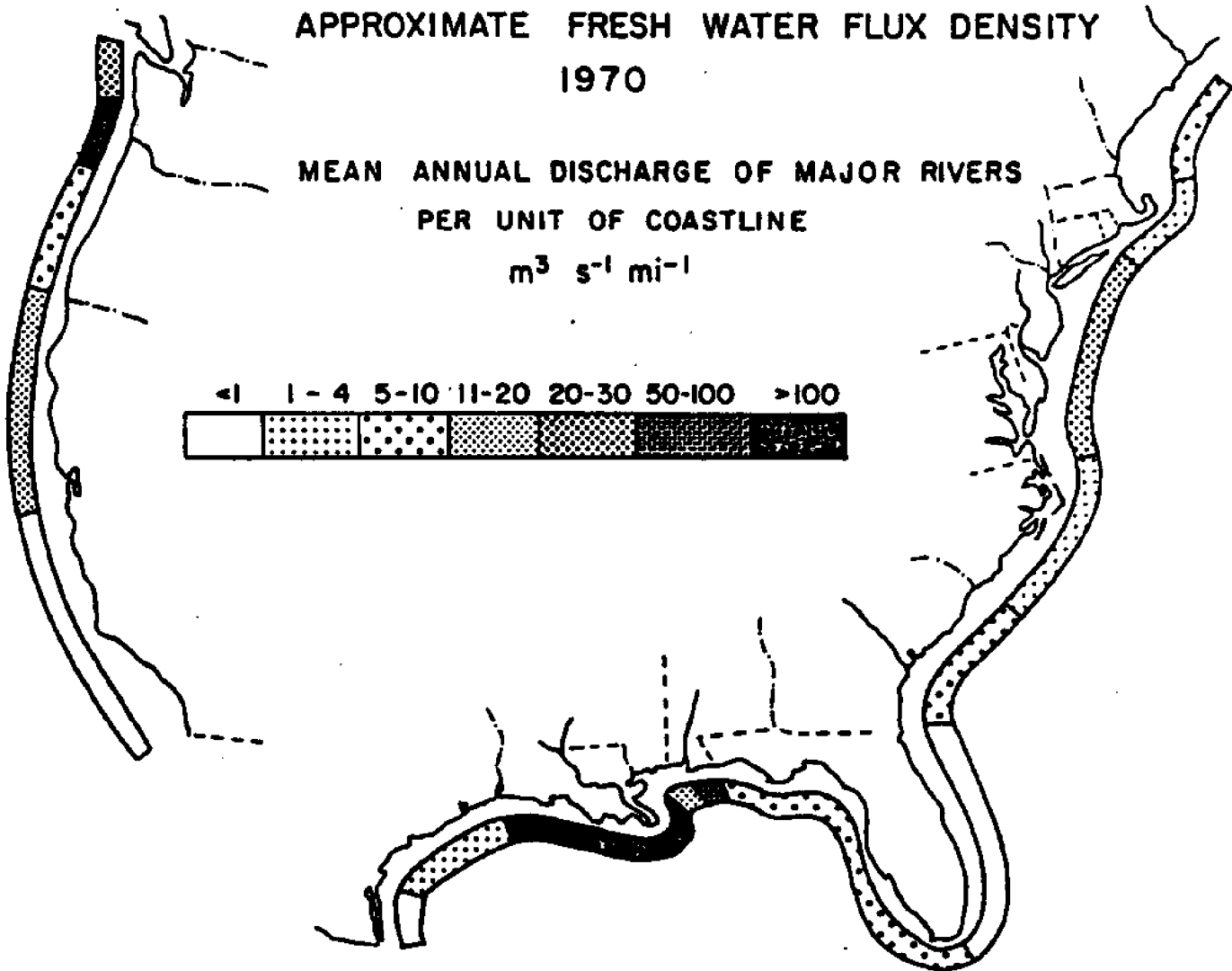


Figure 1. A rough approximation of the flux of fresh water from major rivers along the coast of the coterminous United States (from Nixon 1981).

rine systems (Figure 2). These changes range from increasing sizes of deltaic areas which changed the estuarine systems at the mouth of Colorado in Texas or at the mouth of the Mississippi in Louisiana, to increased turbidities in some estuaries that effect the primary productivity, to the release of stored contaminants which endanger some of our fish and wildlife.

Nutrients and Other Contaminants and Estuarine Productivity.

Many observations indicate increasing nutrient problems in estuaries. More people are living near our nation's coast. The resulting increased use of inorganic fertilizers and conversion of wetlands to urban and agricultural use eliminates the estuary's ability to act as a nutrient and sediment sink and increases estuarine nutrient levels. We do not yet understand the relationships between nutrient inputs, recycling and production. Research is needed to test how an estuarine ecosystem responds to a combination of nutrient inputs and recycling. Scientists need to examine the ultimate fate of a host of synthetic chemicals and metals in estuaries.

An example of one of the few estuaries in the United States where nutrient dynamics have been relatively well studied is the Pamlico River Estuary of North Carolina (Copeland et al. 1984). Enough information is available to construct a summary of annual nutrient inputs and phytoplankton uptake (Table 1). In contrast to the long-held beliefs that the primary driving force of phytoplankton uptake is the input of nutrients from upstream, it was determined that the Pamlico River Estuary phytoplankton production utilizes 95% of its nitrogen and 88% of its phosphorus from recycled nutrients (Kuenzler et al. 1979). Furthermore, about 75% of the annual input of nitrogen and about 70% of the phosphorus entered the estuary during December through March, reflecting the variations in river and estuary discharge. This is contrasted to the bulk of the algal uptake occurring during the summer months. Therefore, this evidence indicates that there is considerably more to the nutrient input question than just measuring nutrient budgets in the estuary.

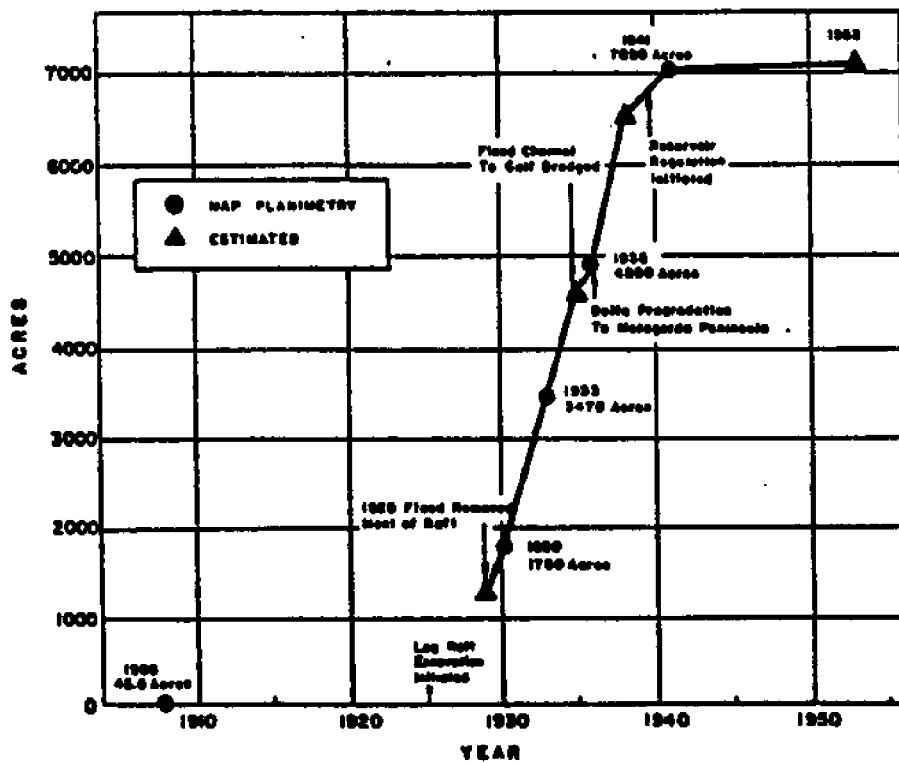


Figure 2. Time history of the area of the Colorado delta, Texas (from Ward and Armstrong 1980).

TABLE 1

Annual Nutrient Inputs and Algal Uptake (tonnes/year) in the Pamlico River Estuary, North Carolina (from Kuenzler et al. 1979).

	Water- shed	Pamlico Sound	Precipi- tation	Total
Input Nitrogen	522	598	286	1,406
Input Phosphorus	331	477	17	825
Algal Uptakes				
Nitrogen				27,091
Phosphorus				7,012
% Uptake from Recycling				
Nitrogen				95%
Phosphorus				88%

Coupling of Primary and Secondary Productivity

Estuarine ecosystems are characterized by high levels of primary and secondary productivity. The connection between high primary and secondary production is uncertain, at best. Thus, the importance and ecological efficiencies of individual food chain pathways remain unresolved. Food chains in estuarine ecosystems are connected quantitatively and qualitatively. We must understand the relationship between the quantity of biomass at one producer level and the quantity and quality of biomass at the next level. For example, while large biomasses of blue-green algae are produced in some of the nation's estuaries, few secondary consumers feed on these poor quality algae.

The concept of the trophic structure in an estuarine ecosystem is more of food web than a food chain. Moreover, the food web trophic structure found in the estuary is generally abbreviated compared to the longer food chain relationships observed in the ocean and freshwater lakes. The problem of understanding the fundamental aspects of this issue is the likelihood that a change in one trophic level impacts other portions of the ecosystem by altering the directions or size of the energy flow from one component to another. This intricacy is illustrated for the Pamlico River Estuary by the simplified food web for one species of fish, menhaden (Figure 3). In spite of all the work that has been directed toward the plant and animal components of this estuary, we are far from understanding the relationship between the components to a degree that we can predict what may happen because of some perturbation at one level or another.

