REPORT OF THE BUREAU OF COMMERCIAL FISHERIES BIOLOGICAL LABORATORY, ST. PETERSBURG BEACH, FLORIDA,

Fiscal Year 1968

UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. FISH AND WILDLIFE SERVICE

BUREAU OF COMMERCIAL FISHERIES

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Report of the Bureau of Commercial Fisheries Biological Laboratory, St. Petersburg Beach, Florida, Fiscal Year 1968

JAMES E. SYKES, Director

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Biological Laboratory, St. Petersburg Beach, Florida 33706

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ABSTRACT

The major goals of the Laboratory are to explore the relatively unknown scope of biological productivity in the coastal zone of the eastern Gulf of Mexico, to measure the effect of changes in that zone, and to develop methods of increasing estuarine fishery resources. The report describes current research on projects in the Estuarine, Red-Tide, and Industrial Schoolfishes Programs. The projects include studies of sediments and organisms in bay bottoms, plankton crops and fishes residing in and transferring between estuaries and the Gulf of Mexico, toxicity of the red-tide organism, and experimental rearing of pompano in an impounded lagoon. A physical, hydrological, biological, and sedimentological inventory of Florida estuaries is also in progress as part of a cooperative effort with the National Oceanographic Data Center and the States of Alabama, Mississippi, and Louisiana.

REPORT OF THE LABORATORY DIRECTOR

James E. Sykes

MISSION OF LABORATORY

Research activities of the Laboratory are designed principally to explore the dynamics of plants and animals in the estuarine zone and the relation of these organisms to their coastal environment. The physical and chemical organization of estuarine habitats is constantly changing. Some of the changes are subtle and barely detectable; for instance, the natural deposition and resuspension of sediments from inflowing streams. Other alterations produce dramatic and easily measured effects, such as those resulting from the diversion of waterways and dredging and filling by man. The relation of aquatic biota to the natural and altered environment must be understood as we seek to sustain coastal nurseries and insure that they will continue into the future as producers of the fishery resource.

RESEARCH STATUS AND TRENDS

From 1962 through 1967 most effort in the Estuarine Program of the Laboratory was applied to the collection of data and investigation of matters related to the biological effects of dredging and filling and other disturbances in estuaries. Biologists were called upon frequently to appear at public hearings and courtroom proceedings to present their findings on those effects. The fact that the researcher's voice was heeded is evidenced by the number of large, prime nurseries which continue to produce fishes but which were originally scheduled to be covered by landfill. Although each developmental proposal was considered separately, some of the positive results have now been converted into legislative protection for entire estuarine zones by responsible States.

The number of requests for us to supply biological data concerning specific proposals for engineering developments that would have damaged estuaries were fewer in fiscal year 1968 than in previous years. We could, therefore, focus more effort on detailed ecological analysis and upon intensifying progress on a Gulf of Mexico estuarine inventory in cooperation with Gulf States. This Federal-State endeavor is in a healthy condition and is now producing results after the necessary period of negotiation and planning.

The Gulf Inventory is approximately 50 percent completed. Biological and Hydrological Phases were begun--both to run simultaneously among cooperators until March 1969. Area Description and Sedimentological Phases are in progress but are not necessarily simultaneous with other parts of the study. An oceanographer from the National Oceanographic Data Center was assigned to the Laboratory to help Inventory participants design data formats and write instructions for ADP (automatic data processing). Coding systems were completed, and data coding is now in progress on standard forms accepted by State cooperators and BCF (Bureau of Commercial Fisheries).

The Industrial Schoolfishes Program completed its first year of operation in June 1968. Data obtained on the early life history and commercial catch composition of thread herring made it possible for the staff to recommend continuation of the fishery despite pressures from those who would have it abolished. On the basis of our testimony that catches had less than 1 percent food fishes, the court ruled that the fishery could continue if food species did not exceed the 1-percent level.

With the completion of a contract this year on the isolation and identification of red-tide (Gymnodinium breve) toxin, all objectives of the Red-Tide Program written in 1962 were fulfilled. We do not intend to imply, however, that a need for further research on the organism no longer exists or that a method has been found to control red tides. Our contract with the University of South Florida succeeded in establishing a qualified research unit on that campus. Now that the contract is terminated, the unit is working in close association with State researchers on other red-tide problems and on an informal basis with the Laboratory.

TRAINING

Physical Science Aid	2-week course, AutoAnalyzer Techniques, New York, N.Y.
Fishery Biologist	48 class hours, Elementary Statistics, Florida Presbyterian College, St. Petersburg, Fla. (audited course).
Fishery Physiologist	1-week course in Marine Pollution Ecology, Federal Water Pollution Control Administration Training Program, University of South Florida, Bayboro Harbor Campus, St. Petersburg, Fla.
Nine employees	Standard Red Cross First-Aid Course.
Nine employees	Advanced Red Cross First-Aid Course.
Ecologist	Continued research toward the Ph. D. degree at the University of Florida, Gainesville, Fla.

PRESENTATIONS

Papers were presented at the following meetings: Florida Academy of Sciences, Deland, Fla.; Marsh and Estuary Management Symposium, Louisiana State University, Baton Rouge, La.; National Association of Soil and Water Conservation Districts, Dallas, Tex.; and Oceanographic Institute, University of South Florida Bayboro Campus, St. Petersburg, Fla. A staff member gave a talk to the Marine Biology Group, Gibbs High School, St. Petersburg, Fla. Five staff members served on the Federal Water Pollution Control Administration faculty in presenting a training course--"Marine Biology and Pollution Ecology (144)."

MEETINGS AND WORK CONFERENCES

Figures in parentheses show the number of persons attending.

- Annual Meeting of the Florida Academy of Sciences, Deland, Fla. (2).
- Editing assistance, Rome Italy, in preparation for FAO "Conference on Fish Behavior in Relation to Fishing Techniques and Tactics," Bergen, Norway (1).
- Five-day trip with representatives of the Vietnamese Directorate of Fisheries to Bureau facilities and points of interest in the fishing industry at Beaufort, N.C., Brunswick, Ga., and Miami, Fla. (1).
- Gulf States Marine Fisheries Commission--Estuarine Technical Coordinating Committee, Montgomery, Ala. (1).
- Gulf States Marine Fisheries Commission--Estuarine Technical Coordinating Committee, Panama City Beach, Fla. (2).
- Internal Improvement Fund Staff Meeting, Tallahassee, Fla. (1).
- Laboratory Directors' Meeting, Woods Hole, Mass. (1).
- Marsh and Estuary Management Symposium, Louisiana State University, Baton Rouge, La. (1).
- National Association of Soil and Water Conservation Districts, Dallas, Tex. (1).
- Oyster Culture Workshop, University of Georgia, Sapelo Island, Ga. (1).
- Program Review, Miami, Fla. (1)
- Steering Committee, Estuarine Workshop Meeting, Charleston, S.C. (1).

The estuarine research program has five projects: bay bottom ecology, plankton ecology, production of marine animals, effects of estuarine alteration, and an inventory of Gulf of Mexico estuaries.

BENTHIC PROJECT

John L. Taylor and Carl H. Saloman

Introduction

Study of benthic ecology in estuaries of the eastern Gulf began at this Laboratory in 1963. The work is designed to give detailed information on the distribution and abundance of benthic species and provide guidelines to assess the biological importance of estuaries and the impact of coastal development.

In fiscal year 1968, the fourth in a series of hydrological reports and a sediment report were completed for Tampa Bay and adjacent waters. Work continued on the identification of bottom animals from the Bay with emphasis on mollusks, echinoderms, and polychaete worms. Biological research was also directed toward four organisms that have actual or potential value as commercial species--the southern quahog, Mercenaria campechiensis; the lugworm, Arenicola cristata; the squid, Lolliguncula brevis; and the sea grass, Thalassia testudinum. Finally, several "fact-finding" surveys were made in Tampa and Sarasota Bays to determine the biological resources that exist in areas proposed for dredge-fill development.

Hydrology

Hydrological data are essential for ecological studies in the estuary and provide a historical record of changes in the aquatic environment. Waters of Tampa Bay are sampled each month at 30 permanent stations. Measurements include water temperature, salinity, pH, total phosphorus, total nitrogen, dissolved oxygen, and turbidity. The same measurements (plus Secchi disc readings) are made on water samples collected daily at the Laboratory dock on Boca Ciega Bay. In addition, chlorophyll determinations are made once each week for samples taken at the dock.

Hydrological conditions in the Bay in 1965-67 (fig. 1) differed little from those in 1961-64 (given in the Laboratory's report for fiscal year 1967). One exceptional feature is the rise in concentration of total nitrogen throughout the Bay since 1965. A cause for this increase (8-16 μg.at./l. (microgram atom per liter)) is the progressive enrichment of the estuary from domestic and industrial sewage.

Sediments

Sediment composition has a great influence on the occurrence and distribution of benthic organisms, and established bottom communities have an effect on the physical and chemical nature of bottom deposits. Sediment samples are therefore collected and analyzed in benthic studies and other Laboratory programs. Textural, chemical, and statistical data for more than 500 samples from Tampa Bay have been recorded since 1963. Throughout most of the Bay, the bottom consists of sediments that are more than 20 percent sand, and patches of shelly sand exist in a few locations. Soft sediments of silt and clay are found in natural and manmade depressions and other areas where tidal currents are weak (fig. 2). Soft sediment is mostly confined to Hillsborough Bay where sewage sludge is a major source of fine-grained material and Boca Ciega Bay where dredging has caused siltation in bayfill canals and elsewhere. Soft sediment in these two areas of the Bay has greatly reduced or eliminated benthic invertebrates normally found in other parts of Tampa Bay.

Mollusks

The study of the relation between mollusks and environmental conditions is complete for three areas of Tampa Bay--Boca Ciega Bay near the mouth of the estuary and Old Tampa Bay and Hillsborough Bay at the head of the estuary. This information shows how the natural environment influences the distribution, abundance, and diversity of shellfish and how development and pollution of parts of the bay can reduce or eliminate mollusks there.

In bottom samples from undisturbed areas of Boca Ciega Bay, we recorded 155 species of live mollusks in 67 families (table 1). The average sample had 60.5 mollusks. Environmental factors that favor such great diversity and abundance include high salinity ($>$ 30 p.p.t.), sandy sediment (91 percent sand and shell), and bottom vegetation (sea grasses and algae). In contrast, dredge hauls from the bayfill canals of Boca Ciega Bay had only five species of mollusks, and the average number of individuals per collection was less than one.

