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REPORT OF THE BUREAU OF COMMERCIAL FISHERIES BIOLOGICAL LABORATORY, GALVESTON, TEXAS

FISCAL YEAR 1969

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BUREAU OF COMMERCIAL FISHERIES

Circular 343

Report of the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas

Fiscal Year 1969

MILTON J. LINDNER, Director
ROBERT E. STEVENSON, Assistant Director

Contribution No. 299, Bureau of Commercial Fisheries Biological Laboratory, Galveston, Tex.

Circular 343

Washington, D.C.
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The Bureau of Commercial Fisheries Biological Laboratory, Galveston, Tex., and its field station in Miami, Fla., conduct fishery research in the Gulf of Mexico as part of the work of the Bureau's Gulf and South Atlantic Region (Region 2), which comprises the eight coastal States from North Carolina to Texas.

Office of the Regional Director, Seton H. Thompson, is in the Federal Office Building, Room 668, 144 First Avenue South, St. Petersburg, Fla., 33701.

Marine Resources:

- Biological Laboratory, Beaufort, N.C.
- Biological Laboratory, Brunswick, Ga.
- Biological Laboratory, Galveston, Tex.
- Tropical Atlantic Biological Laboratory, Miami, Fla.
- Biological Laboratory, St. Petersburg Beach, Fla.
- Radiobiological Field Station, Gulf Breeze, Fla.
- Biological Field Station, Miami, Fla.

Utilization and Engineering:

- Exploratory Fishing and Gear Research Base, Pascagoula, Miss., auxiliary base at St. Simons Island, Ga.
- Marketing--Marketing offices in: Atlanta, Ga.; Dallas, Tex.; Pascagoula, Miss.; and St. Petersburg, Fla.
- Technology--Technological Laboratory, Pascagoula, Miss.

Economics:

- Statistical Center and Market News office, New Orleans, La.

Resource Development:

- Financial Assistance office, St. Petersburg, Fla.

CONTENTS

Cover photo: View of concrete tanks and ponds used for experimental rearing of shrimp at the East Lagoon Field Station.

REPORT OF THE BUREAU OF COMMERCIAL FISHERIES BIOLOGICAL LABORATORY, GALVESTON, TEXAS

Fiscal Year 1969

ABSTRACT

Progress of research is reported. Emphasis is on shrimp, and the research involves the fields of mariculture, population dynamics, ecology, and oceanography.

REPORT OF THE DIRECTOR

General

Research at this Laboratory is designed to provide the information on shrimp that is essential for the development of the resource. State agencies responsible for the discrete use of our natural resources can apply this information to ensure an optimum sustainable harvest of penaeid shrimp from U.S. waters. Our biologists study shrimp stocks in the Gulf of Mexico--the source of about 70 percent of the total U.S. catch in 1968.

The three commercial species of shrimp of most importance are the white, *Penaeus setiferus*; brown, *P. aztecus aztecus*, and pink, *P. duorarum duorarum*, shrimp. These three species have similar life histories, but the environment inhabited by the several life stages dictates a varied approach to a complete understanding of the life cycle. As adults and larvae, the shrimp inhabit waters over the Continental Shelf, but as postlarvae and juveniles they live in estuarine waters, which are being altered constantly by man.

Progress in general research on shrimp over the past few years has made it possible for us to divert our efforts into areas of specific problems. One example is our investigation into the feasibility of shrimp mariculture. Our four programs--Shrimp Biology (Mariculture), Shrimp Dynamics, Estuarine, and Gulf Oceanography--are seemingly diversified, but emphasis remains on shrimp. Progress made in each of these programs constitutes the bulk of this report.