During the past two decades, blue-green algae blooms have been observed with increasing frequency in Atlantic and Gulf coast estuarine systems. Initially, public concern over the blue-green blooms was focused on obvious visible symptoms such as aesthetics of surface scums and odors, fish kills, fouling of fish nets and a decline in fishing success. Recent research information indicates that a more subtle and perhaps more devastating outcome of the blue-green algae blooms is the serious change in food chain dynamic resulting from such massive blooms of blue-green algae. This results from the fact that the blue-green algae in a bloom is almost pure culture tying up the nutrients and organic material. Yet, they are not being utilized by normal food chain organisms.

Habitat Requirements for Fisheries Production

Traditionally, it is thought that one of the primary roles of an estuary is as a nursery for commercially and recreationally important fishes. It has been observed that some estuaries produce more fish than others. Understanding the role of estuarine habitat and quantitative differences in fisheries production will provide the key to more effective fisheries management.

Thus, in order to find out what makes one estuary more productive than another scientists need to address questions

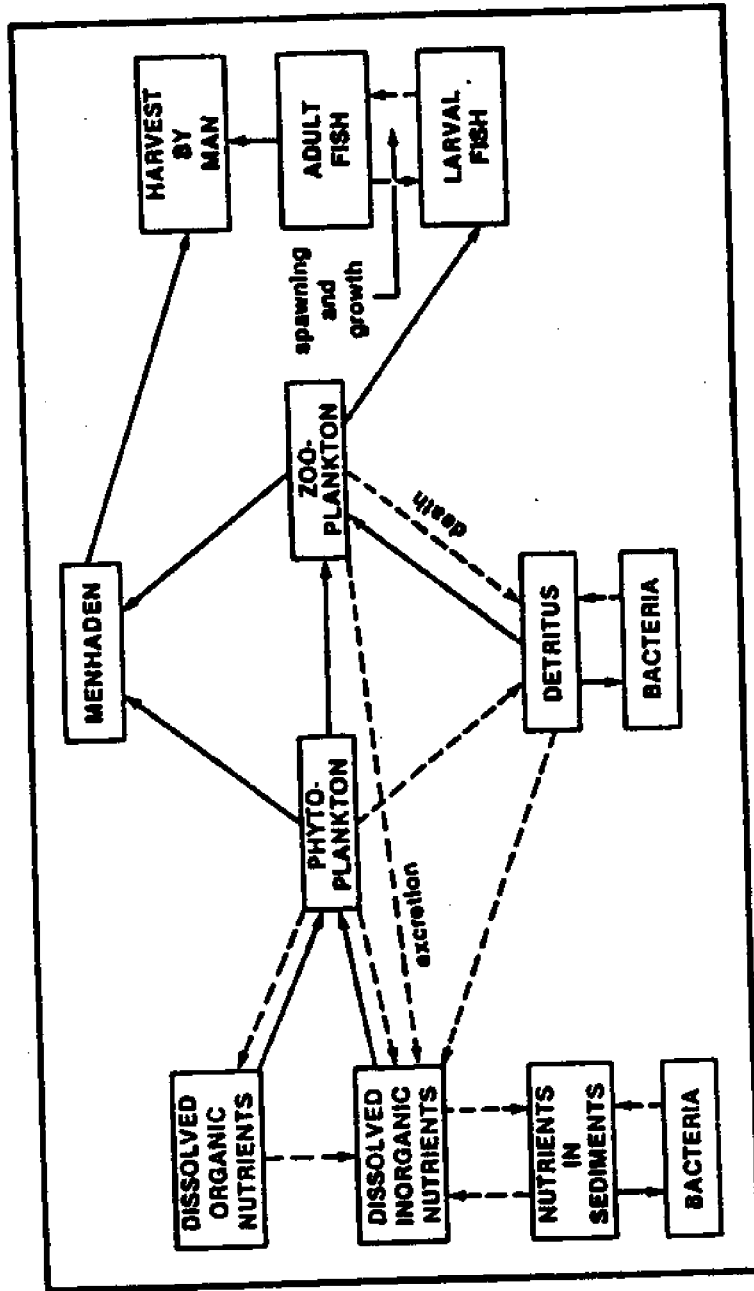


Figure 3. Simplified trophic diagram showing a phytoplankton to menhaden pathway (from Copeland et al. 1984).

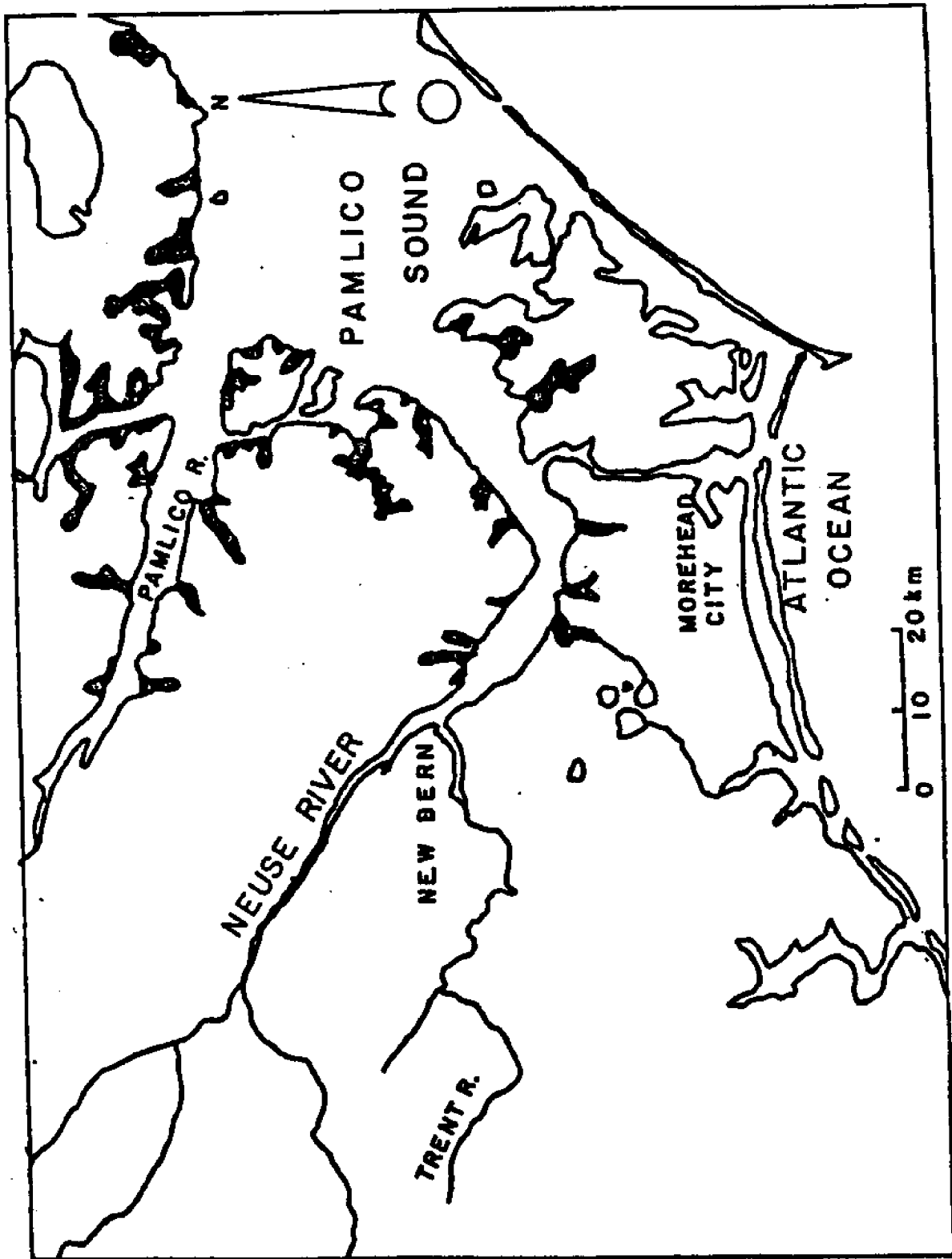


Figure 4. Map of Pamlico Sound, North Carolina, showing primary nursery areas (from Copeland et al. 1983a).

about habitat selection, species migration, species residence times, food availability, circulation and exchange patterns, habitat quality, and the effects of environmental variations on survival, growth, and movement of fish and shellfish. Answers will help resource managers establish criteria to protect the estuarine characteristics that provide suitable fisheries production. Armed with better scientific knowledge, managers may better address the critical question of whether improved and enlarged nursery habitat will improve and enlarge fisheries production in our nation's estuaries.

The area of nursery grounds usually represents only a small portion of the total estuarine system (Copeland et al. 1983a). For example, of the approximately 2.3 million acres of estuaries in North Carolina, only about 75 thousand acres have been designated primary nursery grounds. A relatively large portion of these lie along the northern and western shores of Pamlico Sound (Figure 4). Major questions still remain regarding the specific functional aspects of these shallow zones. Moreover, the primary nursery areas lie at the downstream end of small tributaries to the sound and are, thus, vulnerable to changes in land use patterns and water quality degradation.

Not all primary nursery areas provide the same levels of productivity. In the case of Pamlico Sound, North Carolina, it has 56% of the state's total estuarine area and produces 78% of the total inshore catch (Table 2). In contrast, Albemarle Sound, with 26% of the state's estuarine area, produces only 14% of the total inshore catch. As noteworthy as this disproportionately high productivity is, the higher proportion attributed to Pamlico Sound might be even more startling if the offshore catch could be apportioned to the sounds. The offshore catch exceeds the inshore total in poundage because of the large menhaden contribution, which is thought to be attributable almost entirely to Pamlico Sound and its primary nursery areas.