Table 1.--Number of species of mollusks collected, salinity, and bottom type in three areas of Tampa Bay, Fla. 1963-64

Area	Stations	Species collected alive	Total species	Families	$\bar{X}$ Salinity	Sand and shell	Silt and clay
	Number	Number	Number	Number	P.p.t.	Weight percent	
Boca Ciega Bay (Undredged areas)	24	155	167	67	32.6	91	9
Boca Ciega Bay (Dredged areas)	7	5	5	5	32.6	15	85
Old Tampa Bay	98	97	120	52	23.8	92	8
Hillsborough Bay	45	35	64	40	23.4	78	22

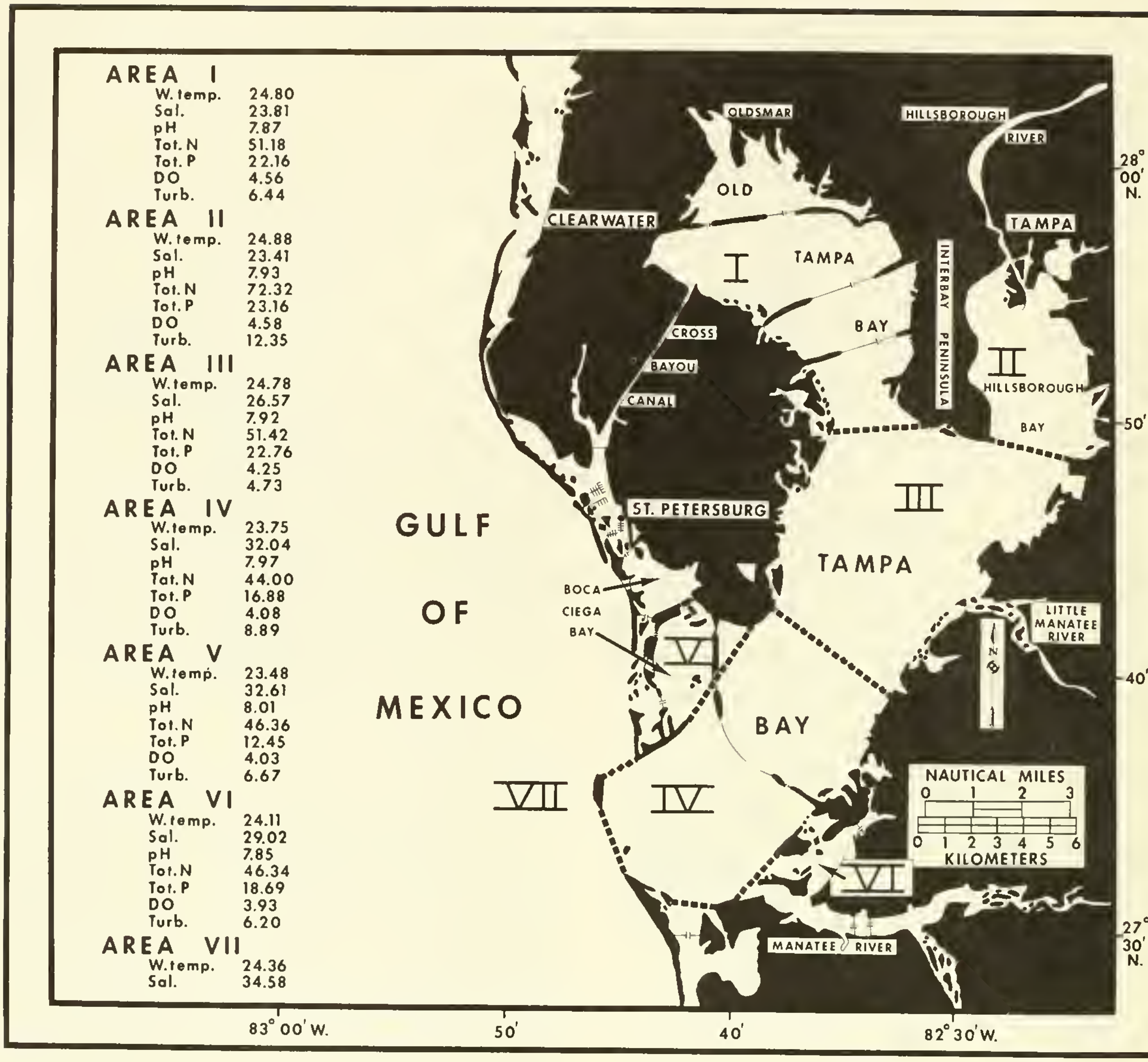

Figure 1.--Hydrological measurements for different areas of Tampa Bay, Fla., and adjacent waters of the Gulf of Mexico, January 1965 through August 1967--water temperature (w. temp.), °C.; salinity (sal.), p.p.t.; pH; total nitrogen (tot. N.), μg. at./l.; total phosphorus (tot. P.), μg. at./l.; dissolved oxygen (DO), ml./l.; turbidity (turb.), J.T.U.

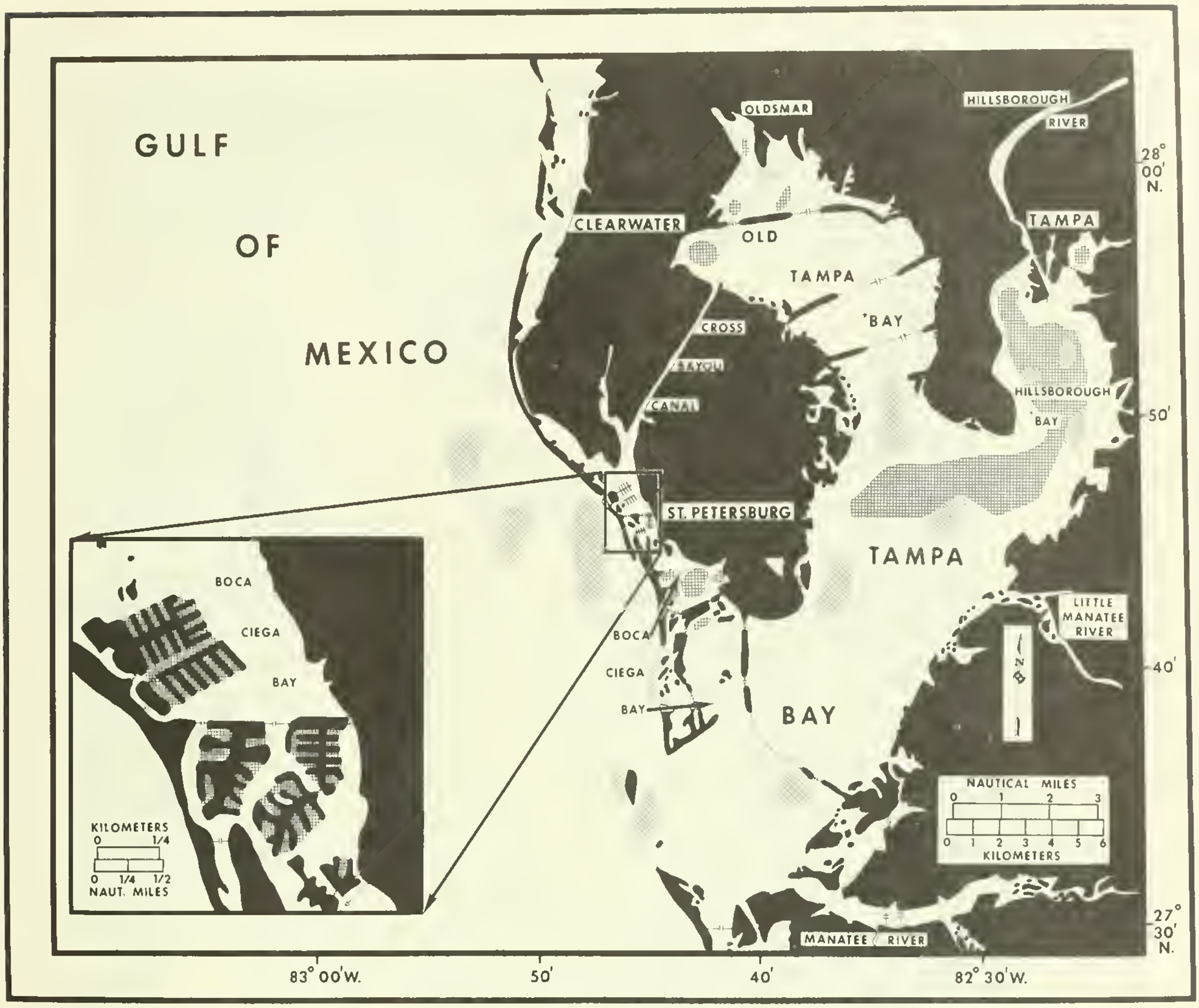

Figure 2.--Schematic illustration of sediment types in Tampa Bay, Fla.--sediments of more than 80 percent silt and clay by weight (crosshatching); sediments of more than 80 percent sand and shell by weight (hatching); sediments of more than 20 percent sand by weight (unshaded).

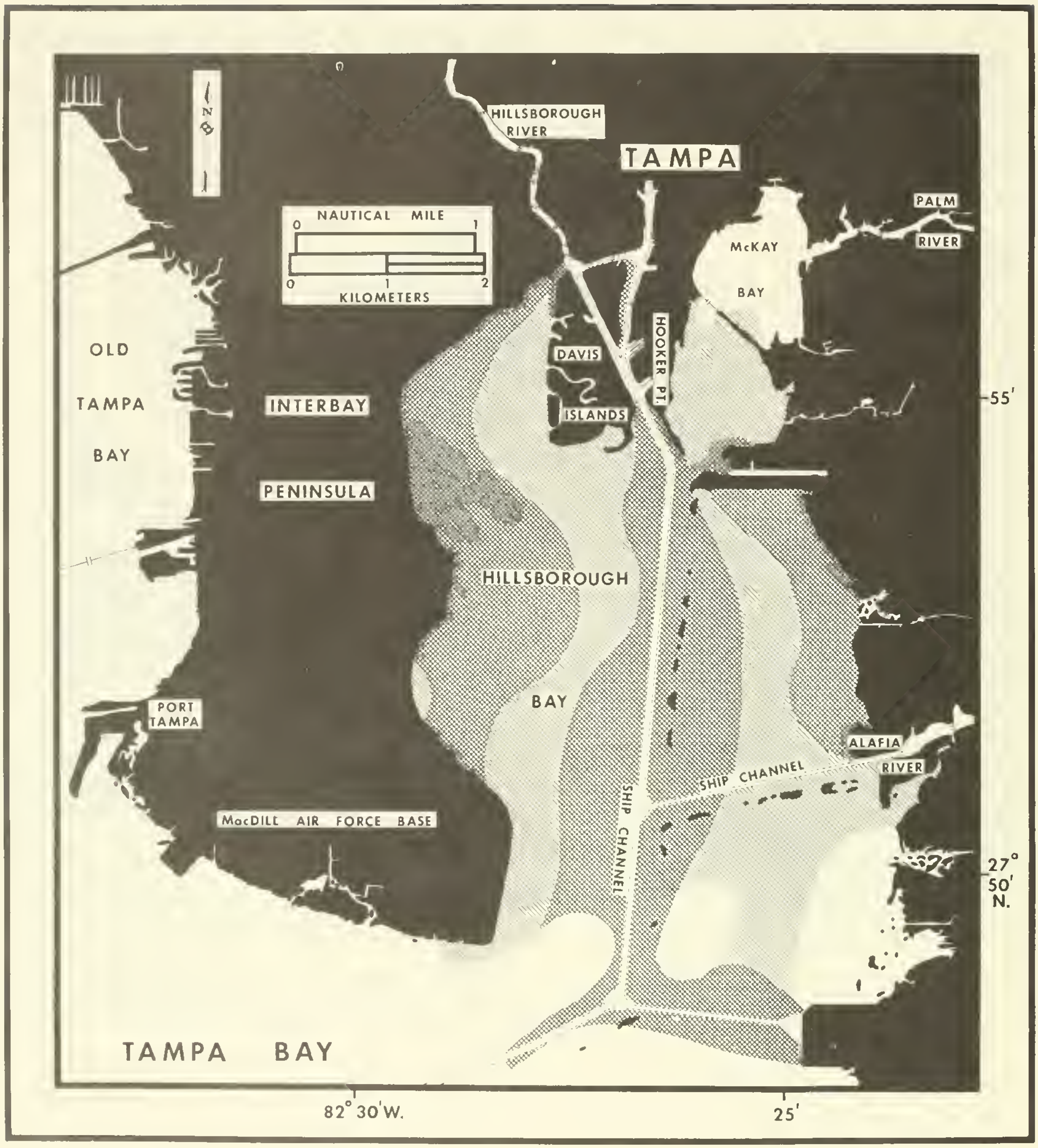

Figure 3.--Benthic life zones in Hillsborough Bay, Fla., based on the comparative diversity of mollusks--healthy zone (unshaded); marginal zone (hatching); unhealthy zone (crosshatching).