Laboratory Facilities

The contract let by the U.S. Army Corps of Engineers to a local contractor in Galveston, Tex., for the rehabilitation of the buildings at the BCF (Bureau of Commercial Fisheries) Biological Laboratory was completed on schedule (June 1968 through March 1969). Chipped concrete on the masonry buildings was repaired, and the buildings were sandblasted. Seven porches in three masonry buildings were enclosed to provide additional storage space. Wooden buildings were sanded and necessary repairs were made. All buildings received two coats of white paint and were trimmed in brown. The main entrances to Buildings 302 and 306 were provided with glass-enclosed vestibules, and aluminum outside blinds for storm protection were installed on five buildings. The cost to repair one wooden building was prohibitive, and the building was demolished. Plans are being made to use the 4,000-ft.^{2} basement of the demolished building as part of a prototype shrimp hatchery.

Equipment has arrived for a sea-water system that will provide constant-flowing water of controlled temperature. Installation is under way, and the system will be operating in fall 1969.

Laboratory Activities

Laboratory personnel were hosts to the Meeting of the Southwest Field Committee on November 7, 1968. About 50 people, representing 12 agencies and 8 States, attended the meeting. Each Program Leader at the Laboratory described his program activities.

Reed S. Armstrong participated in a 3-week biological investigation of the upwelling zone on the rich anchovy fishing grounds along the coast of central and southern Peru. The cruise was made with the R/V *Thomas G. Thompson* by the University of Washington.

An American Broadcasting Company team completed a film on shrimp culture and estuary seeding with the cooperation of members of the BCF Field Station in Miami and Robert E. Stevenson, Assistant Laboratory Director, Galveston.

In addition to carrying on research, many members of the staff lectured to academic or civic groups, attended scientific meetings, received additional training, or participated in workshops. By activity, the total number that participated is as follows:

Lectures - 11	Training - 30
Scientific meetings - 10	Workshops - 17

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Library

Renovation of the library quarters became necessary during the year to relieve crowded conditions that resulted from the general increase in the size of the library collection. Acquisition of an adjoining room for office facilities released space for the expansion of the shelving and reading room areas within the library. This project is partially complete.

We added to the library collection about 500 volumes of books and journals, and over 4,100 reprints, reports, and miscellaneous publications during fiscal year 1969. The library contributed to the Interior Union List of Serials scheduled for publication in 1969. We continued to issue the biweekly list of current acquisitions, which is sent to the Laboratory staff and other laboratories.

In addition to the Laboratory staff, the library served an increasing number of students and faculty members of area universities and laboratories. Various individuals from industrial firms and other institutions used the specialized collection.

Table 1 gives the statistical summary of the library collection for fiscal year 1969.

Museum

In operation since August 1965, the museum maintains valuable collections of biological and botanical specimens. Most specimens are from the Gulf of Mexico, principally from Texas and Florida. Others, however, are from such areas as the Bahamas, the Galapagos Islands, New Zealand, the Philippines, and the Virgin Islands.

Many specimens indigenous to this area are arranged systematically and displayed for educational use (fig. 1). Information provided with many of the species includes common and scientific names, and location, date, and depth of capture. This portion of the collection has been of considerable interest to educational groups.

Several thousand samples of plankton are maintained for study and display. During the past year, aliquots of about 480 samples were processed and shipped to the BCF Biological Laboratory in Beaufort, N.C., where they will be used in menhaden studies.

Public Relations

This year nearly 1,900 people visited our Laboratory. Represented in this group were Federal and State agencies, private industries, foreign countries, universities, high schools, and grade schools. In response to this interest, we provided Laboratory tours, field trips, training sessions, private consultations, and lectures.

Of the 1,900 visitors, 22 were from 12 foreign countries. These countries and the number of representatives are listed below:

Argentina (1)	Malaysia (1)
Australia (2)	Mexico (8)
Chile (1)	Norway (2)
East Pakistan (2)	Philippines (1)
Greece (1)	South Africa (1)
Japan (1)	Thailand (1)

SHRIMP BIOLOGY (MARICULTURE) PROGRAM

During the past year, brown shrimp spawned in the laboratory on five different occasions and pink and white shrimp once. With the resulting larvae, we completed two feeding experiments, two salinity experiments, and an experiment to assess the effects of salinity and EDTA (ethylenediaminetetraacetate) on larval development. Postlarvae were supplied to 10 nonprofit research organizations. In addition, cultures of diatoms and instructions for their culture were supplied to seven organizations.