INSTITUTIONAL BARRIERS

As important as good technical information is for the management of our estuarine habitats, there are several very important aspects related to the institutions involved. Therefore, we need to address the situation of integrating technology with the socioeconomic and jurisdictional questions of management.

Jurisdictional Problems

Several state, local and federal agencies are charged with the responsibility of managing the various resources of our estuarine system. Because of multiple jurisdictions and the concomitant separation of power by the various institutions, it is nearly impossible to develop an effective management program. I shall use the Albemarle Sound, a nine hundred square mile estuary in northeastern North Carolina (Copeland et al. 1983b) to illustrate a jurisdictional problem.

TABLE 2

Distribution of 1980 Commercial Fisheries Catch and Value, Albemarle and Pamlico Sounds, North Carolina (from Copeland et al. 1984).

Parameter	Albemarle Sound	Pamlico Sound
Area (mi ²)	940	2,000
% State Total	26%	56%
Catch (1,000 lb)	13,200	71,430
% Total Inshore Catch	14%	78%
Value (\$1,000)	1,981	26,182
% Total Inshore Value	5%	73%

Seventy percent of the watershed of Albemarle Sound lies in Virginia, while the entire sound lies in North Carolina. Many believe that the water quality problems in the western part of the sound are the result of activities carried out in Virginia. In fact, about 70% of the nitrogen loading and 80% of the phosphorus loading in the Chowan River (a major tributary) are from the Virginia portion of the watershed. In addition to water quality problems, a city in Virginia is currently increasing its municipal use of water from the Albemarle watershed, thereby reducing freshwater inflows to Albemarle Sound. Because of conflicts in the goals of state governments in Virginia and North Carolina, it has been difficult to bring about water quality improvement. Thus, a serious constraint to the management of Albemarle Sound is jurisdictional interactions between two state governments.

Several state, local and federal agencies are charged with the responsibility of managing the various resources in Albemarle Sound. For example, the North Carolina Division of Marine Fisheries manages the marine fisheries of the sound, while the North Carolina Division of Wildlife Resources manages the freshwater fisheries. These and other jurisdictions often overlap. Still different agencies are charged with responsibilities for water quality, water management, shellfish sanitation and land use planning. Many federal agencies operate by enforcing blanket regulations and have management goals that are sometimes in conflict with the goals of state or local governments. All these responsibilities and goals need to be coordinated and optimized for effective management activities.

Economic Constraints

The term management generally refers to taking some action or actions designed to achieve a given goal. Unfortunately, the setting of these goals and developing programs to carry them out often result in the comparison of apples and oranges. For example, the economic return calculated on the basis of wholesale price for agricultural goods versus opportunity costs of water quality prevention versus revenue generated from a common property fisheries stock are not equatable. Therefore, one is faced with establishing goals on the basis of perception of economic return rather than what actually happens.

We generally do not have sufficient data or methodology to resolve the question of whether management of a certain estuary can be cost effective. Any change in resource usage through public policy affects costs and revenues over time and these changes in flows of revenues should be evaluated beforehand. Some of the newly developed dynamic economic modeling provides an additional evaluation technique that we ought to be using. Meanwhile, we might not be able to afford the cost of delaying management decisions until adequate data are available because of the rapid changes that are occurring in some of our nation's estuaries.

Social and Institutional Implications

Many economic forces are focused on estuaries and the potential uses are often in conflict with one another. None of the forces and uses, however, is mutually exclusive of another. Managing estuaries so as to minimize conflicts among different users becomes a major sociological consideration. Social conflicts are particularly apparent when managing within fisheries interests. Although the same environmental criteria are important for the biological management of commercial and recreational fisheries, serious conflicts in economic and social goals exist between the two. Often many of the species sought by both interests are the same. Recreational fishermen blame commercial fishermen for decreasing stocks and catch effort, while commercial fishermen accuse recreational fishermen for such things as getting new restrictions and actions to decrease their fishing rights. Social conflicts also exist within the same fisheries group such as larger boats versus smaller boats and crab potting versus trawling for crabs, etc. Any management scheme developed for any estuary must consider these problems if the plan is to have much chance for success.

Public education is needed to enable management schemes to succeed. While the awareness of the public about environmental issues has rapidly increased, there is a great need for improvement of the social and institutional climate that will allow the manifestation of that awareness. So-called public hearings are often held in relation to a development or change in policy, but the public rarely gets an opportunity to interact on a real basis. Until these issues are resolved, we will continue to have great social conflict in fostering changes in the way we do things.

CONCLUSIONS

To focus the research needed and to develop a national program in dealing with the problems in our estuaries the following goals are suggested:

- 1) To describe the relationships between physical and chemical variables and the productivity of estuarine ecosystems.
- 2) To understand the chemical, sedimentological and biochemical processes in the estuarine environment as they are affected by the introduction of foreign substances, especially pathogenic materials and toxic chemicals.
- 3) To determine the impact of man's activities on the fundamental functioning of estuarine ecosystems.
- 4) To develop appropriate measures for ameliorating undesirable effects and to reclaim damaged estuarine ecosystems.

- 5) To develop a means to increase the harvest of fisheries products.
- 6) To improve the economic return of land around the estuaries by resolving the conflict between land use changes and estuarine productivity.

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MANAGING COASTAL GROWTH FOR QUALITY LIVING

Charles E. Bennett, M.C.

I. It is a great pleasure to join you today in discussing some areas of concern in which the Federal Government is involved in helping to improve and protect the quality of life in coastal zone areas.

The House Merchant, Marine and Fisheries Committee was my original committee assignment in 1949 when I just went to Congress. And I now serve there again. This committee has responsibility in issues which concern you most. I served last year on its subcommittees on fisheries and wildlife conservation and on the environment. I will serve there again in the new Congress. Most federal initiatives must be approved by this committee. So I am given leadership opportunity in most of the issues that this country currently faces relative to coastal zone areas. Of course, this is in addition to my duties on the Armed Services Committee where I serve as Chairman of the Seapower Committee.

II. The growth and development of North East Florida and coastal Georgia is rapidly increasing. Most of the growth here is taking place near the wetlands which currently support over 75% of the sport and commercial fishery in the area. Elected officials, such as myself, are often faced with making decisions regarding preservation of fish habitats and growth in these areas without having confidence in the scientific knowledge available to us. This symposium will be helpful to me and others in bringing together the scientific knowledge needed and presenting it in a workable form helpful to all public officials of this area.

The coastal areas of S.E. Georgia and N.E. Florida are among the most rapidly growing regions of the southeast. According to 1980-81 statistics, Florida is gaining more than 5000 persons per week. North Florida counties such as Clay and Flager have grown more than 100% in the last ten years. Major high intensity development projects, either completed or in various stages of construction, include the Kings Bay Submarine Base at St. Mary's, Georgia; Amelia Island in Nassau County; The Georgia Sea Islands; and Palm Coast in Flager County. Recently, resort development projects have been proposed for Ft. George Island in Duval County and for Porpoise Point and Rattlesnake Island in St. Johns County. All of the above projects involve development on lands adjacent to marine wetlands. The marine wetlands that are or will be impacted by this high intensity development support major commercial and sports fishing industries in the Florida-Georgia area. These wetlands contain some of the most extensive Salt Marsh Ecosystems remaining in the southeastern United States.

Obvious impacts include drainage alteration, increase in point and non-point pollution, dredge and fill problems, and bulkheading. That development will continue to occur is probably a foregone conclusion. That such development should be planned in ways that will minimize the potential impact on adjacent wetlands is not always obvious either to the developer or to the local decisionmaker (county commissioner or zoning officer). We can look at South Florida to see the results of uncontrolled development. Local decisionmakers need to be made aware of the impacts of growth and development on fishery habitats.

III. Many of these wetland habitats have been poorly studied. The available scientific data have not been widely disseminated nor, in many cases, synthesized into a coherent body of knowledge available to other scientists or to the decisionmakers.

The Marine Advisory Committees of Nassau, Duval, St. Johns, Flager, and Volusia Counties, for the past three years, have unanimously agreed that the top priority should be to develop awareness among local decisionmakers about the impacts of growth and development on fishery habitats.

The lack of readily available, scientifically based information for local decisionmaking is more pronounced in the more rural counties. These counties do not have their own professional environmental planners or researchers to aid them in arriving at informed decisions regarding development adjacent to wetlands. The long range impact on marine fisheries of ill-informed planning decisions that have already been made is still unknown.

IV. The heroic Jean Ribault when he came to N.E. Florida and S.E. Georgia in 1562 said of the virgin countryside which he saw, that it was "the fairest, frutefullest and pleasantest of all the worlde, habouding in honey, veneson, wildfowle, forrestes, woodes of all sortes." And speaking of the marshlands he said: "The sight of the faire medows is a pleasure not able to be expressed with tongue". Rene Laudonniere, who accompanied Ribault, and in 1564 settled the St. Johns Bluff on the St. Johns River, said of the bluff area looking toward today's Nassau River: "Concerning the pleasantness of the place, the sea may be seen clearly and openly from it; and more than six leagues off toward the Belle River one may see Broad Meadows divided by isles and islets interlacing each other. Briefly the place is so pleasant that it would force the depressed to life their spirits."

Two hundred years later (and 200 years ago) the botanist, John Bartram came and on October 1, 1765 discovered the flowering bush "Franklinia" on the Satilla River in Southern Georgia. He then pushed on to Northern Florida where he noted the Sabal Palm saying "Hereabout we observed ye tree palm (which) growed 30 feet and held thro several Bay Swamps". John's son William Bartram came back to south Georgia and to Florida in 1774. He recorded in detail the beauties of nature he observed - marshes, rivers, cypress and magnolia, the paraquete and wild pigeons, now both extinct - he wrote: "Let us rely on Providence, and by studying

and contemplating the works and power of the creator, learn wisdom and understanding in the economy of nature, and be seriously attentive to that divine monitor within. Let us be obedient to the ruling powers in such things as regard human affairs, our duties to each other, and all creatures and concerns that are submitted to our care and contact."