Soft sediments (> 80 percent silt and clay) and lack of vegetation account for the few shellfish in deep dredged canals.

Old Tampa Bay is more brackish (< 25 p.p.t.) than Boca Ciega Bay, but sediments are mostly sandy and submerged vegetation is extensive. Bottom samples there contained 97 species of live mollusks in 52 families. Although the number of species in Old Tampa Bay was 62 percent less than in Boca Ciega Bay, the cause is lower salinity rather than dredging or pollution.

Only 35 species of live mollusks were collected in Hillsborough Bay, where salinity is about the same as in Old Tampa Bay but where dredging and pollution are responsible for widespread accumulation of soft sediments and elimination of bottom vegetation in water more than a few feet deep. Furthermore, no live mollusks were collected at 19 of the 45 stations sampled. On the basis of these 19 stations and the incidence of four species in other samples (Mulinia lateralis, Amygdalum papyria, Tagelus plebeius, and Nassarius vibex), we divided Hillsborough Bay into three life zones--healthy, marginal, and unhealthy (fig. 3). These four species apparently are tolerant to a high degree of pollution. They made up less than 50 percent of the species present at healthy stations and 50 percent or more of the species present at marginal stations; no living mollusks were found at stations designated unhealthy. Most of the healthy areas are between Hillsborough and Tampa Bays where pollutants are somewhat diluted and much of the bottom remains sandy and vegetated. The term "healthy" is partially misleading, however, because many species found in Old Tampa Bay have not been found in any part of Hillsborough Bay.

Echinoderms and Polychaetes

Work this year on taxonomy of echinoderms raised the number of species recorded from Tampa Bay to 36. Lowell Thomas, University of Miami, identified the brittle stars. Elisabeth Deichmann, Harvard University Museum of Comparative Zoology, identified the sea cucumbers.

Polychaete worms from stations within Tampa Bay have been sorted to family or lower taxonomic level. Thirty-nine families and more than 140 species were recorded.

Southern Quahog

Growth of a clam population in lower Boca Ciega Bay was recorded for the fifth year. Average length of individuals in the sample was 5 mm. greater than in 1967 and nearly twice the mean length of clams measured in 1964. A poor set on the bed is illustrated again this year by the scarcity of small clams (fig. 4).

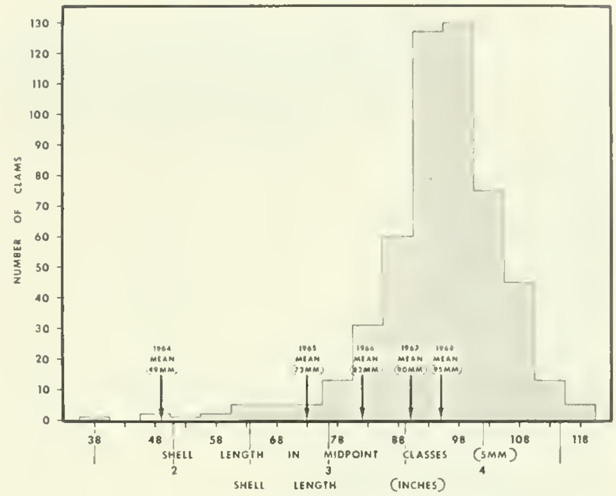

Figure 4.--Size frequency distribution (May 1968--sample size 520) and average shell length (arrow) of the southern quahog (M. campechiensis) from a population in Boca Ciega Bay, Fla., 1964-68 (1 mm. = 0.04 inch).

Table 2.--Biometric data for six large southern quahogs from Boca Ciega Bay, Fla.

Clam condition	Estimated age	Length	Height	Width	Fresh whole weight	Shell weight	Weight of meat and juice
	Years	Mm.	Mm.	Mm.	G.	G.	G.
Alive	20	172	161	102	2,100	1,442	658
Alive	19	169	170	99	2,485	1,865	620
Alive	20	167	159	109	2,354	1,681	673
Alive	17	166	164	105	2,247	1,549	698
Dead	14	179	168	102	-	-	-
Dead	19	173	172	102	-	-	-

We also collected more than 100 large clams in northern Boca Ciega Bay where a record-size clam was reported in 1964. The specimen was 168 mm. long and weighed 3 kg. (kilograms). Our collection had two living and two recently dead clams whose length exceeded that of the record specimen (table 2). We determined the age of the clams by counting annual growth lines on the shell; the distance between successive annuli showed yearly increments of growth. To help identify the annuli, we used a diamond-toothed saw to cut shells transversely from the umbo to the ventral edge (fig. 5). The estimated age of the six largest clams in the collection was 14 years or more (table 2). The largest living clam had a shell length of 172 mm. (fig. 6) and an estimated age of 20 years.

Lugworm

A large marine baitworm commonly called the lugworm (Arenicola cristata) was introduced this year as a prospect for aquaculture. The worm is good bait for spotted sea trout, sheepshead, and red and black drums. The

Figure 5.--Cross section of a southern quahog shell (M. campechiensis) showing laminated structure. Dark bands (closely spaced laminae) represent annuli that appear as deep depressions on the outer surface of the shell (marked by lines).

Figure 6.--Largest known southern quahog (M. campechiensis)--172 mm.--collected alive from Boca Ciega Bay, Fla. The shell has been cut transversely to show laminated structure from which the age of the clam can be determined.

characteristic that makes it well suited for aquaculture is its mode of reproduction. Eggs are laid in a jelly mass attached to the bay bottom where they can be picked up at low tide and transferred to prepared trays of sediment in tanks of running sea water. Preliminary experiments show that at least 72 worms with an average length of 15.2 cm. can be harvested in 6 months from a 15-cm. layer of sand, 1 $m.^2$. Locally, the worms sell for 50 cents per dozen. At this rate, worm production from one sediment tray is worth $3.00 every 6 months. Feeding the worms is no problem, because they consume algal detritus that accumulates in the tanks.

The marine baitworm business now depends on blood and clam worms dug along the coasts of New England and Eastern Canada. These worms are hard to rear because they spawn into the sea and produce planktonic larvae that are difficult to obtain and feed. We believe that the culture of lugworms can be a profitable business capable of increasing the income from marine bait worms (now valued at about $1.3 million annually).

Squid

Biological collections in Tampa Bay in 1961 and 1962 showed that the squid (Lolliguncula brevis) occurs throughout the Bay, especially in the brackish waters of Old Tampa Bay, Hillsborough Bay, and upper Tampa Bay. In 1968, egg masses of L. brevis were found in Tampa Bay in February and April. These finds are of interest because the embryological development of L. brevis has never been described. Embryos were maintained in the laboratory, and a developmental series for further study was photographed and preserved. Gross anatomical features of the embryonic squid are clearly visible through the clear matrix of the egg mass and egg (fig. 7).

Sea Grass

We started a cooperative project with the BCF Technological Laboratory in College Park, Md., in the summer of 1967 to determine the nutritional value of a sea grass known as turtle grass (Thalassia testudinum). Turtle grass is the most common sea grass in Tampa Bay and in shallow water along the west coast of Florida. Grass beds harbor a rich assemblage of marine life and produce enormous amounts of organic matter. In the past, biologists have successfully used leaves of turtle grass as a mulch and fertilizer on an experimental basis for crops such as tomatoes and strawberries.

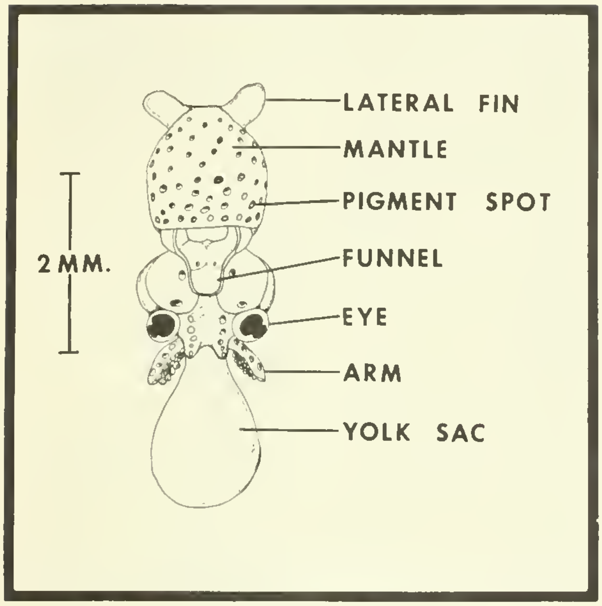

Figure 7.--Late embryo of the squid, L. brevis, from Tampa Bay, Fla.

Table 3.--Proximate analysis of turtle grass from Boca Ciega Bay, Fla.

Plant part	Protein	Moisture	Ash	Fat
	Percent	Percent	Percent	Percent
Leaves	11.76	7.62	46.57	0.66
Roots and rhizomes	10.27	7.60	42.15	0.27
Debris	4.53	1.65	88.61	0.10

Analysis of whole plants of turtle grass shows that it is notably high in protein (table 3), and this knowledge prompted us to explore the idea of using turtle grass as a feed for livestock. In August about 363 kg. (dry weight) of turtle grass were harvested and shipped to College Park (fig. 8). The grass was processed and fed to sheep. One group of sheep was fed a normal diet, and an experimental group was fed in the same way except that turtle grass was substituted for 20 percent of the regular ration. Sheep that received the feed containing turtle grass grew significantly more than the control group.