We completed two experiments to screen various fish and animal feeds as possible food for shrimp in ponds. In all, the 11 different

Table 1.--Statistical summary of library collection, Biological Laboratory, Galveston, Tex., 1968-69

Item	On hand June 30, 1968	Additions fiscal year 1969	On hand June 30, 1969
	Number	Number	Number
Books	3,295	141	3,436
Journals (bound)	726	107	833
Journals (Unbound)	2,274	233	2,507
Reprints	4,415	411	4,826
Publications from State and foreign offices	17,020	3,661	20,681
Other	1,782	89	1,871
Total items	29,512	4,642	34,154

Figure 1.--Biological and botanical specimens in the museum interest our many visitors.

foods we used included 9 commercial foods and 2 gelatin-bound formulations that we prepared. Concurrent studies on food particle size suggest that juvenile shrimp prefer large food particles which they can hold and break pieces from rather than small particles that can be ingested whole.

We also directed research toward the problem of bringing penaeid shrimp into spawning condition in the laboratory. Adult shrimp, held in four ponds and several large tanks inside the laboratory, were fed different diets and observed for sexual development. Only males in ponds showed apparent signs (externally) of sexual maturation.

We added several new research facilities and modified others this past year. Twelve concrete tanks, 3 m. long, 1 m. wide, and 1 m. deep (10 ft. by 3 ft. by 3 ft.) were constructed adjacent to our East Lagoon Laboratory. These tanks are connected to the Laboratory's sea-water system and are covered by an open-sided shed roofed with fiberglass. A heat exchanger was incorporated into the sea-water system at Fort Crockett. A 7,700-liter (2,100-gallon) tank, six 1,850-liter (500-gallon) tanks, and equipment for regulating water temperature in the tanks were installed in the East Lagoon Laboratory. We now have a pellet maker that we can use to make experimental foods in sufficient quantity for large-scale experimentation. We made many modifications to facilitate handling and care of larval shrimp, and installed a light room for the mass culture of algae. In addition, a contract was let to the U.S. Army Corps of Engineers for a design to convert the basement of a demolished building into a recirculating sea-water system.

Personnel in the Florida Bay Ecology Studies Project prepared manuscripts that summarized the results of past research. Following the recommendation of the budget review committee, we terminated this project at the end of the year and transferred the personnel to the Bureau's TABL (Tropical Atlantic Biological Laboratory), Miami, Fla.

Harry L. Cook, Program Leader

Larval Culture

We concentrated during the year on determining the physiological requirements of shrimp larvae and developing a prototype hatchery for the culture of larval shrimp. To supply food for the larval shrimp, we also spent considerable time developing a method to grow mass cultures of algae in artificial media.

Larval physiology.--As the result of feeding experiments completed during the year, we concluded that *Thalassiosira* sp. is the most suitable alga of those tested as food for the larval shrimp. Other algae tested were *Skeletonema costatum*, *Cerataulina* sp., *Cyclotella nana*, and *Isochrysis galbana*. Table 2 shows the results of one experiment in which brown shrimp protozoeae were fed *Thalassiosira*. Further analysis of these data showed that protozoeae I survived best when *Thalassiosira* was supplied at rates of 180,000 to 190,000 cells per larva per day; protozoeae II at rates of 240,000 to 290,000 cells; and protozoeae III at 340,000 to 370,000 cells. In another experiment myses of brown shrimp were fed *Artemia* nauplii and *Thalassiosira*. Those animals fed a mixture of *Artemia* and algae grew faster than those fed only *Artemia*, but survival was similar except when the numbers of *Artemia* nauplii supplied were too low.

Table 2.--Concentrations of *Thalassiosira* supporting the best survival of brown shrimp protozoeae, Biological Laboratory, Galveston, Tex.