Many environmental changes have occurred in this area since those colonial times, particularly in recent decades. Industry and exploding population on the St. Johns and the St. Mary's Rivers have threatened safe and quality living for ourselves and for future generations. Recently, exploration for oil offshore poses new threats to Florida and to Georgia.

Let us look at the federal legislative picture for a few minutes.

V. Coastal Zone Management Programs

Perhaps the biggest challenge to persons dealing with coastal zone management problems is the Reagan Administration itself. The tremendous tax reduction achieved by it in 1981 has left us a new trillion dollars of dangerous red ink; and environmental programs are now a target of the Administration's budget advisors. The major grant programs of the Coastal Zone Management Act of 1972 have been repeatedly scheduled for substantial reductions and orderly phaseouts by the Reagan Administration. These programs fund projects to mitigate the impact of offshore oil and gas development and to administer state approved coastal resource plans. However, Congress has reaffirmed support for these programs by repeatedly providing significantly higher levels of funding than the administration has purposed.

As a little background, the Coastal Management Act (passed in 1972 to provide grants to states to develop and administer programs for managing resources in their coastal zone) was amended in 1976 in response to rapid expansion of offshore oil and gas activities. The 1976 amendments created a \$1.2 billion dollar program of loans and grants to help states and localities accommodate anticipated disruptions associated with Outer Continental Shelf activities. Although participation in these programs is voluntary, all 35 eligible coastal states and territories have participated in the State Management Grant Programs since 1972.

The office of Coastal Zone Management of the National Oceanic and Atmospheric Administration of the Department of Commerce, which administers this program, also operates two smaller programs. One of these is to develop a system of estuarine sanctuaries as a cooperative Federal-State activity. The other program is to develop a system of marine sanctuaries and is strictly a Federal activity. Although the Reagan Administration has proposed drastic reductions in the funding for these programs over the past four years, Congress has also continued to fund these by increasing appropriations over funding levels for prior years.

VI. OCS Block Grant Legislation

I believe Congress' strongest response to the Administration's proposed cuts have been legislation to provide a long term more secure funding source for coastal management. This legislation, which I have co-sponsored, would create new block grant programs funded from Outer Continental Shelf (OCS) revenues. This legislation has passed the House in the past two Congresses but has been tied up by the Senate.

It would establish an ocean and coastal resources management and development fund from Federal receipts and production of oil and gas on the Outer Continental Shelf to be used to provide National Ocean and Coastal Resources Management and Development Block Grants to Coastal States. A grant allocation formula would be established based upon the actual and expected leasing on the Outer Continental Shelf adjacent to a particular state, the volume of energy resources obtained, the coastal population of the state, and other factors. Block grants would be earmarked to support activities authorized by the 1972 Act as well as the programs established by the later Amendments of the Act.

Support for this Legislation comes from those of us who favor sharing Federal Outer Continental Shelf revenues with the coastal States. This policy makes sense to me since increased energy production due to accelerated exploration and development on the Outer Continental Shelf would cause increased impact on Coastal States such as Florida and Georgia. A share of Federal receipts from OSC activities could partially compensate for these impacts through support of the coastal and ocean programs for which the administration is trying to withdraw Federal support.

I believe that States would be less inclined to oppose the leasing of OSC tracks adjacent to their coasts if states were to receive a portion of the Federal revenues from these leasing activities as proposed in this legislation. The Administration opposes this on the theory that it would be a further drain on the U.S. Treasury and increase the Federal deficit. I continue to think that the proposed legislation as a cosponsor in the coming Congress.

VII. Consistency Legislation

In January of last year, the Supreme Court held that sales of offshore oil and gas leases are not activities that affect the coastal zone, and are, therefore, not subject to the consistency provision in the CZM Act which requires that offshore operations be approved as consistent with the adjacent State's coastal zone management plan before being undertaken.

In response to this, legislation has been introduced which I and most of the members of the Florida Congressional Delegation have co-sponsored, that would specify that coastal States affected by the sale of leases must determine such sales to be consistent in advance of leasing activity.

This legislation is needed because a lease sale initiates a range of possible activities that could severely affect the coastal zone. This is especially true in the State of Florida, where the tourist industry and the recreational and commercial fishing industries are so important to the economy and the quality of life. The Governor has strongly urged passage of this legislation and I expect this to be a major issue in the coming Congress. Even if this offshore activity did not produce a need for funds for protection of the shore environment, such funds are needed to protect that environment and this is a logical source of funds.

VIII. Coastal Barrier Protection

Perhaps the greatest single legislative accomplishment in the last 3 or 4 years by the Congress that impacts the quality of life in the coastal zone areas is the passage of the Coastal Barriers Resources Protection Act which I cosponsored in 1982.

In that legislation, Congress prohibited for the first time the sale of Federal flood insurance after October 1, 1983 for any new construction on barriers defined as undeveloped by the Department of the Interior. Since that time, we have gone through much controversy in working with the Department of the Interior to define precisely what is a coastal barrier that should be protected by the legislation. We managed to have part of Amelia Island included in this system as well as Big Talbot Island. Each of these inclusions is logical and proper and I supported these needed inclusions.

Coastal barriers are generally defined as elongated, narrow land forms separated from the mainland by marshes or open water eminently related to the island. These barriers include both true island and mainland beach systems. Hurricanes and other large storms have caused extensive damage to coastal areas. Environmental scientists have told us these lands might be very substantially reduced by erosion if we don't adequately preserve the coastal barriers. Coastal barriers also protect estuarine and wetlands areas from the forces of the sea and provide a highly productive environment for many plant and animal species.

The Apalachicola Bay System in Western Florida is a prime example of a coastal barrier system. It provides over 80% of the state's oysters and serves as one of the most productive areas of blue crab propagation along the Gulf Coast of Florida. In addition, this system is a major nursing ground for shrimp and for a broad range of invertebrates and finfish which supply extensive commercial and sport fisheries.

IX. Non-Point Source Pollution

One other issue which I believe will be of significant importance to the 99th Congress is the problem of what to do with non-profit sources of water pollution, that is sources that are not discharged from a discreet identifiable pipe or conveyance. The importance of putting a stop to uncontrolled nonpoint source

pollution has become very evident over the past decade as industrial and municipal point sources have come in line with the Clean Water Act, and yet we still have wide spread pollution. Congress is expected to carefully examine the adequacy of current water quality standards in other programs to control non-point sources of pollution and to see whether new Federal programs may be needed.

Nonprofit source pollution is transported to streams and lakes primarily by rainfall run off from agricultural lands, forestry and construction operations, abandoned mine sites, and urban and suburban areas. The pollutants include conventional and toxic materials, animal waste, fertilizer and pesticides washed off crop lands, metals and oils from roads, and other agricultural materials. EPA officials have estimated that non-profit sources contribute at least 50% of total pollution levels in the Nation's waters.

Very little attention was given to these non-profit sources of pollution in the 1972 Water Pollution Control Act or in its amendments. The time has probably now come to do something about it. Many complex and difficult decisions will, of course, need to be made in formulating the appropriate legislation to combat this course of pollution. I am hopeful that your group will be able to work with myself and other members of Congress in producing effective legislation.

X. Nassau Valley Protection

I have introduced my own legislation this year which I introduced last year that would provide protection for the marshes of the Nassau River Valley and some of the adjacent upper lands. I am certain that most of you are familiar with the environmental and recreational values provided by this gorgeous marsh river bed system between the St. John's and St. Mary's Rivers. My legislation would establish a conservation district throughout the entire area which would place restrictions on the type of development that would be allowed throughout. The restrictions would be determined by a Commission of local and state representatives which would be composed of persons representing the diverse interests in the adjacent areas of Duval and Nassau Counties.

Congressman Seiberling, the Chairman of the public lands subcommittee of the House Interior Committee, is planning to visit this area this spring. He and I then expect to fly over the area in a helicopter with some of his staffers and other Federal officials, and I think that the chances of getting protection legislation will be very good this year.

The 99th Congress will continue to improve the quality of life in the coastal zone areas of our country. Seminars like this one will help to bring about positive results. I am grateful for your work in this field and for your kindness in including me in this effort.

CONNECTIONS BETWEEN COASTAL GROWTH AND FISHERY HABITAT
ISSUES IN NORTHEAST FLORIDA AND GEORGIA

William Seaman, Jr.

The natural coastal and marine resources of Georgia and northeast Florida make a significant contribution to the region's economy. Moreover, these resources are not only closely intertwined with each other but also are a significant part of the social fabric. In reviewing the extensive material presented at the conference it is important to consider the diverse audiences concerned with the resource base and which the conference sought to embrace. Furthermore, tying together the perspectives of those interests identified on the program brochure, namely:

- .Elected Officials
- .Scientists
- .Coastal Developers
- .Fishermen
- .Marine Businesses
- .Citizens
- .Marine Professionals

requires a broad and balanced approach. Within these guidelines there are three jobs to perform in providing a synopsis for both those who attended the conference as well as those who only will have the written record of it: To summarize what happened; to note what did not happen; and to indicate where we go from here.