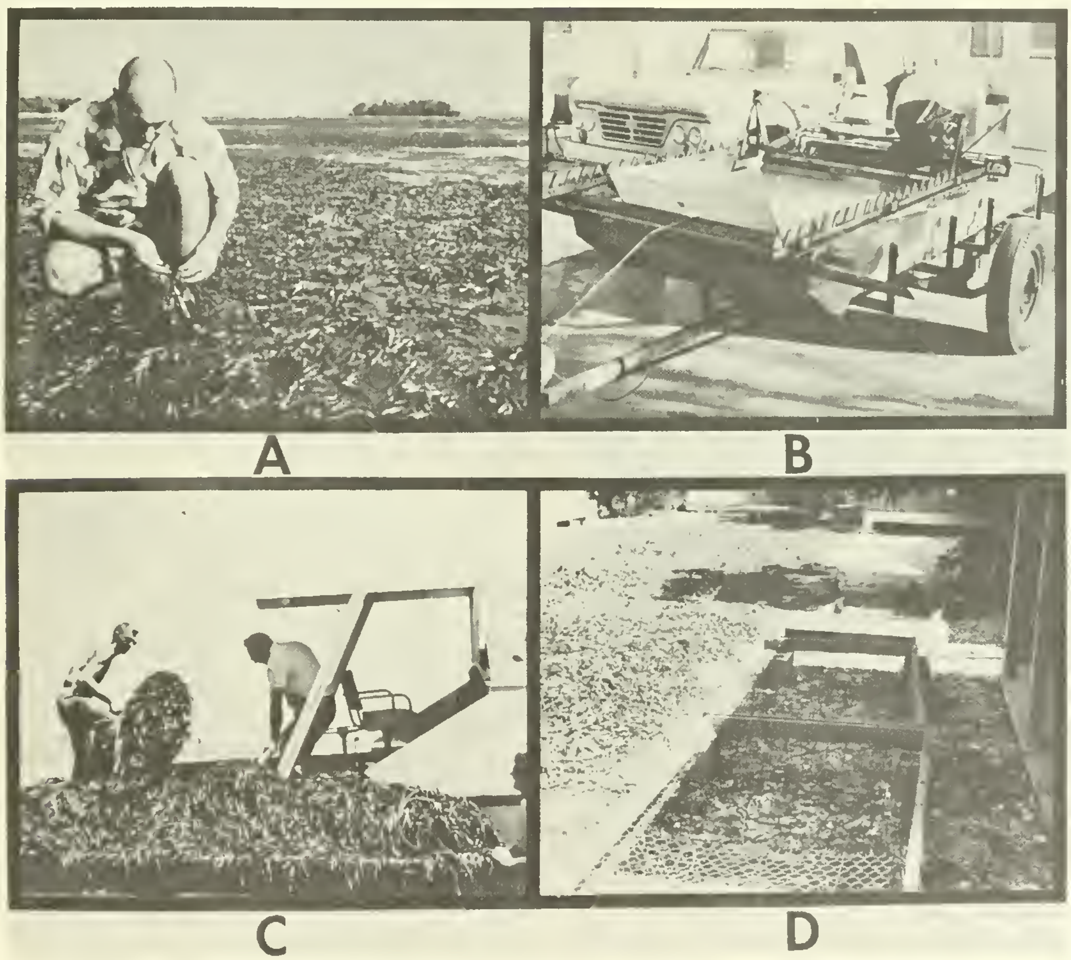

Figure 8.--Harvesting turtle grass (T. testudinum). A--turtle grass beds along the west coast of Florida; B--mower for cutting sea grass; C--harvesting operation; D--rinsing racks and drying turtle grass leaves.

Dredge-fill

On many occasions governmental agencies have asked us to make bottom surveys of areas proposed for dredge-fill development. Our findings are used to estimate the value of endangered biological resources. This value must be weighed against anticipated benefits of bayfill projects. To facilitate the collection of quantitative field data, we designed several pieces of equipment for use in estuaries along the Florida west coast (fig. 9).

The plug sampler is a box of stainless steel .125 m. wide, .125 m. long, and 23 cm. deep. Handles (1.2 cm. in diameter) and screening (0.701 $mm.^2$ mesh) are welded to the top.

In operation, the sampler is pushed into the bottom, dug out with a shovel, and emptied into a sieve box (0.701 $mm.^2$ mesh) that is supported on a screen-covered frame with styrene plastic flotation. The sample is then washed free of fine sediment and preserved. Jars, preservative, thermometer, water sample bottles, notebook, and other equipment can be transported on the water in a tub placed inside an inflated tire tube. The sampler can also be used by divers for surveys in deep water; one man operates the sampler and shovel, and another transfers each sample to the surface in a plastic bag. We generally take 10 samples at random in each habitat under investigation.

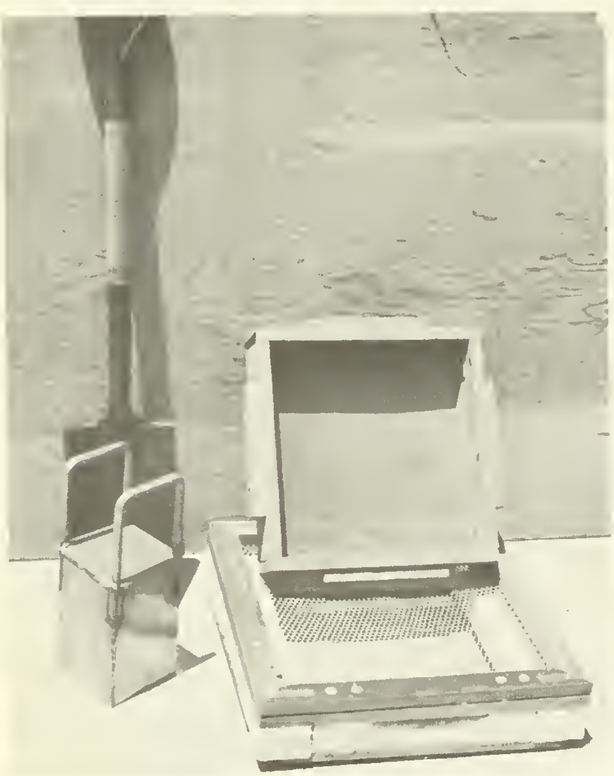

Figure 9.--Benthic sampling equipment: plug sampler and shovel, sieve box, and styrene plastic frame to support sieve box.

Table 4.--Number of benthic species and individuals in 10 samples of 0.125 $m.^2$ from each of three subtidal beds of turtle grass in Sarasota Bay, Fla., December 7, 1967[1/]

Taxon	Otter Key		South Lido Key		Pansy Bayou	
	Species	Individuals	Species	Individuals	Species	Individuals
	Number					
Platyhelminthes	-	-	-	-	1	2
Rhynchocoela	-	-	2	3	1	1
Mollusca	12	23	17	45	12	17
Annelida						
Oligochaetes	1	18	1	53	1	23
Polychaetes	15	73	21	85	13	154
Arthropoda						
Decapods	11	24	11	22	9	26
Amphipods	3	39	4	125	4	147
Isopods	1	2	1	5	2	41
Phoronida	-	-	1	3	-	-
Echinodermata	1	1	2	11	1	14
Totals	44	180	60	352	44	425
Total individuals		957				
Average individuals per sample		32				
Individuals per square meter		2,048				
Individuals per hectare		20,480,000				

1/ Cnidarians, serpulid worms, ectoprocts, ascidians, and various egg masses attached to turtle grass have not been included.

Data from a benthic survey in three areas of Sarasota Bay, Fla., were influential in a recent decision to deny a dredge-fill permit requested by the Arvida Corporation (table 4). In controversies that involve estuarine conservation, information on the diversity and abundance of bottom invertebrates is particularly useful because the infauna is a comparatively stable element in the estuarine community.

BIOGEOCHEMICAL ALTERATION AND EFFECT PROJECT

Charles M. Fuss, Jr. and John A. Kelly, Jr.

The Biogeochemical Alteration and Effect Project terminated on December 31, 1967. Two studies were completed during its existence: a comparative study on the transplanting, survival, and growth of two sea grasses under artificial conditions and a field phase on the transplant survival of turtle grass in areas where the bottom is disturbed. Both studies have provided useful and previously unavailable information for evaluating the feasibility of restoring sea grasses to areas where dredges have removed them.

Results show that turtle grass can be transplanted, that it will survive in a dredged finger-fill canal, and that the problem of erosion in canals--a major one--can be solved. On the negative side, however, the number of transplants made was small, only two finger-fill canals in the same landfill were planted, and 14 of 20 variations in planting failed--4 almost immediately. Six of the transplant methods showed various degrees of success,

Figure 10.--Transplants with new root and long-shoot growth.

Table 5.--Growth data on turtle grass transplants that showed 100 percent survival for 160 days

Growth data	Anchoring device					
	5-cm. diameter pipe			Construction rod		
	Mean	Min.	Max.	Mean	Min.	Max.
Length of new long shoots (mm.)	34	16	61	31	14	29
Number of roots on new long shoots	1	1	1	2	1	3
Length of roots on new long shoots (mm.)	16	12	18	25	7	48
Number of new short shoots on new long shoots	1	0	1	1	0	2
Number of new roots on old short shoots	6	5	8	4	3	6
Length of new roots on old short shoots (mm.)	92	65	131	87	52	139

and two resulted in 100 percent plant survival. To anchor plants in the substrate and nullify the eroding effect of currents, one of the methods used steel construction rod and the other method 5-cm. diameter metal pipe. In each method, before planting, the grass was washed to remove adhering sediments and dipped in the hormone, Napthalene Acetic Acid. None of the transplants had tips on their long-shoots. All continued to bear green leaves after planting and at the end of 5 months had put out new roots and developed new long-shoots with tips (fig. 10). Table 5 shows growth data on turtle grass transplants that had 100 percent survival for 160 days.

Further studies are necessary before large-scale transplanting of sea grasses can be unequivocally recommended. The conditions that determine the suitability of proposed transplanting areas need to be learned, additional plantings using the successful methods need to be made in varied environments, and the economic feasibility of a sizeable transplantation should be determined.

FAUNAL PRODUCTION PROJECT

John H. Finucane

The results of our preliminary fish farming experiment with the pompano, Trachinotus carolinus, have helped determine some of the problems associated with aquaculture in Florida, especially in the Tampa Bay area. The methods and techniques developed from this study will help provide information for other similar research with marine animals.

Pompano Aquaculture

Part of the success of rearing pompano in captivity depends on suitable water. In our impoundment at the mouth of Tampa Bay (fig. 11), tides were mainly responsible for water movement, and daily fluctuations in water chemistry were usually small. Water temperature during the year was 13.0° to 32.6° C., and salinity 30.59 to 36.26 p.p.t. Total phosphate, total nitrogen, oxygen, and pH were all within the normal limits expected during this period. In our test area, only temperature adversely affected the pompano. When water temperature was less than 18° C., the pompano ate less, and, at about 13° C., they became inactive and stopped feeding. Some fish never resumed feeding.

Since successful fish farming depends also on the elimination of animals that compete for food and space, Antimycin A (Fintrol 5- and -15)[1] was used to poison undersirable fish species before pompano were stocked. Our

[1] References to trade names in this publication do not imply endorsement of commercial products.