Larval stage	Shrimp	*Thalassiosira*
	Number per liter	Number per ml. (X 1,000)
Protozoea I[1].....	133	30
	167	40
	266	50
	333	60
Protozoea II[2]....	133	40
	167	50
	266	60
Protozoea III[3]...	133	50
	167	60

[1] First-stage protozoea.
[2] Second-stage protozoea.
[3] Third-stage protozoea.

We performed two experiments to determine the effects of salinity on the growth and survival of larvae of brown shrimp. All larval stages in these experiments were held at salinities of 24, 28, 30, and 34 p.p.t. (parts per thousand). EDTA was added to the water in which a portion of the shrimp were held. Survival was best at 28 and 30 p.p.t. Variable survival at 34 p.p.t. indicated that the salinity level probably was near the upper limits of tolerance. Larvae survived well at 24 p.p.t. with EDTA, but they suffered complete mortalities when EDTA was absent. EDTA benefited all stages of larvae at all salinities.

A further test of the effect of EDTA involved the use of a synthetic sea water. Protozoeae III were placed in synthetic sea water (30 p.p.t.) with and without EDTA. Survival was similar in the two groups, but the larvae developed fastest in the water with EDTA.

Mass culture.--Work was directed primarily to the development of a prototype shrimp hatchery. We modified equipment, incorporated new procedures, and developed new techniques. We modified the larval rearing tanks by adding bulkhead fittings and valves to the bottom of each tank. This arrangement and the addition of a filter screen, which threads into the bulkhead fitting, make it possible to filter, drain, or recirculate the water by opening or closing two valves (fig. 2). A high-pressure power washer (500 pounds per square inch) now used for cleaning equipment in the hatchery enables us to wash and rinse a tank in minutes.

Procedures were developed for estimating numbers of food organisms and larval shrimp. We use a hemocytometer to count diatoms and an electronic counter for first- and second-stage nauplii of the larval shrimp as well as Artemia nauplii. To estimate numbers of more advanced shrimp larvae and postlarvae, we photograph aliquot samples that we place in a petri dish. These pictures are then placed under a dissecting scope and the shrimp counted. We calculate the mean, standard deviation, mortality rate, and confidence limits of the population from these counts.

Gravid white and pink shrimp that we captured offshore spawned successfully in the laboratory. Spawning occurred in the 950-liter (250-gallon) rearing tanks and several 19-liter (5-gallon) carboys. After a female spawned in a carboy, we removed her and put the eggs in the large rearing tanks. We fed the diatom Cyclotella nana to the protozoeal stages and Artemia to the mysis stages. Survival from protozoea to mysis was poor for both species. Although we increased the amount of diatoms fed to the shrimp from 30,000 cells per milliliter to 750,000 cells per milliliter, shrimp larvae continued to die. Only 11 percent of the pink shrimp and 18 percent of the white shrimp survived. We attributed this poor success directly to the diatom Cyclotella, which is an unsuitable food when used alone.

The successful hatching of white shrimp was no doubt due to the fact that their ovaries were fully ripe. Their eggs were a dark olive green. We examined each female and found no attached spermatophore. Water temperature in the spawning tanks were 26.9° to 28.2° C. (80.4° - 82.8° F.), and the salinity 29.1 to 31.2 p.p.t. EDTA at a level of 0.1 g. per liter (0.01 ounce per gallon) was placed in each tank and carboy before the shrimp spawned.

Diatoms are now cultured in artificial sea water in 300-liter (79-gallon) tanks in a temperature-controlled light room. Banks of fluorescent lamps that can be raised or lowered were constructed to provide the required intensity of light. At present, electric pumps transfer the diatoms to the harvesting tanks; however, construction is underway to provide space in the attic where the algae culture room can be transferred. From the attic the algae will be able to flow by gravity to the rearing tanks.