What Did Happen

This section might appropriately be sub-titled "A synopsis of the fish-habitat story." In terms of format we began with six invited review papers that summarized knowledge, trends, and themes pertinent to Georgia and Northeast Florida coastal resource issues. Topics included fisheries and their economics, coastal habitats, the contribution of rivers and upland drainages to coastal ecology, and management of wetlands. Key agency and academic people active in this field shared information, as presented in greater detail elsewhere in this document. Among

Associate Professor, Fisheries, University of Florida and
Associate Director, Florida Sea Grant College Program, Building
803, UF, Gainesville 32611.

the significant findings worth a summary remark here, however, were these five:

1. Economics. This region yields economically valuable fisheries. Commercial dockside landings exceeded \$32,000,00 in a recent year. Furthermore, this value is multiplied through processing and sales. And recreational fishing is even larger, but not quantified monetarily.
2. Linkages. At least 75% of the sport and commercial fish catch in these waters is based on species that are dependent upon the estuary for part or all of their life cycle. Examples are shrimp, menhaden, and blue crab. A second linkage is the upland-coastal drainage pattern, whereby critical freshwater is provided to the coast.
3. Fishery trends. There is an apparent decline in fishery production, particularly noted for blue crabs and shrimp.
4. Finite resources. Natural resources of this coast are limited, yet anticipated increase in their usage will add to pressures for multiple use. Estimated habitat losses include 36% of the lower St. Johns system since the 1940's, and 18% of Georgia oyster beds over the last century.
5. Role of science. Scientists of both states remain committed to long-term and informed decision-making about resource issues, and are able to both explain the structure and function of natural systems (e.g., salt marshes), and demonstrate successful research that anticipates and answers practical management questions (e.g., shrimp fishing).

Sixteen contributed papers then addressed issues such as water quality, pollution, coastal ecology, impacts of development, characteristics of fisheries and habitat restoration/enhancement. The two states were the subject of six papers each. Key points and themes, some reinforcing the contributed papers, included:

1. Confirming the decline of oyster fisheries in this region.
2. Characterizing the environmental monitoring of local and state agencies.
3. Explaining how habitat restoration works.
4. Noting increases in fishery pressure.
5. Describing how fisheries are part of the region's rural social fabric.

6. Pinpointing localized pollution problems.
7. Reviewing how research and management interact.
8. Concluding that fisheries and habitat have declined in overall quality, but finding it difficult to completely quantify the degree to which estuaries are endangered.

Information from the review and contributed papers allows a useful comparison of the differences and similarities of the two states, letting us step back to appreciate resource utilization and management in this region, and possible to discern new ways to enhance the process. The following section integrates some of this material.

A New Perspective

To sports fans the conference location, Jacksonville, inevitably calls forth reference to the athletic highlight of the year, namely a certain annual interstate college football game at the Gator Bowl! This rivalry suggests a way to look at the data presented by the Conferees in a somewhat different manner, so that a "Georgia-Florida faceoff" is offered as part of this summary presentation (Table 1). Such an analysis reveals that there are some real and very important differences between the two states in terms of the coastal natural resource base, socio-political-economic systems, and fisheries supported along the stretch of the U.S. South Atlantic coast between Savannah and Daytona Beach. These differences have implications for management approaches that may differ according to location.

In a sense, the sub-title for this discussion might be "The Country Mouse and the City Mouse." The Northeast Florida coast is three times more heavily populated than coastal Georgia, reflecting the trend statewide for Florida residents (75%) to settle on the coast, while Georgians (80%) reside inland. Despite a smaller population base Georgia supports a larger commercial fishery, based largely upon shrimp. The Florida catch is more diverse, as is its network of coastal habitats. While the economic magnitude of recreational fishing may be even larger, the lack of data on the number of Florida saltwater anglers prevents conclusive discussion.

The current combined population of the 13-county bi-state area is 1.45 million, up from 950,000 in 1960. This increased pressure on coastal resources, and the two states responded differently. Georgia's 1970 Marsh Protection Act streamlined the management of coastal resources, and only a small fraction of the habitat loss seen in Florida was experienced in Georgia (Table 1). The explanation for this hinges on more than just a single Act, however, since for example a significant fraction of the Georgia coast is in public ownership. By contrast, Florida's coast is more heavily urbanized and more in private ownership. Also, the geographic area addressed by the conference is only a fraction of the total Florida coastline, so that on a statewide basis Florida has a greater array of issues to resolve. In this case the more rural neighbor, Georgia, has done a "better" job of

management, if minimizing wetlands loss is used as the criterion of success.

Missing Parts of the Record

Subject-wise, it still is not possible to provide a totally quantitative picture of the status of coastal resources in this region. For example, there are few data regarding contamination from heavy metals or presence or absence of pesticides. Also, recreational data are less complete than commercial fishing descriptors, so that a definite statement of the economic "impact" of the natural resource base is not available.

Regarding conference participants, four agencies involved with coastal issues did not submit presentations including two that did not send representatives. Nonetheless these federal agencies maintain regulatory and research obligations for coastal areas. Absent were the Environmental Protection Agency and the Army Corps of Engineers, while presentations were not made by representatives of either the Fish and Wildlife Service or the National Marine Fisheries Service who did attend the conference.

An interesting difference in the authorship of contributed papers was the equal split between academic and Department of Natural Resources (DNR) presentations from Georgia (three each), while Florida subjects were covered by academic (six) and only non-DNR (four) authors.

Agenda for the Future

Finally, it seems that there are at least five action items for conference follow-up. In other words, we need to get to work on:

1. The Widening Gap in Marine Literacy. As pressures on coastal resources grow, public awareness is tending to fall behind concerning decisions for long-term development and conservation of marine and coastal resources. In Southwest Florida, for example, only one-third of the surveyed public could correctly tell what a mangrove is. Meanwhile, the Florida DNR actually has fewer professionals in "Information and Education" than it did a few years ago. Among other things, we need to expand "K-12" school programs in marine education, and hire more extension agents to serve coastal audiences.
2. The Scientific Data Gap. One principal need is to fill in the gaps concerning the economic contribution of coastal resources to society. For example, a system to count the number of recreational anglers is needed. Secondly, the marine scientists employed by each state are professionals, and should be paid as such. The salaries of Florida fishery biologists, for example, are in the bottom 10 in the nation.

3. **Preparing for Future Issues.** As described in the keynote presentation, issues such as the allocation of freshwater to different users--including estuaries and their plants and fishes--are emerging as significant resource management questions in the 1980's. Both public decisionmakers and science must prepare for them while there is time to gather advance information on which to base rational action.
4. **Developing a Constituency for the Coast, Sounds, and Estuaries.** In a sense, the coastal resource needs a "press secretary", an informed, rational, reasoned voice to keep public and private audiences informed of issues, needs, and opportunities, and to promote continuing exchange of information. Such an effort could enhance the attempts to improve shellfish waters or explain proposed actions such as Congressman Bennett's Nassau Valley plan.
5. **Technical Follow-Up to the Conference.** The leadership provided by the conference planning committee offers one vehicle to track issues that the participants identified as worthy of future attention. This group could consider ways to consolidate existing information or resolve data gaps, with a longer-range objective of regional cooperation on common issues. Possibly a formal group, patterned after some organization such as the Marine Resources Council of East Central Florida, Inc., could be established. Such a group in this region might provide a head-start for avoiding the problems common to more urbanized coastal areas. In another area, for example, formation of the Tampa Bay Study Committee eventually led to State legislative funding for coastal programs in that area. Information dissemination will remain a key concern. Joint technical sessions for Georgia and Florida scientists should continue regularly, and could provide a means to compile research data for use in management. Because of the differences in coastal management in Georgia and Florida, each state might prepare management interests separately, yet occasional information exchange would be useful. Finally, workshops at the county level could address local issues.

For two-and-a-half days, between 50 and 60 people conferred on significant coastal issues. Certainly the conference represented a landmark effort, as the first of its kind in this region. Yet when we consider the regional population of nearly 1.5 million, the task before us becomes apparent. With this kind of perspective, the conference organizers and participants should work to meet the challenge of broadening the pool of interests that benefit from the findings of the conference. The "fish-habitat story" is an important and timely one. In a real sense, the work of the conference is only just starting. Indeed the "fish-habitat story" is incomplete, and part of its ending will be written by those who put ideas from the conference into action.

Table 1. Comparative resource statistics for Atlantic coastal areas of Georgia and Northeast Florida 1984, with selected statewide data. (Compiled from individual conference papers.)

Factor	Georgia	Northeast Florida
<u>Regional Data</u>		
Coastal Counties	6	7
Coastal Population	350,000	1,100,000
Recreational Boats	22,000	50,000
Recreational Fishermen	60,000-280,000	?
Commercial Fishery Landings		
Finfish	\$600,000	\$4,600,000
Shellfish	\$18,000,000	\$9,600,000
Major Habitats	Marsh, sound	Marsh, mangrove, lagoon
<u>Statewide Coastal Data</u>		
Population on Coast	20%	75%
Habitat Loss	Since 1970: <300 acres	Last 2 years: 7,500 acres
Organization of Management	Streamlined	Complex, more local controls, many broad issues
Waterfront Ownership	Significant public holdings	Mostly private