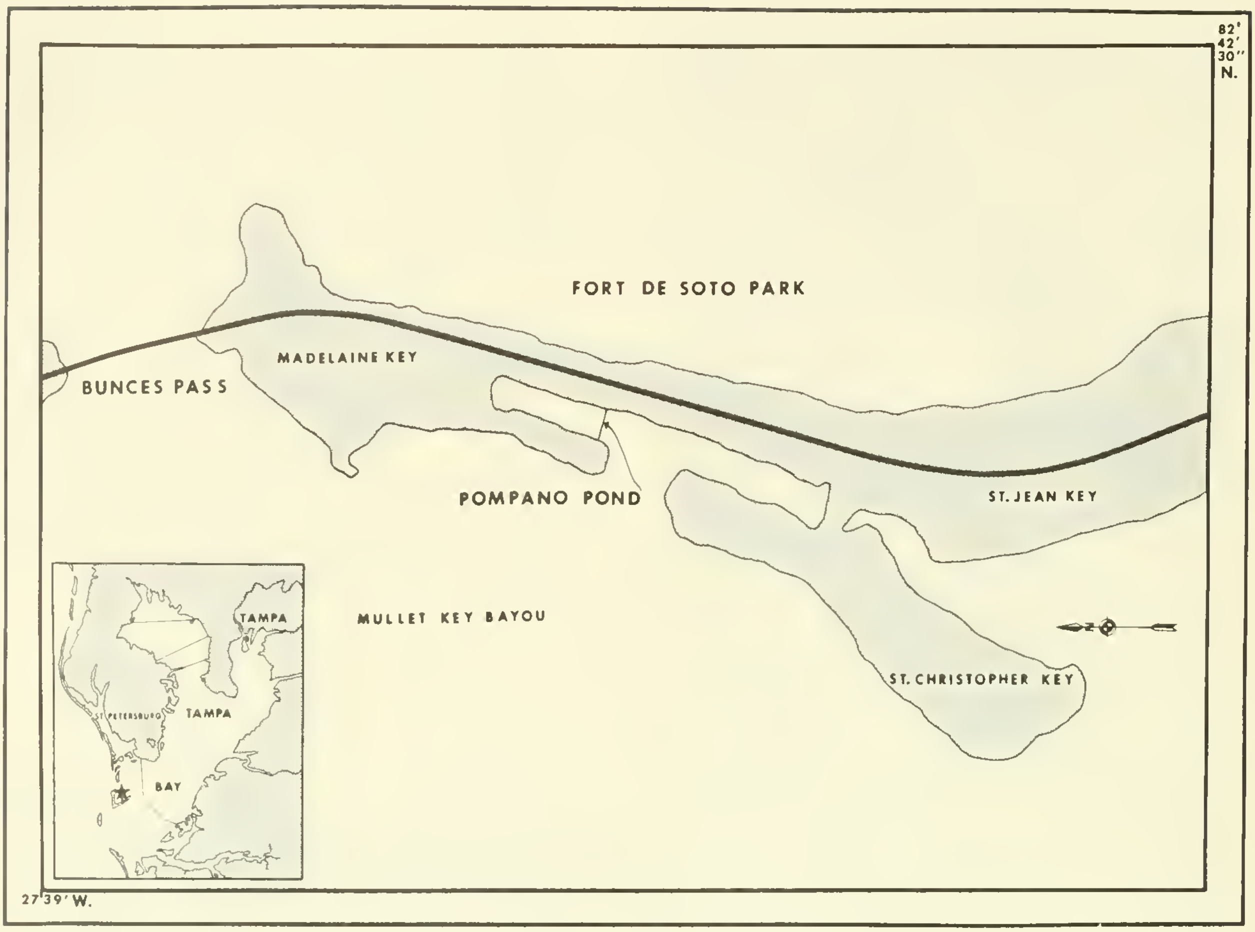

Figure 11.--Location of pompano pond in Fort De Soto Park, Fla.

evaluation of this newly developed toxicant showed that it was effective in killing 38 species of fish (table 6). The degree of sensitivity of the fish to the toxin varied among species, genera, and families. Eleven species of fish survived Antimycin at a concentration of 7 p.p.b. Fintrol-15 killed pompano at 15 p.p.b. These preliminary results indicate that Antimycin may prove useful in aquaculture; it has little effect on mollusks and crustaceans, and selective fish kills can be obtained by controlling the concentration. Detoxification took only 4 to 5 days, and stocking of pompano was possible within a week after poisoning.

To determine the suitability of diets for rearing pompano, a dry ration containing 40 percent protein was fed experimentally to 6,000 juveniles for 6 months (June-December). This commercial floating food (Trout Chow) is available in various grades and was fed mainly from an automatic feeder. The amount of food fed daily was governed by the average body weight of the fish. As a starting diet, pompano (25-75 mm. long) were fed about 10 percent of their body weight six times daily for about a month. This amount was later reduced to 5 percent for the next 3 months and then to 2 percent for the rest of the year. (Feeding frequency for the last 5 months was three times daily, 6 days a week.) Pompano readily adjusted to a dry ration, but in October we noted that fat had infiltrated the livers. This caused excessive mortality, and we ended the experiment in December.

In continuing pompano studies, we began in 1968 to compare a wet ration (cod) with the day ration. Juvenile fish are being confined in pens (7.9 by 13.9 m.) in the pond. Our primary purpose is to raise fish to market size as economically and rapidly as possible.

Growth of young pompano in the first experiments (1967) was rapid: during a 6-month period from June through December, average monthly gains were about 30 mm. in length and 27 g. (grams) in weight. The greatest average monthly weight gain was 86 g. in November. By December the largest specimens weighed over 300 g. The length-weight curve of captive fish was similar to that of wild stock. From these data it appears possible to grow pompano to market size of

Table 6.--Sensitivity of fish to Antimycin A (Fintrol-5) at 7 p.p.b. during a 5-day period. All fish listed as highly sensitive were killed while the resistent group survived.

HIGHLY SENSITIVE	SENSITIVE
Engraulidae	Dasyatidae
Anchoa hepsetus	*Dasyatis sabina*
Anchoa mitchilli	*Dasyatis sayi*
	Gymnura micrura
Synodontidae	
Synodus foetens	Elopidae
	Elops saurus
Syngnathidae	
Syngnathus floridae	Belonidae
Hippocampus erectus	*Strongylura notata*
	Strongylura timucu
Pomadasyidae	
Orthopristis chrysopterus	Cyprinodontidae
	Fundulus similis
Clupeidae	
Brevoortia smithi	Gerridae
Harengula pensacolae	*Eucinostomus argenteus*
	Eucinostomus gula
Sparidae	
Archosargus probatocephalus	Sciaenidae
Lagodon rhomboides	*Bairdiella chrysura*
	Cynoscion arenarius
Ephippidae	*Cynoscion nebulosus*
Chaetodipterus faber	*Leiostomus xanthurus*
Gobiidae	Mugilidae
Gobiosoma robustum	*Mugil cephalus*
Gobiosoma bosci	
Microgobius gulosus	Atherinidae
	Menidia beryllina
Triglidae	
Prionotus scitulus	RESISTANT
Prionotus tribulus	Ariidae
	Galeichthys felis
Bothidae	
Paralichthys albigutta	Cyprinodontidae
	Cyprinodon variegatus
Cynoglossidae	*Lucania parva*
Symphurus plagiusa	
	Carangidae
Balistidae	*Caranx hippos*
Monacanthus hispidus	*Caranx ruber*
	Oligoplites saurus
Ostraciidae	*Selene vomer*
Lactophrys quadricornis	
	Sciaenidae
Tetraodontidae	*Sciaenops ocellata*
Lagocephalus laevigatus	*Pogonias cromis*
Sphaeroides nephelus	
	Echeneidae
Diodontidae	*Echeneis naucrates*
Chilomycterus schoepfi	
	Centropomidae
	Centropomus undecimalis

Figure 12.--Seining pompano to determine growth rates.

255-356 mm. and a weight of 454-567 g. in about 1 year.

If commercial rearing of pompano is to be economically successful, a number of major problems must be solved. Inadequate diet and low water temperatures appeared to be the main causes of pompano mortality in our pond the first year. Both of these factors are controllable. Hatchery techniques must be developed and methods found to rear pompano from eggs after natural or artificial spawning. Seining wild stock yearly from beach habitats is costly and time consuming (fig. 12). Pond designs must also be perfected, and basic engineering techniques improved. Farming techniques for a number of species such as clams and crabs, as well as for pompano and other fishes, need to be explored.

Pompano Ecology

Knowledge of the life history of the pompano is important in understanding its environmental preference and limitations. Successful culture of these fish requires information on their spawning, age, parasites, and food preferences.

Ovaries and testes of adult pompano were examined from fish caught at the mouth of Tampa Bay during April. The presence of at least four different egg stages in the same ripe ovary may indicate that pompano spawn over an extended time period. The mature unfertilized eggs averaged 0.7 mm. in diameter, had a large yolk, and were symmetrical in shape. Egg counts indicate that the average female has 600,000 to 800,000 eggs. Ripe fish were 275 to 380 mm. in total length and weighed 456 to 1,140 g. The size of the smaller fish indicates that some probably spawn during the second year of life. In pond culture of these fish, it may be possible to spawn them in less than 2 years.

Juvenile and adult pompano are remarkably free of external and internal parasites. A few isopod parasites of the genera Ione and Aegathoa were found in the mouth or gill area and attached to various parts of the body and fins. Also, several parasitic copepods (Argulus sp.) were found on the skin. Mature or immature nematodes (Ascaris spp.) were sometimes found in the body cavity or encysted in the viscera. We saw no evidence of bacterial or fungal infections in the pond, although pompano appeared to be highly susceptible to these infections in overcrowded laboratory aquariums contaminated by uneaten food.

Food habits of adult pompano are still largely unknown, but there is some evidence that the diet becomes more diversified as they mature. Mollusks are the favorite food of all size groups. In Tampa Bay, adult pompano feed on a small branched mussel, Branchidontes exustus, which is attached to rocks on the bottom. No fish remains were found in several hundred specimens of a wide range of sizes from the Tampa Bay area. A single juvenile pompano (51 mm. SL) from St. Augustine, Fla., had 46 postlarval sciaenids in its stomach, but fish apparently do not normally constitute a major item in the diet.

GULF OF MEXICO ESTUARINE INVENTORY PROJECT

J. Kneeland McNulty

Collection of closely comparable data from Florida to Texas is a major goal of the Inventory. It is being accomplished by the cooperative work of the marine fishery departments of Alabama, Louisiana, and Mississippi; the Bureau of Commercial Fisheries Laboratories at Galveston (covering Texas) and St. Petersburg Beach (covering Florida); and several other governmental agencies and educational institutions.

The data are comparable because participants decided unanimously what work is to be accomplished and how it is to be done. Work outlines being followed were written, discussed, modified, and adopted in fiscal year 1967. A few improvements were made in 1968 after people began using the outlines.

The group with the authority to resolve problems on methods, procedures, and policies continues to be the ETCC (Estuarine Technical Coordinating Committee) of the Gulf States Marine Fisheries Commission.

Two ETCC subcommittees have worked effectively during this fiscal year to solve key problems. The subcommittee on automatic data processing produced data formats and coding instructions for Biology, Hydrology, and Sedimentology phases which were mutually acceptable to the participants and the NODC (National Oceanographic Data Center), Washington, D.C. NODC has agreed to do the card punching, machine printouts (listings), storage, and eventually the computer analyses. NODC assigned a staff member temporarily to this Laboratory on October 30, 1967, to design preliminary data formats and write drafts of coding instructions in cooperation with the participants. The resulting formats and instructions are the first of their kind in estuarine work; they are being examined by the Federal Water Pollution Control Administration and the Atlantic States Marine Fisheries Commission for possible application to their work.