Algal culture.--The diatom, Cyclotella nana, was grown for shrimp food in carboy cultures and in mass cultures with Instant Ocean[1] artificial sea salt (mixed in tap water and prepared without heat) as the basic culture media. To this salt water we added Tris buffer, EDTA, KNO_3, Na_2SiO_3, vitamins B-12 and thiamin, and iron, either as $FeCl_3$ or $FeNH_4(SO_4)_2$. We counted 3 to 6 million diatom cells per milliliter. After the number of diatoms reached a peak (usually 2 days), we harvested about two-thirds of the volume daily and replaced it with new medium to maintain the quality of the culture. We maintained cultures for as long as 14 days.

We studied how artificial sea-salt media would be affected by adding three sources of iron--ferric sequestrine, ferric ammonium sulfate, and ferric chloride. Ferric sequestrine and ferric ammonium sulfate supported good growth of Skeletonema sp. in test-tube cultures, whereas ferric ammonium sulfate supported the best growth of Thalassiosira sp. in tube and carboy cultures.

General suitability of the Instant Ocean-tap water medium for certain flagellates, dinoflagellates, and diatoms in tube cultures was indicated by good growth of 19 to 22 organisms tested.

Harry L. Cook, Project Leader
Ausbon Brown
Cornelius R. Mock
M. Alice Murphy

Food and Experimental Environments

The purpose of our research has been to find a suitable food for raising shrimp. Once we have accomplished this, we can turn our energies to selective breeding. We studied the growth of shrimp fed various foods prepared in our laboratory and fed commercially available foods. We have also completed studies to determine if shrimp prefer certain sizes of food particles.

We continued to use the fish protein concentrate pellet developed last year and modified it to test additional proteins. Pellets were made with fish protein concentrate, cottonseed meal, and soybean meal as the source of protein, either singly or in combination. Test shrimp ate pellets made with fish protein concentrate but not pellets made only with cottonseed meal or soybean meal. The animals tore apart the pellets containing fish and vegetable meals and appeared to extract as much of the fish protein concentrate as possible. A great portion of the vegetable material was left on the bottom of the tank. All experiments had negligible growth and poor survival, apparently from a heavy growth of micro-organisms, fouling of the water, or a combination of these factors.

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

Figure 2.--Modification of larval-rearing tank permits more efficient operation by Laboratory worker.

The most promising food prepared in the laboratory is a gelatin-bound diet of fish protein concentrate, homogenized clams, and vitamins. The shrimp reacted to this food as when they were fed marine worms. The shrimp moved rapidly about the tank probing the bottom with their first three walking legs. The shrimp grew little, but we believe that with more experiments with other combinations of ingredients, we can prepare a suitable diet.

The size of food particle may be an important factor in whether the shrimp accepts or rejects an artificial food. To test this theory we used shrimp that were 25 mm. (1 inch) to 76 mm. (3 inches) long. The shrimp were fed either 6-mm. (0.3-inch) cubes of gelatin-bound food or some of the same food "riced" through a screen with 14 meshes per inch. In every test, the shrimp ate the cubes first; sometimes they left the riced food untouched for 24 hours.

At the East Lagoon Laboratory, we held shrimp in outdoor cement tanks supplied with running sea water filtered through a fine mesh bag (fig. 3). These animals were fed various commercial foods and foods developed in the laboratory. In the first test we tried two gelatin-bound diets, two trout diets, one catfish diet, and one salmon diet. With the exception of the salmon food, we tested each diet in duplicate. We kept 30 white shrimp that averaged 95 mm. (3.8 inches) total length in each tank for 4 weeks. Growth was similar for all animals, regardless of diet, and the average increase in length over the 4-week period was about 4 mm. (0.2 inch). We attributed poor growth to the low water temperature of 19° to 24.5° C. (67° - 76° F.). Survival was 97 percent or better in 9 of the 11 tanks.