FISH HABITAT SYMPOSIUM:
GROWTH IMPACTS ON COASTAL N.E. FLORIDA AND GEORGIA

SCHEDULE OF EVENTS

- Wednesday, January 23 EARLY REGISTRATION - Thunderbird Hotel Lobby
(3:00-5:00 P.M.)
- Thursday, January 24
- 8:00 A.M. REGISTRATION (Convention Center Lobby)
- 8:30 A.M. MEETINGS (Indian River Room)
- OPENING REMARKS - Joe Halusky, Florida Sea Grant
Extension Program; and Taylor Schoettle, Georgia Sea
Grant Extension Program
- 9:00 A.M. REVIEW PAPER I - James Cato, Florida Sea Grant
College: "Review of Regional Fisheries Resources.
Values, Trends, and Ties to Coastal Habitats and
Human Development Activities"
- 9:45-10:00 BREAK
- 10:00 A.M. CONTRIBUTED PAPERS, SESSION I - G. Warren Leve, U.S.
Geological Survey (Retired): Geophysical Descrip-
tions of Region's Coastal Environmental Systems and
Interactions.
- 10:00-10:20 William Bigler, Tom Savage, and Forrest Ware: "Heavy
Metals in Sediments and Biota of the Chipola and Santa
Fe Rivers"
- 10:20-10:40 Lary Perkins: "St. Johns Estuary Ambient Water Quality"
- 10:40-11:00 Joel Steward, Palmer Kinser, and Carol Fall: "A Pre-
liminary Description of Water Quality, Hydrology and
Wetlands in the Nassau River Basin"
- 11:00 A.M. REVIEW PAPER II - Don Ekberg and Gene Huntsman,
National Marine Fisheries Service: "Offshore
Fisheries - Issues and Impacts for Florida and
Georgia: Trends and Relations to Wetland Systems"
- 12:00 P.M. LUNCH (on your own)
- 1:00 P.M. CONTRIBUTED PAPERS, SESSION II - Quinton White,
Jacksonville University: Biological Systems
Associated with Coastal Regions, Inshore and Offshore
Fisheries
- 1:00- 1:20 Virginia Baisden: "Preliminary Analysis of the
Impacts of Kings Bay Submarine Base on Cumberland
Estuary with Regard to White Shrimp"

- 1:20- 1:40 Roy R. Lewis, III and Steve H. Lumbert: "Tidal Marsh Restoration and Creation"
- 1:40- 2:00 S. Gordon Rogers, Timothy D. Targett, and Scott B. VanSant: "Utilization in Georgia Salt Marsh Estuaries: The Influence of Springtime Fresh Water Conditions"
- 2:00- 2:20 James K. Schooley: "Patterns of Energy Flow in the Seagrass Beds and Impounded Marshes of the Indian River's Mosquito Lagoon, Florida"
- 2:40- 3:00 BREAK
- 3:00 P.M. REVIEW PAPERS III - Mike Durako, Florida Dept. of Natural Resources: "Coastal Fisheries and Habitats - Issues and Impacts: NE Florida (St. Marys to Mosquito Lagoon)"
- 4:00 P.M. REVIEW PAPER IV - Susan Shipman, Georgia Department of Natural Resources: "Coastal Fisheries and Habitats - Issues and Impacts: Georgia (Savannah to St. Marys)"
- 5:00 P.M. CONCLUSION OF THURSDAY SESSIONS
- 7:00 P.M. CASH BAR (Duval Room)
- 8:00 P.M. DINNER (Duval Room)
Scientific Keynote Speaker - B. J. Copeland, University of North Carolina Sea Grant Program: "A National Perspective on Coastal Fishery Habitats"
- Friday
January 25
9:00 A.M. MEETINGS (Indian River Room)
- 9:00 A.M. REVIEW PAPER V - Carole DeMort, University of North Florida and Dave Gillespie, University of Georgia: "Coastal Fisheries and Habitats - Issues and Impacts: River Basin Contributions to Estuaries"
- 10:00 A.M. BREAK
- 10:20 A.M. CONTRIBUTED PAPERS, SESSION III - "Mac" Reigger, BHR Planning Group, and Larry Gerry, St. Johns River Water Management District: Socioeconomic and Political Impacts: Issues and Policies Affecting Land Use and Fisheries Habitats
- 10:20-10:40 Ronald J. Essig and Andre C. Kvaternick: "Recent Trends in Landings and Characteristics of the Georgia Commercial Fishing Fleet, 1979-1983"
- 10:40-11:00 Mary Margaret Overbey: "The Socioeconomic Impact of Kings Bay Naval Base on the Commercial and Noncommercial Fisheries of Camden County, Georgia"

- 11:00-11:40 Susan Shipman, Virginia Baisden, Ron Essig, Jim Music, and Duane Harris: "An Overview of the Conditional Opening of Georgia's Sounds to Commercial Shrimping"
- 11:40-12:00 L. L. Beason, W. W. Honour, K. I. Miller, A. Q. White: "Fish Consumption and Mercury Contamination in the St. Johns River"
- 12:00 P.M. LUNCH (on your own)
- 1:30 P.M. CONTRIBUTED PAPERS, SESSION IV - "Chuck" Flowe, Jacksonville Bioenvironmental Services: General Contributed Papers on Region's Fisheries Habitats and Related Items
- 1:30-1:50 Michael D. Calinski: "The Postlarval Ocean Management Study (POMS) - Nursery Habitat and Coastal Development"
- 1:50- 2:10 Matthew R. Gilligan: "Early Colonization and Utilization of a Concrete Artificial Reef of the Georgia Coast by Invertebrates and Fishes"
- 2:10- 2:30 Frank G. Nordlie: "Ontogenetic and Seasonal Patterns of Osmotic and Ionic Regulation and the Energetic Cost of a Variable Salinity Environment in the Striped Mullet"
- 2:30-3:05 BREAK
- 3:05- 3:25 James A. Valade: "Manatees of Northeast Florida"
- 3:25- 3:45 William T. Young and Glenn L. Butts: "Biological Assessment Pollution Abatement Impact in Western Choctahatchee Bay"
- 4:00 P.M. REVIEW PAPER VI - James W. Stoutamire, Office of Coastal Management, Department of Environmental Regulation and Owens Smith, University of Georgia, Department of Natural Sciences: "Growth and Management of Coastal Wetland and Wetland Adjacent Lands: Fish Habitat Quality and the Decision Making Process"
- 5:00 P.M. CONCLUSION OF FRIDAY SESSIONS
- NOTE: EXHIBITS ARE ON DISPLAY IN THE SEMINOLE ROOM
- 7:15 P.M. RECEPTION AND CASH BAR
- 8:15 P.M. CONCERT AND COASTAL POETRY (Duval Room)
 "Listen to the Water Song" - Dale and Linda Crider, Florida Game and Freshwater Fish Commission, and Don Grooms, Journalist-singer
 "Ocean Love" - John Hammond, Jacksonville Poetry Society

Saturday
January 26
7:30 A.M.

FISH HABITAT SYMPOSIUM REVIEW

REGISTRATION (Convention Center Lobby, Thunderbird Hotel)

8:00 A.M.

CONTINENTAL BREAKFAST AND ROUND TABLE DISCUSSIONS
(Indian River Room)

MODERATORS: "Mac" Reigger, BHR Planning Group; and
Larry Gerry, St. Johns River Water Management
District

BREAKFAST SPEAKER: Honorable Charles E. Bennett,
U.S. Congressman, Jacksonville, Florida: "Managing
Coastal Growth for Quality Living"

ROUND TABLE DISCUSSIONS WITH CONFERENCE SPEAKERS
An opportunity for attendees to exchange ideas with
professional researchers

PANEL DISCUSSION BY SYMPOSIUM REVIEW SPEAKERS

12:30 P.M.

LUNCHEON (Duval Room)

Speaker - William Seaman, Florida Sea Grant College -
A Synopsis of the Fish Habitat Story

Exhibits and exhibitors will remain available for
informal discussions after the luncheon.

Abstract

SESSION 1

TITLE: Heavy Metals in Sediments and Biota of the Chipola and Santa Fe Rivers

AUTHOR(S): William Bigler¹, Tom Savage², and Forrest Ware³

ADDRESS(S): ¹Department of Health & Rehabilitative Services;
²Department of Environmental Regulations;
³Game and Fresh Water Fish Commission

An interagency work group composed of personnel from the Department of Health and Rehabilitative Services (HRS), the Department of Environmental Regulation (DER), the Game and Fresh Water Fish Commission (GFC), and the Department of Natural Resources (DNR), conducted an investigation of the Chipola River and Santa Fe River in North Florida to determine baseline concentrations of selected heavy metals in water, sediments, shellfish, and finfish.

Water samples from the Chipola River were below minimum detectable limits for Mercury (Hg), Chromium (Cr), and Copper (Cu). All results from Lead (Pb) were less than the actual value of 5.0 ppm reported and all cadmium values were less than 0.20 ppm.

Sediments from the Chipola River were as follows: Cadmium values 0.4 to 0.8 ppm, Chromium 16.5 to 35.6 ppm, Copper 1.53 to 6.63 ppm, Lead 6.2 to 19.8 ppm and Mercury 0.03 to 0.19 ppm.

Two species of clams, Corbicula manilensis and Elliptio sp. from the Chipola and Santa Fe Rivers were analysed for the presence of metals. Mean concentrations of Cadmium, Chromium, and Mercury were below levels which would be determined hazardous to human health (1.0 ppm). However, Lead levels in Chipola River clams ranged from 0.60 to 1.0 ppm with a mean of .843. In addition, clams from two or four stations along the Santa Fe River had Mercury concentrations at or above 1 ppm.

Mean concentration of Cadmium, Chromium, Copper, Lead and Mercury in fish were below levels which could be determined hazardous to human health. However, at least a few fish from each of the three groups taken from both rivers exceeded 0.5 ppm for Lead. In addition, some individual fish in both rivers approached 1.0 ppm for Mercury. The mean level of 0.511 ppm Mercury in bass from the Chipola River is a classic example of biomagnification of this metal in the food chain.

Abstract

SESSION 1

TITLE: St. Johns Estuary Ambient Quality

AUTHOR(S): Lary Perkins

ADDRESS(S): 515 W. 6th Street, Jacksonville, Florida 32206

The St. Johns River Survey is conducted on a bimonthly basis and includes twelve (12) sample sites. The survey covers an area beginning in northeast Duval County with the ICWW and extends south to Julington Creek. The water is analyzed for nineteen (19) parameters at each site. Parameters include:

Tide	Total Phosphorus
Temperature	Ammonia
pH	Total Kjeldahl
Dissolved Oxygen	Nitrogen
5-day Bio-Chemical	Nitrate-Nitrite
Oxygen Demand	Iron
Turbidity	Lead
Suspended Solids	Copper
Conductivity	Cadmium
Chlorides	Zinc
	Fecal Coliform

This data is compared to the State Standards for Class III Waters and any violations noted. Periodically, current data is compared with data of previous years to determine trends. Violations will be discussed in the context of aquatic or human health impact.