A second subcommittee resolved various opinions on the scales and symbols to be used in maps. A uniform set of symbols to depict various elements--such as sources of pollution, submerged vegetation, and oyster beds--was unanimously adopted, and agreement was reached on the scale of maps which are to appear in the State atlases.

Thus, several institutions from Florida to Texas are accomplishing a comprehensive and uniform study of estuaries. We feel that the benefits extend beyond the tangible accomplishments to the intangible benefits derived from many people in several institutions working in harmony toward a worthwhile goal.

During the past year, this Laboratory nearly completed gathering data for the Area Description phase for Florida, and started field work concurrently with other participants on the Biology and Hydrology phases.

Area Description

The basic data of the Area Description phase are available as aerial photographs, navigation charts, population figures, oyster lease descriptions, county pollution data, knowledge of local fishermen, stream discharge data, etc. The purpose of this phase is to organize the data and present them as a useful body of information.

We have learned many new things about the estuaries on Florida's west coast. For example, we have known in a general way that their total area is large but did not realize that their combined area (including Florida Bay) of 8,000 $km.^2$ is over 4 times the area of Lake Okeechobee, over 1-1/2 times the area of Long Island Sound, and about 84 percent of the area of Chesapeake Bay.

Large-scale aerial photographs usually show underwater patches of vegetation as mottled dark areas. By examining all available photographs of the coast and mapping the submerged areas of vegetation, we found that 26 percent of all bay bottoms have plants. The figure is 20 percent larger if only depths less than 2 m. are considered. The published atlas is to include maps of submerged vegetation. The resource is limited, and the Inventory shows the limits for the first time.

Hydraulic dredge-and-fill operations have aroused concern over their effects on fish and wildlife resources; yet they have not been mapped to determine their total impact. We

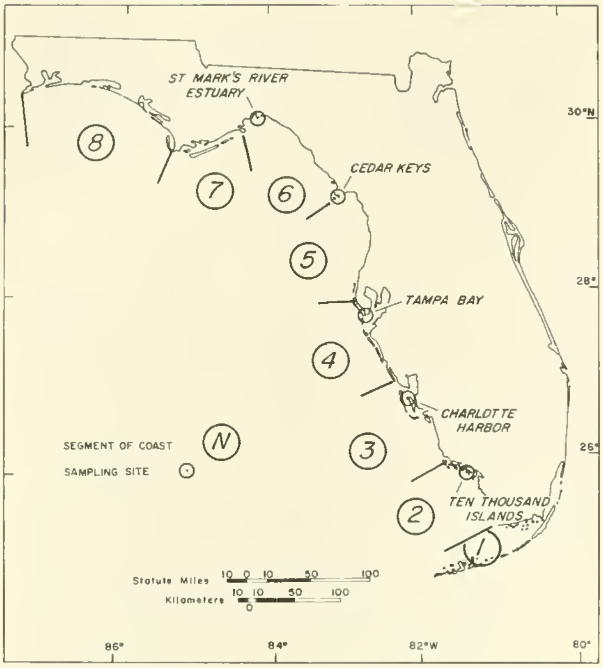

Figure 13.--Segments of the west coast of Florida and sampling sites at which biological and hydrological field work is taking place.

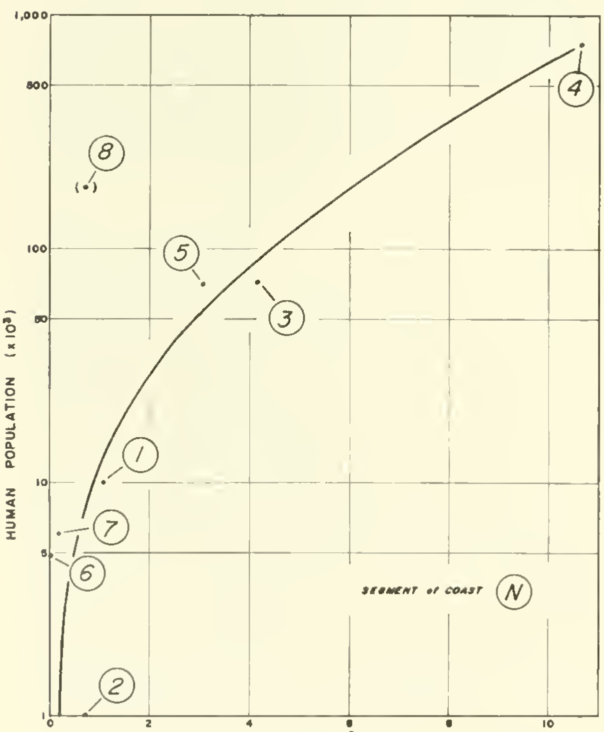

Figure 14.--Relations of the human population in segments of the Florida west coast to estuarine acreage filled for residential and industrial use. (1 acre = 0.405 hectare).

Table 7.--Flow rates of industrial and domestic pollutants into the estuaries of eight segments of the Florida Gulf coast (see fig. 13) in m.g.d. (millions of gallons per day)1/

Coastal segment	Industrial pollutants	Domestic2/ pollutants	Population
	M.g.d.	M.g.d.	Thousands
1	3/	3/	10
2	0.018	0.090	1
3	3/	7.190	72
4	10.309	82.689	746
5	3.008	6.797	71
6	3/	3/	4
7	3/	0.951	6
8	118.231	22.310	186
Total	131.566	120.027	1,096
Grand total of all pollutants	251.593		

1/ To convert millions of gallons per day to millions of liters per day, multiply by 3.785.
2/ Includes plant design capacity where true flow is unknown.
3/ Insignificant.

have compared the earliest charts of the coast with present charts to map filled areas and have supplemented this work with field observations. The total filled area is 8,851 ha. (hectares). As one would expect, the greater the human population the greater the area that has been filled, with the exception of the northwestern segment of the coast where little filling has been done up to now (figs. 13 and 14).

The location, nature, and quantity of pollution were determined from available sources and the rates of flow totalled by segment (table 7). Although the general magnitude of pollution of estuaries has been known for several years, the specific points of discharge and their relation to the living resources--such as oyster and clam beds and submerged vegetated areas--have not been mapped and described previously.

Thus, the Area Description study generates basic knowledge that is statistical in nature and can be mapped readily to show the extent of man's inroads into estuarine resources. It will provide new, basic information for those who are acting to protect the fisheries.

Biology

The purpose of the Biology phase is more dynamic than that of the Area Description phase. It documents the importance of the estuaries as nurseries and contributors to the success of the Gulf of Mexico fisheries.

The participants have unanimously agreed to define:

1. The major commercial species appearing in the estuaries as immature animals and, within sampling limitations, as adults.

2. The quantitative distribution of each of the species by season and area for 1 to 2 years; all participants are to sample simultaneously for the minimum period April 1, 1967, through March 31, 1969.

3. The value of harvested species that live in estuaries during part or all of their lives.

4. The correlation between hydrological characteristics and relative abundance of selected organisms, mainly with respect to salinity and temperature.

All participants are using 30.4-m. seines, 4.9-m. flat otter trawls, and 1/2-m. plankton nets that are fitted with No. 2 plankton netting and flow meters.

The west coast of the Florida peninsula is sampled once each month at five locations from Chokoloskee, in the Ten Thousand Islands, to the St. Marks River estuary (fig. 13). We chose the stations because they are physically and hydrologically similar. The five sampling stations are on 644 km. of coast, which is sampled in 5 days whereas previous studies of this kind have been confined to single or adjacent estuaries.

The seasonal and geographic variations in the species and numbers of fish are marked. From January through May, total number of fish were in the ratio 1:3:3:5:5 for January, February, March, April, and May, respectively (table 8). More fish were caught at the three more southerly stations than at the two northerly stations. Grand totals of abundance were in the ratio 4:4:7:1:1 from southernmost to northernmost locations.

Seventy-eight species were identified. Twelve occurred universally along the 644 km. of coast; 8 at either the three northernmost or the three southernmost locations only; and the rest at only one or two adjacent locations. As the waters warmed in the spring, many species increased their distribution, especially northward.

Although it is too soon to attempt to evaluate biological results, it appears that a new conception will emerge of the seasonal and geographical population dynamics of fishes--especially of commercial species which inhabit the estuaries as young.

Table 8.--Numbers of fish caught by seine and trawl nets at five locations on the Gulf of Mexico coast of Florida, January through May 1968

Locations and principal species	Month: January	February	March	April	May	Grand total
	Number					
Chokoloskee						
Anchoa mitchilli (bay anchovy)	116	1,700	700	-	3	
Lagodon rhomboides (pinfish)	-	9	4	-	610	
Others	223	65	45	33	343	
Total	339	1,774	749	33	956	3,851
Bokeelia						
Anchoa mitchilli (bay anchovy)	-	7	6	-	-	
Lagodon rhomboides (pinfish)	3	438	165	567	1,159	
Menidia beryllina (tidewater silverside)	25	7	41	960	113	
Others	7	44	11	155	192	
Total	35	496	223	1,682	1,464	3,900
Maximo Point						
Anchoa mitchilli (bay anchovy)	267	533	1,520	-	261	
Lagodon rhomboides (pinfish)	18	3	25	1,254	612	
Menidia beryllina (tidewater silverside)	36	9	2	258	12	
Others	426	146	113	609	703	
Total	747	691	1,660	2,121	1,588	6,807

Table 8.--Numbers of fish caught by seine and trawl nets at five locations on the Gulf of Mexico coast of Florida, January, through May 1968--Continued

Locations and principal species	Month					Grand total
	January	February	March	April	May	
	Number					
Cedar Key						
Anchoa mitchilli (bay anchovy)	145	-	19	20	-	
Lagodon rhomboides (pinfish)	-	3	5	2	9	
Menidia beryllina (tidewater silverside)	111	43	85	401	21	
Others	25	18	20	125	172	
Total	281	64	129	548	202	1,224
St. Marks Lighthouse						
Lagodon rhomboides (pinfish)	-	8	24	12	93	
Menidia beryllina (tidewater silverside)	-	185	5	28	190	
Others	-	90	17	69	146	
Total	-	283	46	109	429	867
Grand total	1,402	3,308	2,807	4,493	4,639	16,649

BIOLOGY OF INDUSTRIAL SCHOOLFISHES PROGRAM

Charles M. Fuss, Jr., and John A. Kelly, Jr.

This program was initiated at the beginning of the fiscal year to study the biology of thread herring (Opisthonema oglinum) and other potential industrial schoolfishes (excluding menhaden) in coastal waters of the eastern Gulf of Mexico. A preliminary study entitled "Biology of Thread Herring" under the East Gulf Estuarine Program was activated 3 months earlier (April 1, 1967). Recent industrial interest in the use of thread herring as an alternate to diminishing menhaden stocks stimulated us to expand our efforts in this area.

Aerial and surface surveys by the Exploratory Fishing and Gear Research Base at Pascagoula, Miss., and IRT (aerial infrared temperature) surveys by this Laboratory have shown that thread herring occur in extensive concentrations along the west coast of Florida. Biological information on the species is extremely sketchy, but the present study is expected to provide many of the data needed to ensure the orderly development and expansion of the fishery on the basis of sound biological principles.