Juvenile brown shrimp that averaged about 76 mm. (3 inches) total length were used as test animals in a second experiment in the outside tanks. The commercially prepared foods fed in this 4-week experiment were cat food, hog food, two dog foods, puppy food, and salmon food. Shrimp fed one of the dog foods and puppy food were significantly smaller than shrimp fed the other four diets. Those animals fed salmon food grew best with an average increase in length of 23.5 mm. (0.9 inch). Survival was 90 percent or better in all tanks. These shrimp may have grown more because of the higher water temperature--25° to 29.5° C. (77° - 85° F.)--than during the previous test.

Zoula P. Zein-Eldin, Project Leader
George W. Griffith
Larry J. Hollis

Figure 3.--Cement tanks in which shrimp were held during food studies. Workers tested various diets to determine which food(s) supported the best growth and survival.

Culture of Juvenile and Adult Shrimp

At the beginning of the fiscal year, we were testing four methods of growing shrimp in our ponds. In each of four 0.02-hectare (1/20-acre) ponds, immature brown shrimp had been stocked at a density of one shrimp per 0.2 m.^{2} (2 ft.^{2}) of bottom surface. This year we stocked juvenile rather than postlarval shrimp so that we could concentrate our efforts on determining how to offset the slow growth (past studies) experienced when shrimp in ponds became 76 to 100 mm. (about 3 - 4 inches) long. Table 3 summarizes the treatment and results in each pond.

Feeding rates throughout the 114-day study were based on initial stocking density, but it was apparent at harvest that we had supplied too much food. Loss of nutrients from the excess food apparently supported dense growth of algae in both ponds. Temperatures reached 34° C. (93° F.), and pH values rose above 9 several times in the study. To prevent oxygen levels from dropping below 2 ml. per liter, we aerated each pond with a low-pressure, high-volume air pump. This technique did maintain oxygen levels above 2 ml. per liter in pond 2, but the shrimp suffered extensive mortality due to some other factor or combination of factors.

At the time of harvest, we recovered 14 white shrimp with the brown shrimp from pond 4. Although they were the same size as the brown shrimp when stocked, their average size at harvest was 23 per pound as compared to 55 per pound for brown shrimp.

Shrimp retained from the feeding studies were restocked in our ponds and examined periodically in the fall and winter for signs of sexual development. Males in two ponds had signs of advanced maturation. Spermatophores were visible as whitish bodies beneath the lower posterior edge of the carapace (fig. 4). Several females had mated, but only a few had developing ovaries. Sexual development was arrested by the approach of winter and the accompanying low water temperatures. At that time we removed a number of the largest shrimp from the ponds and placed them indoors in a 9,000-liter (2,400-gallon) tank in which the temperature was maintained at 27° C. (81° F.) and salinity at 33 p.p.t. These shrimp failed to show any signs of maturity over a 4-month period.

This spring we continued to try to bring shrimp into spawning condition in a controlled environment. Adult shrimp, placed in each of four ponds and in seven large fiberglass tanks in the laboratory, are fed different diets and observed closely for sexual development. To date, only pond-reared males show signs of becoming mature.

Since the construction of our first ponds, one of our major problems has been to stabilize

Table 3.--Summary of results obtained from experimental rearing of shrimp in four brackish-water ponds at Galveston, Tex., 1968

Pond number	Treatment	Size at stocking	Size at harvest	Average individual gain		Survival	Total food added		Total weight gained or lost	
		Number per pound		Grams	Ounces	Percent	Kilograms	Pounds	Kilograms	Pounds
1	No food or fertilizer.	59	52	1.0	0.03	82	0	0	-0.6	-1.3
2	Fed 5 percent of body weight daily. Trout food 50 percent; rabbit food 50 percent.	33	21	8.0	.28	22	58.7	129.5	-6.7	-14.8
3	Fed 5 percent of body weight daily. Trout food 100 percent; fertilized once[1].	62	34	6.1	.22	68	31.1	68.6	3.5	7.8
4	Fertilized[1] once.	70	55	1.8	.06	60	0	0	-.6	-1.4

[1] N:P:K = 10:40:10

Figure 4.--The presence of a spermatophore (white arrow) in a male brown shrimp reared in a pond indicates approaching sexual maturity.

the banks and levees. By the first of February, we had transplanted successfully salt marsh-grass, Spartina alterniflora; rush marsh-grass, S. patens; and salt-grass, Distichlis spicata, on several banks and levees. On February 14, tides about 1 m. (3 ft.) above mean water flooded our ponds. Our experimental shrimp were lost, and banks and levees not protected by marsh-grass were damaged extensively (fig. 5). Our bank stabilization work continued this summer.