In 1982, the Environmental Protection Agency (EPA) and Bio-Environmental Services Division (BESD) conducted a survey of the St. Johns River which involved analyzing the water column, sediment, and fish tissue for PCB's. At the time of the survey, the EPA chose Trout River as a central location from which to collect the fish. Later, PCB concentrations in the sediment progressively increased in an upstream direction with the highest concentrations being in the Cedar River. BESD to conducted fish tissue analysis in the Cedar River area. Fish were collected in cooperation with the Florida Game and Freshwater Fish Commission. Coupled with fish consumption data, a health risk assessment was conducted and presented.

Abstract

SESSION I

TITLE: The Nassau River Basin Hydrologic and Environmental Study

AUTHOR(S): Joel Steward, Palmer Kinser and Carol Fall

ADDRESS(S): P.O. Box 1429, Palatka, Florida 32078

The St. Johns River Water Management District, in cooperation with USGS, is conducting a long-term hydrologic and water quality monitoring program, and wetland vegetative survey of the Nassau River Basin. Hydrologic monitoring entails the collection of stage, flow, rainfall, temperature and conductivity data using a basin-wide network of remote, continuous measuring instruments. The main objectives of this effort are to describe the location of a freshwater-saltwater interface and its movement as affected by tidal stage and freshwater inflow, and to develop a one-dimensional model to determine flow at various points in the river given rainfall and stage data. The objectives of the water quality program are to generate water and sediment chemistry data base, to delineate existing or potential water quality problems, to further characterize the chemical and physical nature of the interface or mixing zone and to describe spatial and temporal trends with respect to chemical constituent concentrations and loadings.

Preliminary data analysis (8 sampling events) reveals that the most apparent anthropogenic water quality impact is the effluent from a municipal wastewater treatment plant discharged to Mills Creek, on the Nassau's headwater tributaries. Nitrogen and phosphorus concentrations in Mills Creek are a magnitude greater than concentrations measured elsewhere in the river system. These nutrient concentrations drop sharply downstream from Mills Creek, exhibiting a tight consistency with little variability throughout the freshwater-saltwater mixing zone. The mixing zone, as defined by high salinity fluctuations, is not discrete, but is rather spatially extensive. The mixing zone has experienced a 78% to 88% variability in surface salinity ranging from 0‰ to 18‰, as influenced by various rainfall events and stages in the tidal cycle.

The objective of the wetland vegetative survey is to map and classify wetland areas in the basin. The primary source of information for this survey is color infra-red aerial photographs (1:24,000), which have been recently taken of the tidal portion of the Nassau River Basin. This information can be used to develop technical criteria for wetland management and protection policies, plans or regulations.

Abstract

SESSION II

TITLE: Preliminary Analyses of the Impacts of Kings Bay Submarine Base on Culberland Estuary With Regard to White Shrimp

AUTHOR(S): Virginia Baisden

ADDRESS(S): 1200 Glynn Avenue, Brunswick, GA 31523

An extensive monthly data base has been collected and compiled since 1974 for penaeid shrimp and blue crabs in many of Georgia's estuarine systems, including Cumberland estuary, for fisheries assessment purposes and managment recommendations. One of the former Cumberland sampling sites was located in the area of Kings Bay Submarine Base. Initiation of dredging and construction forced this sampling station to be relocated.

The initial Kings Bay channel construction, expansion of the Kings Bay facilities, and subsequent maintenance dredging has greatly modified that portion of Cumberland estuary. The estuarine area that is now the Kings Bay Basin and the Intracoastal Waterway - Ship's Channel was a relatively shallow area prior to these dredging activities. It is now maintained at an approximate depth of 50 feet at mean low water. The possible deleterious impact of this habitat,, alteration, including this disruption and possible destruction of penaeid shrimp nursery grounds, will be discussed. The possible beneficial effects of the increasd channel depths will also be examined, including the role that these areas play as overwintering grounds for penaeid shrimp. This function could be especially important during winters characterized by devastating freezes such as those experienced during 1977, 1978, 1981, and 1983.

Abstract

SESSION II

TITLE: Tidal Marsh Restoration and Creation

AUTHOR(S): Roy R. Lewis III and Steve H. Lumbert

ADDRESS(S): Mangrove Systems, Inc., P.O. Box 15759, Tampa, FL 33684

The restoration and creation of tidal marshes utilizing smooth cordgrass (Spartina alterniflora) has become a routine procedure in Georgia and South Florida. Tidal marsh restoration/creation in northeast Florida has not been attempted on a large scale. A demonstration project utilizing native marine plant materials to stabilize an excavated drainage canal into the intercoastal waterway in Duval County was begun in June of 1983. The success of the project and its application to future marsh creation efforts is discussed.

Abstract

SESSION II

TITLE: Fish Nursery Utilization in Georgia Salt Marsh Estuaries: The Influence of Springtime Freshwater Conditions

AUTHOR(S): S. Gordon Rogers, Timothy E. Targett, and Scott B. Van Sant

ADDRESS(S): Skidaway Institute of Oceanography, P.O. Box 13687, Savannah, GA 31416

The fish assemblage utilizing shallow nursery habitats in the Ogeechee River-Ossabaw Sound salt marsh estuary, Georgia was investigated during the winter and spring of two successive years. High river discharges during these periods produced fully freshwater conditions (all tidal stages and amplitudes) in the upper portion of the study area for up to four months. Abundances of Atlantic croaker (Micropogonias undulatus), southern flounder (Paralichthys lethostigma), silver perch (Bairdiella chrysours), and hogchoker (Trinectes maculatus), recruits were highest in oligohaline to freshwater portions of the estuary. Spot (Leiostomus xanthurus) were more evenly distributed, but continued to utilize upper estuary nursery areas during periods of high river discharge. Although the recruitment of several species was likely inhibited during discharge peaks, only striped mullet (Mugil cephalus) avoided freshwater conditions. Occurrence, distribution, and/or length data, indicate that spot, southern flounder, Atlantic menhaden, and silver perch utilized shallow nursery areas on a sizespecific basis. Abundance, length, and rank analyses showed that recruitment and utilization patterns of fishes spawned in deeper areas were generally maintained throughout prolonged periods (up to 100 days) of freshwater conditions. The precise function of upper estuary nursery areas is governed by the timing and magnitude of discharge events, but remains essentially intact through the seasonal encroachment of freshwater. (w/perm. Trans. Am. Fish. Soc.).

Abstract

SESSION II

TITLE: Factors influencing the patterns of energy flow in the seagrass beds and impounded marshes of the Indian River's Mosquito Lagoon, Florida

AUTHOR(S): James K. Schooley

ADDRESS(S): Department of Zoology, University of Florida, Gainesville, Florida

A fourteen-month study of the physical and biological factors influencing the secondary production of estuarine fishes was conducted at four sites in the Mosquito Lagoon and surrounding impounded marshes in east central Florida. The temperature of waters of the impounded marshes ranged from 6 to 39°C. Salinity varied between 10 and 38 ppt. The seagrass beds ranged from 8 to 39°C in temperature and 18 to 38 ppt salinity. For the period of this study, the ranges of temperature and salinity experienced by resident fish of the impoundments and seagrass beds appeared comparable. Salinity was positively correlated with fish standing crop at one of the two impoundments, but at neither seagrass bed. Median monthly water temperature was positively correlated with several aspects of fish community structure in both the impoundments and seagrass beds. Preliminary estimates of annual macrophyte production are 4,306 kJ.m⁻² in one impoundment and 2,413 and 3,707 kJ.m⁻² in the seagrass beds. Impoundment site II had a significantly higher percentage of combustible organic material in the surface sediment than did the seagrass bed tested ($p < 0.001$). Neither zooplankton abundance nor community composition were significantly different between the impounded marshes and seagrass beds. When nematodes were excluded from the zooplankton analysis, the two habitats are distinctive in composition during winter and spring. None of the differences in temperature, salinity, macrophyte production or the zooplankton community explains the large functional differences found in the fish communities of the two habitat types. Several lines of future investigation are proposed.

Abstract

SESSION III

TITLE: Recent Trends in Landings and Characteristics of the Georgia Commercial Fishing Fleet, 1979-1983.

AUTHOR(S): Ronald J. Essig and Andre C. Kvaternick

ADDRESS: Georgia Department of Natural Resources,
Coastal Resources Division, 1200 Glynn Avenue,
Brunswick, Georgia 31523

A State/Federal Cooperative Regional Fishery Statistics Program was started in the South Atlantic in the late 1970's. Through this program detailed commercial landings, effort, and associated fleet characteristics have been collected in a coordinated manner by the National Marine Fisheries Service and state fishery management agencies. During the past five years (1979-1983) shrimp accounted for 86% of the ex-vessel value of Georgia seafood. Hard blue crabs accounted for 11% and all other species only accounted to 3% of the value of Georgia landings. With the Georgia fishery so heavily dependent on shrimp, trends in fishing activity can be associated with the quality of the shrimp season. Georgia shrimp landings are strongly correlated with effort in terms of licenses sold, number of trips, and days fished. Vessel mobility between states has been particularly important in the shrimp fishery in recent years and is documented by license sales. Shrimp vessels have also tended to fish for longer periods of time before unloading compared to the predominant single-day trip in the past. Diversification of species sought is becoming a more common fishing strategy as exemplified by the recent expansion of the Georgia conch fishery.