DEVELOPMENT OF THE FISHERY

An industrial thread herring fishery in the eastern Gulf began in August 1967 when the Protein Products Corporation opened its processing plant on Charlotte Harbor near Fort Myers. A locally based, Bureau-financed vessel (fig. 15) began fishing in late August, and a typical menhaden vessel joined the operation from October to December 1967 and again in February 1968. In November and December 1967, a number of Louisiana-based menhaden vessels entered the fishery, landing catches at the Ocean Protein, Inc., plant at

Figure 15.--Single-boat-rig purse seiner used in thread herring fishery.

DuLac, La. In May 1968, the original single-boat-rig purse seiner was replaced by a menhaden vessel.

Fishing has been restricted to a relatively small area between Gasparilla Island and Sanibel Island in nearshore waters 6 to 20 m. deep (fig. 16). Poor bottom conditions to the north and south and a scarcity of fish in offshore waters have restricted the fishing area.

Almost 5,100 metric tons of fish were landed at the Fort Myers plant from August 1967 to June 1968 despite a series of legal conflicts concerning the taking of food fish that were incidental to the thread herring in the catches. The food fish problem was eventually settled with Bureau assistance by a court decision in February 1968 that allows a small percentage of food fish in catches of industrial fish. About 1,150 metric tons of thread herring were landed in Louisiana during the winter.

The new thread herring fishery is of great importance because of the continuing decline of menhaden stocks and an increasing demand for animal protein. The commercial catch of about 6,250 metric tons in 10 months despite adversities shows that the fishery has capacity for further development.

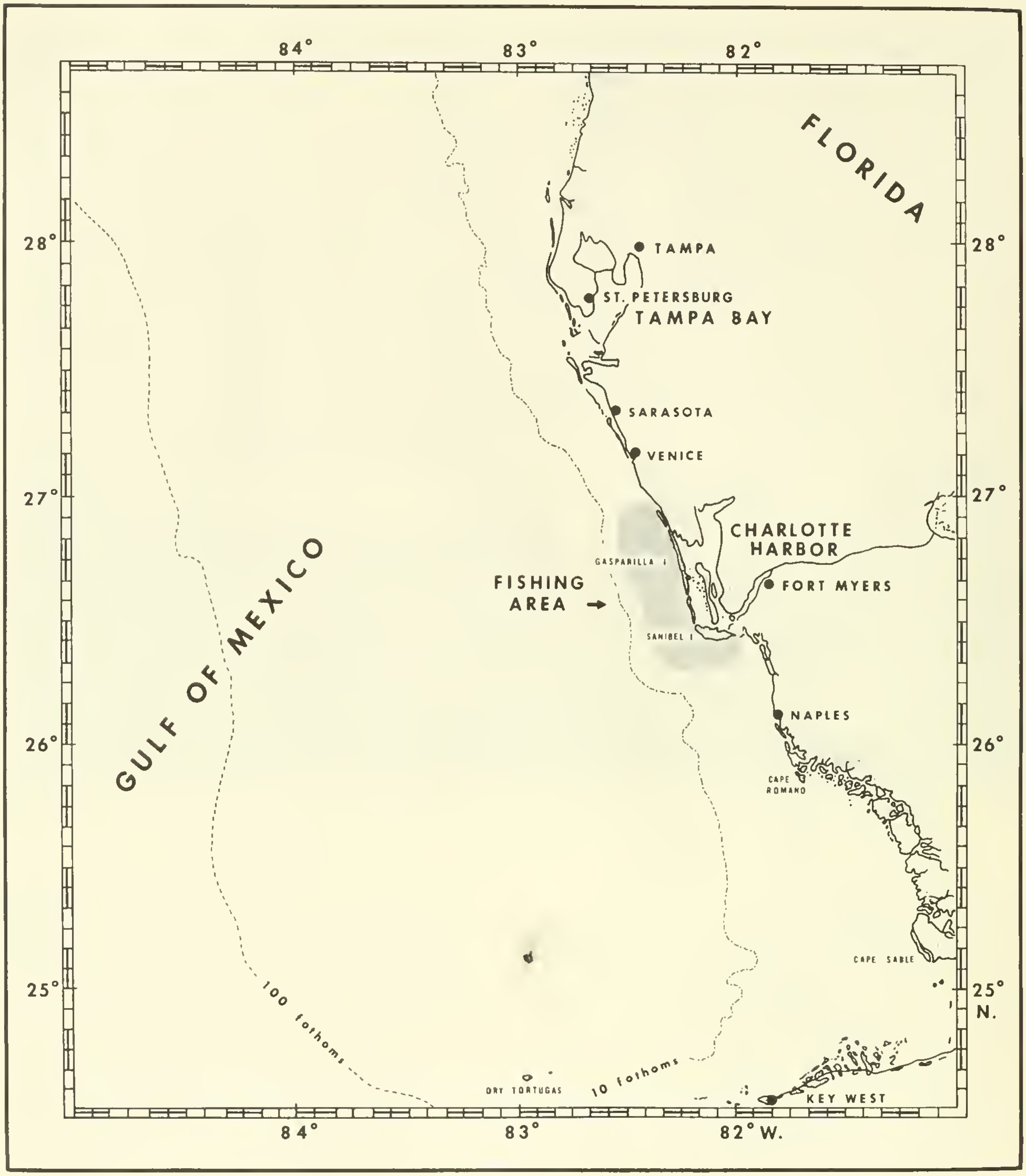

Figure 16.--Thread herring fishing grounds on the Florida west coast.

PROGRAM GOALS

Board program goals were developed to formulate future management principles for taking thread herring and other potential industrial fish along the Florida west coast. Because of limited funding and personnel, however, we have had to restrict the initial objectives to the studies considered most important to the immediate needs of the developing thread herring fishery. We have emphasized goals that may be achieved in 5 years. Life history, distribution, commercial catch analysis, and some aspects of natural behavior are priority items.

Some of the immediate questions to be answered are as follows:

1. How long do thread herring live, and how fast do they grow?
2. What year classes make up the commercial catch, particularly during the early stages of the developing fishery?
3. When and where does spawning occur, and what areas serve as nurseries?
4. Do thread herring migrate, and if so, what are seasonal patterns?
5. How does water temperature affect the distribution of stocks?
6. What factors affect vertical distribution of fish and schools of fish?
7. Do game fish feed on thread herring, and if so, to what extent?

FACILITIES AND PROCEDURES

The R/V Kingfish is equipped with a hydraulic power block for fishing monofilament gill nets of various mesh sizes. Adult fish are sampled in Tampa Bay, Charlotte Harbor-Pine Island Sound, and nearshore Gulf waters between the two estuaries. At each gill net station, plankton tows are made for eggs and larval fish, and oceanographic data are recorded. Beach seines and lift nets were used to collect junvenile thread herring in shallow areas and near docks and bridges.

We have collected samples of the catch of commercial vessels since the beginning of the fishery. Commercial fishermen have cooperated in providing samples from purse seine catches along with information on fishing effort and areas of operation. Fishing logbooks have been placed aboard all vessels engaged in the fishery.

Conversion of part of a dockside warehouse gave us a new laboratory for processing fish samples. Laboratory processing of fish samples includes measurements of body length and depth, body weight, and where applicable, gonad weight. Fish are sexed, and scales, stomach, and gonad samples preserved for future analysis. Samples from our fishing operations and from commercial catches received the same treatment.

A through-flow sea-water system is available for holding live fish. Attempts are being made to hold fish for long periods to provide data for age and growth studies and for experiments in artificial fertilization.

PROGRESS DURING THE YEAR

The highlights of research results during the first year are as follows:

1. Analyses of commercial catches landed at the Protein Products plant showed that food fish taken incidentally in thread herring purse seine sets did not exceed about 0.35 percent (by weight) of the total catch. At court hearings on the food fish problem, we presented these data along with opinions stating that the thread herring fishery would have no significant adverse effects on stocks of food and sport fish. As a result, the court delivered a declaratory judgment permitting the taking of a small amount (unofficial agreement is 1 percent) of food fish in purse seining for nonfood fish. Testimony given has thus been instrumental in assuring the continued growth and development of the thread herring fishery on the Florida west coast.

2. Thread herring catches per unit of effort (30-minute set with a 5.1-cm. mesh, 30.5 m. by 3.1 m. monofilament gill net) in Gulf waters off St. Petersburg Beach reached a peak in late spring and early summer and declined with falling water temperatures in the fall. Very few thread herring were taken during the winter (fig. 17). When coastal waters cool, the thread herring concentrate in the south, and when the waters warm, the fish disperse to the north, and possibly offshore.

3. Catch per set by commercial vessels off Fort Myers reached a peak in winter and declined with the warming of coastal waters in the spring. Warming water and possibly factors associated with warming water, such as feeding and spawning habits, seem to affect the schooling behavior of thread herring. In the warmer months many surface schools occur off Fort Myers, but individual schools contain fewer fish than in the cooler months. Purse seine sets therefore produce fewer fish in the summer.

4. Juvenile thread herring appeared in beach seine samples along Gulf beaches in the Tampa Bay area in July and disappeared by October.

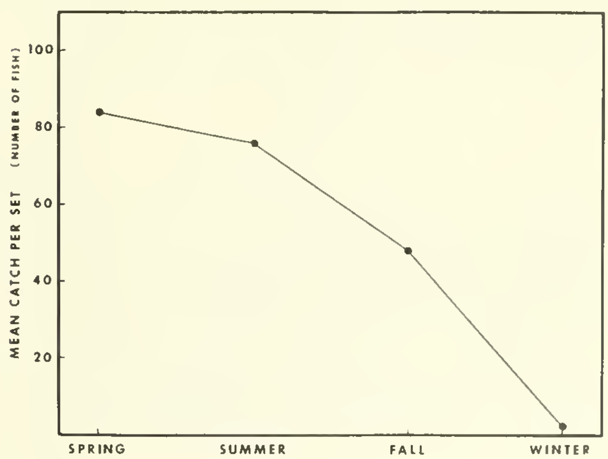

Figure 17.--Mean number of thread herring caught per set of a 30.5-m., 5.1-cm. mesh monofilament gill net in Gulf waters off St. Petersburg Beach.

5. Fully developed gonads were found in thread herring 140 to 165 mm. fork length taken off St. Petersburg Beach in early April. Spent gonads, indicative of spawning, were found by late May when water temperature was about 27° C. Gonad development indicates a spawning peak in June.

6. The ratio of males to females in the summer thread herring population off St. Petersburg Beach was about 1 to 5 whereas that in the winter population off Fort Myers was about 1 to 1.

7. Ripe thread herring were induced to spawn in laboratory tanks, but the eggs did not survive.

8. The stomachs of 200 mackerel taken by commercial fishermen in the Naples area were examined, and no thread herring were found.

RED-TIDE PROGRAM

TOXIN RESEARCH

Dean F. Martin

The University of South Florida completed a contract with this Laboratory to isolate and characterize the fish-killing toxin of red tide.

Contract research demonstrated that there are two chemically distinct toxins. A procedure was developed to isolate and purify both substances from cultures and natural blooms. One toxin is minor and can be isolated only in trace quantities. The major substance is a neurotoxin, and properties from samples isolated from unialgal cultures and blooms of Gymnodinium breve appear to be identical on the basis of infrared data.

The major toxin isolated is a light yellow, low-melting solid. Qualitative elemental analysis identified the presence of carbon, hydrogen, and phosphorus. Sulphur, chlorine, bromine, and nitrogen were absent. The substance was characterized by the absorption spectra (ultraviolet and infrared), the nuclear magnetic resonance spectrum, and optical activity measurements. A molecular weight of 650 and the formula $C_{90} H_{162} O_{17} P$ were determined for the major toxic substance.

ENCYSTMENT STAGE OF GYMNODINIUM BREVE

William N. Lindall, Jr.

Studies on the encysted forms of G. breve were completed through use of an electron microscope. By using standard fixation solutions (gluteraldehyde and osmic acid) with variations in fixing times and dehydration, repeatable results were obtained. These results are not ideal because of difficulties in preserving, dehydrating, and embedding such a fragile organism, but the basic organelles within the cell were photographed and identified. Trichocysts were found within the cells, which to our knowledge have never been reported in G. breve.

The reason for labeling the results "not ideal" is that the cytoplasm is vacuolated and appears to have been leached out during the harsh preparation that is required for electron microscopy. This vacuolation may, however, be characteristic of the cyst form, which is rounded and smaller than the motile form. The same techniques are being applied to the motile cell in an attempt to compare the two forms.

PLANKTON ECOLOGY PROJECT

J. Kneeland McNulty

A study of primary productivity in Tampa Bay continued in the past year. Its purpose was to learn more about fundamental ecological processes at work in the Bay, especially those which relate directly to the production of phytoplankton including Gymnodinium breve, the causative agent of red tide.

All fisheries depend directly or indirectly on plant production. Even so, estimates of phytoplankton productivity are available for less than 10 inshore areas worldwide. The Tampa Bay study may be the most extensive of its kind in any estuary. It dates from September 1962, and covers representative areas seasonally.

The sequence of pertinent ecological events in Tampa Bay in fiscal year 1968 is described in this report to illustrate the seasonal interrelationships of environmental and biological processes. The data are graphed as if they were in chronological sequence despite the discontinuity between June 1968 and July 1967 (fig. 18). Moving averages of the order three were used to smooth the data.

Average annual solar radiation at Tampa is one of the highest at a seacoast location in the Nation. Seasonal variations during the past year were typical. Solar radiation rose sharply in March, peaked in late May, dropped to a summer low in August because of summer rains, reached a second peak from mid-August to late September, then dropped steadily to the winter minimum in mid-December.

Primary productivity attained two peaks--one in April-May and the other in August-September. Separate stimuli apparently triggered the two peaks. The spring increase began when water temperature reached about 22° C., 40 days after solar radiation began to

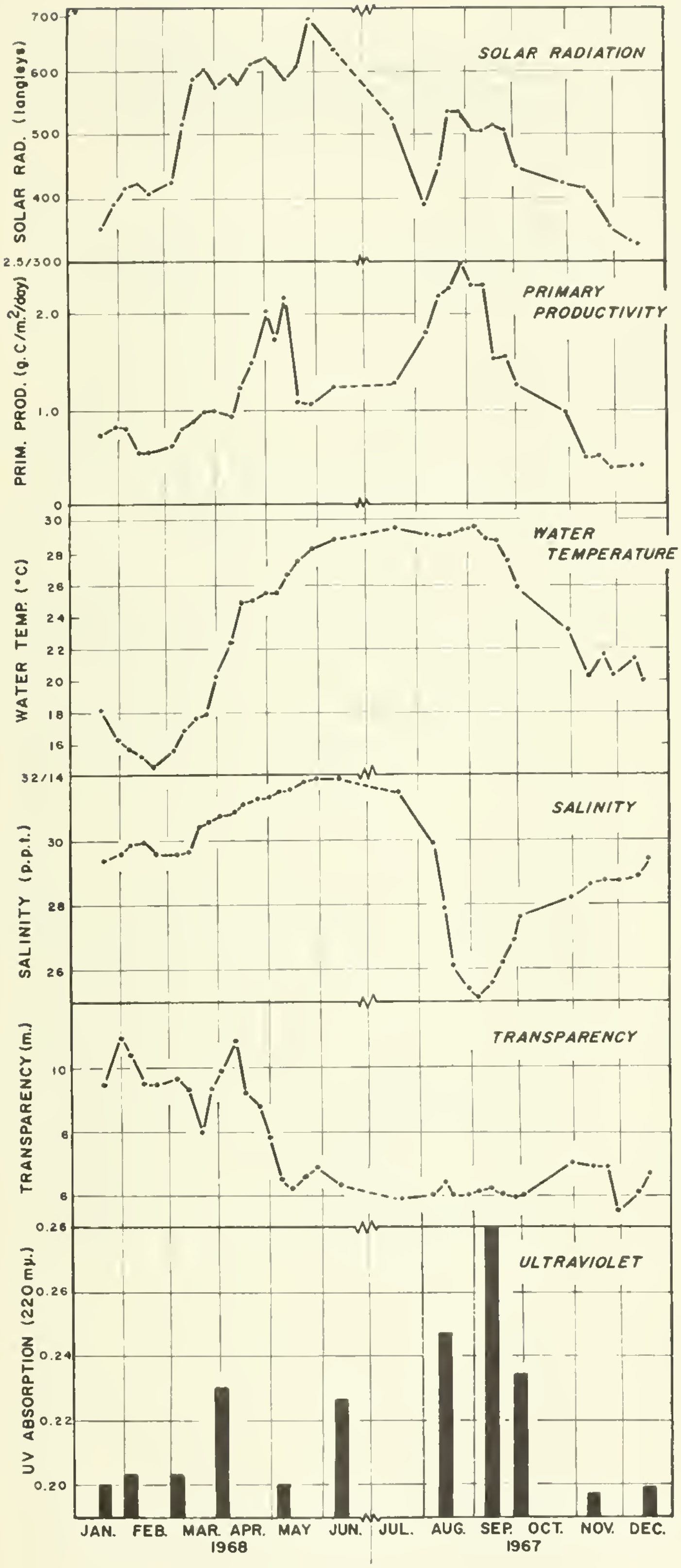

Figure 18.--Comparison of selected properties of the environment in fiscal year 1968. Moving averages of the order three were used to smooth the data except for ultraviolet absorption--for it, raw data were used. Transparency is the depth (m.) to which 35 percent of surface light penetrated. Dashed lines indicate discontinuity between June 1968 and July 1967.

increase rapidly. The summer increase began when salinity began to decrease, i.e., from runoff of summer rains entering the Bay. Thus, the spring bloom appeared to be temperature-related, probably through the release of nutrients by bacteria at a critical temperature, whereas the summer increase was probably salinity-related. As would be expected, water transparency decreased at the same time that phytoplankton production increased.

Ultraviolet absorption was measured during the past year as it has been since February 1963. Two peaks occurred, one in early April and the other in September. The early April peak preceded the spring bloom of phytoplankton by a few days; the September peak was coincident with a minimum of salinity and a maximum of phytoplankton productivity. The fact that the spring increase occurred at a time of increasing salinity shows that river runoff and ultraviolet absorption are not necessarily related.

The ultraviolet absorption test was initiated in 1963 because of its possible utility in predicting red-tide outbreaks. The test is simple and rapid. The reasoning was that ultraviolet absorption might be an indicator of the presence of nutrients which are essential to a bloom of G. breve. Ultraviolet absorption is related to the organic content of water; therefore, unusually high or low absorption might indicate unusually high or low concentrations of the nutrients associated with organic substances. Field data substantiated this reasoning. In the spring of 1963, ultraviolet absorption increased markedly just before a red-tide outbreak and decreased markedly just after the bloom. There were no red-tide outbreaks from then until September 1967, when a relatively mild one occurred. Again, ultraviolet absorption increased markedly just before and during the outbreak. However, unusually high values of ultraviolet absorption are not necessarily accompanied by a red-tide bloom. An increase in absorption in September 1965 was not accompanied by unusually high counts of G. breve. Increases of ultraviolet absorption are usually accompanied by decreases of salinity, but the relation is only approximate as shown by the graph of maximum, minimum, and average values of both properties from February 1963 to June 1968 (fig. 19).

How does the phytoplankton primary productivity of Tampa Bay compare with that of other inshore areas? The average gross annual rate in fiscal year 1968 was 401 g.C/m.^{2} (grams of carbon per square meter), whereas the annual rates published for other waters are 99.6 in shallow North Carolina estuaries, 39 to 175 in certain Danish bays, and 380 g.C/m.^{2} in Long Island Sound. Thus, Tampa Bay's phytoplankton primary production is one of the highest that has been measured.

The productivity of Tampa Bay can be viewed also in relation to terrestrial plant production.

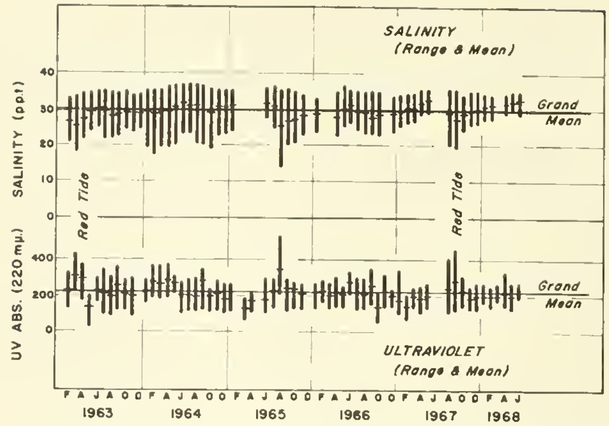

Figure 19.--The range and mean of monthly salinity and ultraviolet absorption from February 1963 through June 1968. Red tide was coincident with two of three periods of high ultraviolet absorption.

The orange crop is by far the most valuable of Florida's agricultural products. Orange groves abound in the Tampa Bay area. The Statewide average production of oranges over a recent representative 5-year period was 3,937 kg./ha./year (kilograms per hectare per year) (dry weight) whereas the average production of phytoplankton in Tampa Bay was 10,017 kg./ha./year in fiscal year 1968. Benthic algae and grasses boost the total annual production of plant material in Tampa Bay to two or three times the annual phytoplankton production, so that the total is in the range of 20,000 to 30,000 kg./ha. per year. For comparison, the world average annual production of wheat is about 3,400 kg./ha., and the highest production of wheat and corn in northern Europe is about 16,000 kg./ha. per year, including straw and roots.

Thus, the annual production of plant material in Tampa Bay is high compared with the annual production of terrestrial crops, just as it is high in relation to production of phytoplankton in other inshore marine areas. The waste of organic material in Tampa Bay and other fertile estuaries is prodigious in terms of potential direct benefits to man. It is tempting to speculate that herbivore yield as high as 10 to 20 percent of primary production of plants is theoretically possible, as has been attained in the conversion of corn to hogs, although a yield of 3 percent is apparently the highest yet achieved in marine farm ponds. The usual harvest of seafood is a small fraction of 1 percent of primary production. The losses occur at various stages in the complicated food chains between primary production and edible fishery products. Man's grasp of the facts is fragmentary and hence his control of the processes involved is insignificant. One of the major scientific and engineering challenges of our time is to attain better control of the processes involved in estuarine seafood production.

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