ABSTRACT

SESSION III

TITLE: The Socioeconomic Impact of Kings Bay Naval Base on the Commercial and Noncommercial Fisheries of Camden County, Georgia

AUTHOR: Dr. Mary Margaret Overbey

ADDRESS: Department of Anthropology, 1350 GPA,
University of Florida, Gainesville, FL 32611

This case study examines the socioeconomic impact of a newly constructed nuclear submarine base on the rural coastal community of Camden County, Georgia. Camden County, located on the coastal strand of southeastern Georgia, is part of the Barrier Island Region. Analyzing the socioeconomic impact of large-scale development projects on coastal communities entails consideration of the productivity of the local environment, the human use patterns of exploiting local resources, and the adverse effects of the construction, operation, and incoming population on these activities. Although the region is defined by shared geographical, economic, historical, and social features, it is named for its most striking characteristic -- the chain of barrier islands that separate the mainland from the Atlantic Ocean and allow the development of an extensive marsh estuary. Basic to the economy and lifestyle of Camden County residents is an orientation to and a dependence on the Cumberland Sound estuarine complex. In this situation, however, the interests of residents in a productive estuary compete with the national security interests of the United States Navy to utilize the estuary for submarine traffic. This paper examines the traditional land use patterns of the area and the importance of the estuary to the economic activities of the county. It further addresses some of the adverse impacts of base construction, operation, and the associated influx of naval personnel on the productivity of the estuary on which commercial and noncommercial fishermen rely. The paper concludes that the construction and operation of the base will alter the biological productivity and human use patterns of the estuary. The military influx, expected to double the original county population, will place additional stress on the estuary and increase competition for diminishing resources.

Abstract

SESSION III

TITLE: An Overview of the Conditional Opening of Georgia's Sound to Commercial Shrimping

AUTHOR(S): Susan Shipman, Virginia Baisden, Ron Essig, Jim Music and Duane Harris

ADDRESS: Georgia Department of Natural Resources
Coastal Resources Division, 1200 Glynn Avenue
Brunswick, Georgia 31523

The decision to open Georgia's sounds to commercial shrimp trawling in the fall in 1983 was an example of the application of flexible fisheries management to maximize yield of a state's valuable commercial shrimp fishery. Shrimp harvested from six Georgia sounds during eleven days in November and December yielded approximately 179,000 lb valued at \$0.8 million. Abnormally warm, dry conditions that persisted during fall of 1983 effected an interruption in the normal offshore emigration of large, premium value shrimp. Anticipating the emigration and southward migration of these shrimp during severe weather conditions prohibitive to trawling, as suggested by previous mark-recapture studies, fisheries managers recommend a limited opening of Georgia's sounds to commercial shrimping. This conditional strategy was adopted to maximize economic and biological yield and to minimize adverse impacts on users of the shrimp resource as well as other resources.

The principles of fisheries management considered in formulating this decision, including shrimp life history and population dynamics, social and economic considerations, environmental conditions, and additional resource considerations, are presented. The resultant production and impacts on other resources and resource users are examined. Additionally, the overall success of this management decision, as evidenced by Coastal Resources Division shrimp assessment, mark-recapture studies and commercial landings statistics, is presented.

Abstract

SESSION III

TITLE: Fish Consumption and Mercury Contamination
in the St. Johns River

AUTHOR(S): L.L. Beason, W. Honour, K.I. Miller, and
A.Q. White

ADDRESS(S): Department of Biology and Marine Sciences
Jacksonville University, Jacksonville, Fl. 32211

Mercury is a significant contaminant of the aquatic environment. In addition to contamination of water through natural weathering processes, industrial sources of mercury and inorganic mercury salts can be transformed into highly toxic methyl mercury by microorganisms dwelling in sediments.

Methyl mercury is readily concentrated within the aquatic food chain and is, therefore, a hazard at excessive levels. Bioaccumulation of this material occurs within the food web as a function of the second law of thermodynamics and its slow biodegradability.

This study examined the possibility of mercury contamination in individuals who eat a significant amount of fish from the St. Johns River. It addresses the potential health hazard faced by this population.

The preliminary results suggest that the current mercury levels in the fish from the St. Johns River are not sufficient to promote mercury poisoning in humans. These results are based on a survey of local fishermen, average fish consumption per person per week and mercury levels in selected species. The results are based on 807 individuals who responded to the survey.

Abstract

SESSION IV

TITLE: Early Colonization and Utilization of a Concrete Artificial Reef off the Georgia Coast by Invertebrates and Fishes

AUTHOR: Matthew R. Gilligan

ADDRESS: Department of Biology and Life Sciences,
Savannah State College, Savannah, Georgia 31404

The Savannah Sport Fishing Club, on March 31, 1983, placed 406 tons of precast concrete culvert (249 units) at Artificial Reef "L" off the Georgia Coast in an effort to enhance its recreational and sport fishing potential. The reef is located 19 miles WSW of Savannah at a depth of 60 feet. This report describes efforts to monitor and assess the early colonization and community development of the reef by invertebrates and fishes.

Immigration or recruitment and growth of organisms on the reef were investigated monthly at the reef for five months following placement and irregularly thereafter. During each visit to the reef by SCUBA divers a rapid visual census of fishes was conducted, 1:3 close-up photographs of concrete surfaces were taken, and samples of concrete were collected for laboratory analysis.

The results indicate that colonization by encrusting invertebrates and immigration by adult black sea bass began within weeks of placement. Nearly 100 percent cover of some concrete surfaces was achieved within four months of placement. After five months over 20 fish species had become resident or were found in some degree of association with the reef.

Growth of some of the invertebrates and fishes was measured. Encrusting invertebrate animals continued to grow during the winter months but most of the fish species were not present on the reef during the cold water temperature months.

Abstract

SESSION IV

TITLE: Ontogenetic and Seasonal Patterns of Osmotic and Ionic Regulation and the Energetic Cost of a Variable Salinity Environment in the Striped Mullet

AUTHOR: Frank G. Nordile

ADDRESS: Department of Zoology, University of Florida
Gainesville, Florida 32611

Striped mullet embryos are stenohaline marine forms and the juveniles gradually expand their salinity tolerances as they develop. The full range of salinity tolerances is developed later when the juveniles are in estuarine waters. The smallest individuals found in estuarine areas cannot yet tolerate extremely low salinities and the ability of these individuals to regulate their plasma concentrations is also very limited, especially at high environmental salinities. As they continue to develop, both their salinity tolerances and osmotic regulatory capabilities develop so that individuals of 55 mm total length show roughly the broad range of tolerance of environmental salinity and the good osmotic regulatory capacity of adult striped mullet.

Seasonally, plasma inorganic ionic concentrations, and as a result, plasma-osmotic concentrations in this species, alter as functions of environmental temperature. These alterations tend to stabilize the osmotic concentration differences between the blood and environmental medium under altered temperature conditions.

Aerobic respiration, as evidenced from rates of oxygen consumption in striped mullet, is lowest at environmental salinities roughly equivalent in concentration to the blood plasma and rises at both lower and higher salinities. This means that it is energetically least costly for such a form to inhabit waters of roughly one third the concentration of average sea water.

These physiological relationships will be discussed in the context of the life history of the species in Florida waters.

Abstract

SESSION IV

TITLE: Manatees of Northeast Florida: A Synopsis of Manatees Research in Northeast Florida, 1980-1984

AUTHOR: James A. Valade

ADDRESS: Jacksonville University, P.O. Box 11635
Jacksonville, Florida 32211

Manatee population dynamics in Northeast Florida over a four-year period will be discussed. Data presented will include literature reviews as well as the results of a Manatee Watch Program initiated in 1984 by the Jacksonville Electric Authority. Major points include seasonal presence, migratory patterns, abundance and identification of individuals.

Abstract

SESSION IV

TITLE: Biological Assessment of Pollution Abatement Impacts in Western Choctawhatchee Bay

AUTHOR(S): William T. Young and Glenn L. Butts

ADDRESS: 160 Governmental Center, Pensacola, Fl. 32501

Western Choctawhatchee Bay experienced population growth eutrophication from sewage treatment plants up until two or three years ago. These plants have converted to upland disposal and water quality improvement is indicated. Substrate degradation including sludge deposits and seagrass elimination remains. It is necessary to conduct comparative artificial and natural substrate assessments in order to determine the true water quality improvement impact on food chain macroinvertebrates and periphyton. Supporting water quality and sediment data will be discussed.

Abstract

SESSION IV

TITLE: The Postlarval Ocean Management Study (POMS)
Nursery Habitat and Coastal Development

AUTHOR: Michael D. Calinski

ADDRESS: Division of Natural Science, New College,
University of South Florida, 5700 N Tamiami Terrace,
Sarasota, Florida 33580

Four one-eighth cubic meter artificial nursery habitats were designed and tested to determine their viability in functionally replacing natural habitat that had been destroyed by dredging at a location where a developer proposed to build 41 piers. The nurseries were designed and "targeted" for the stone crab Menippe mercenaria. Within 30 days after being placed in the water as barren (yet highly structured) substrates, the habitats began attracting and supporting megalopa and postlarval crabs. Dense phytoplankton supported an extra-ordinarily lush fouling assemblage. Within 6 months the various designs were capable of supporting from 20 to over 100 developing crabs (2 to 35 mm CW) each. A new method of tagging postlarval crabs showed postlarval to juvenile survival to range from 12 to 30 percent. Juvenile fishery recruits from naturally occurring megalops ranged from 5 to 30 per habitat per month.

It has been calculated that 123 cubic meters of nursery habitat could be installed under the 41 piers proposed for the study site. Such habitat could produce approximately 236,160 extra fishery recruits per year. Over a 10-year period such habitats would cost approximately \$148,000.00 and would produce approximately \$590,000.00 dockside worth of crabs. In this manner the detrimental effects of coastal development can be reversed in an ecologically viable and economically feasible manner. The concept of the artificial nursery habitats is applicable to virtually all non-pelagic species of sport and commercial importance.

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