Ray S. Wheeler, Project Leader

Experimental Seeding

To develop and refine techniques for experimental seeding of shrimp in Florida Bay, we reared pink shrimp in the laboratory from the egg to juvenile stage.

We caught gravid female pink shrimp on the Tortugas grounds and transported them to TABL in Miami. Several shrimp spawned, and the viable eggs developed in a 1,890-liter (500-gallon) tank. Following techniques devised at the Biological Laboratory, Galveston, we reared about 26,000 pink shrimp postlarvae; however, we cancelled our plans to place this group of postlarvae in a selected seeding site in northeast Florida Bay.

Some of the 26,000 postlarvae were preserved for study, whereas others perished because of crowded conditions in the rearing tanks as the size of the shrimp increased. We gave Florida State University one group of about 6,000 postlarvae for use in nutrition studies by graduate students. These shrimp were transported by automobile to Tallahassee where they arrived in good condition. An additional 3,000 to 4,000 postlarvae, 7 to 15 mm. (0.3 - 0.6 inch) long, were placed in a sea-water reservoir tank at the TABL on September 9, 1968. They survived well on the natural food growing in the tank or entering the tank with the incoming water. We sampled these shrimp on December 3, 1968; they were 36 to 69 mm. (1.4 - 2.7 inches) long.

In August 1968, after 32 months of sampling, we stopped taking quantitative samples of planktonic postlarval shrimp (mostly pink shrimp) entering Florida Bay via Whale Harbor Channel (Islamorada, Fla.). Analysis of past

Figure 5.--Flooding of a rearing pond by an excessively high tide destroyed a bank unprotected by transplanted marsh-grass.

data indicated that postlarvae entered Whale Harbor Channel year around. They usually were most abundant during the spring, summer, and fall; the numbers were greatest in the summer when water temperatures were highest (fig. 6). Postlarvae were 5 to 14 mm. (0.2 - 0.5 inch) long. Sizes varied seasonally; the smallest postlarvae arrived in July and the largest in April.

Thomas J. Costello, Project Leader
Donald M. Allen

SHRIMP DYNAMICS PROGRAM

Work in this program continued toward the goals of (1) predicting shrimp abundance, (2) describing relations between the abundance of shrimp at different stages in their life history, (3) describing the effects of size at harvest on weight and value of the harvest, and (4) determining the levels of fishing that will maximize long-term yields from the shrimp fisheries.

Our effort toward the first two goals concentrated on the refinement of our sampling methods. An automatic plankton pump was operated to sample continuously the postlarvae entering Galveston Bay. We expanded the collection of statistics and information from interviews from the white shrimp fishery and worked toward a description of white shrimp spawning times and locations off the upper Texas coast. Our supplemental sampling of the commercial landings was designed to demonstrate those portions of the standard landing statistics that provide the best measures of the abundance. Once established, past and future landing data will be considerably more valuable to us.

Growth and mortality rates necessary to determine optimum size at harvest were calculated primarily from the results of mark-recapture experiments. We continued to improve our methods for marking shrimp and have made several modifications during the year. It was apparent that we must plan carefully the location and timing of the releases of marked shrimp if we are to obtain the specific information we need. Knowledge of when and where to release shrimp to obtain specific information, gained previously through numerous mark-recapture experiments, was of considerable value to us as we planned the studies that were completed this year.

More intensive work with the commercial landings statistics was begun to obtain independent estimates of mortality rates, and information on the optimum level of fishing effort on a long-term basis. We spent much effort to interpret the landing statistics. In some

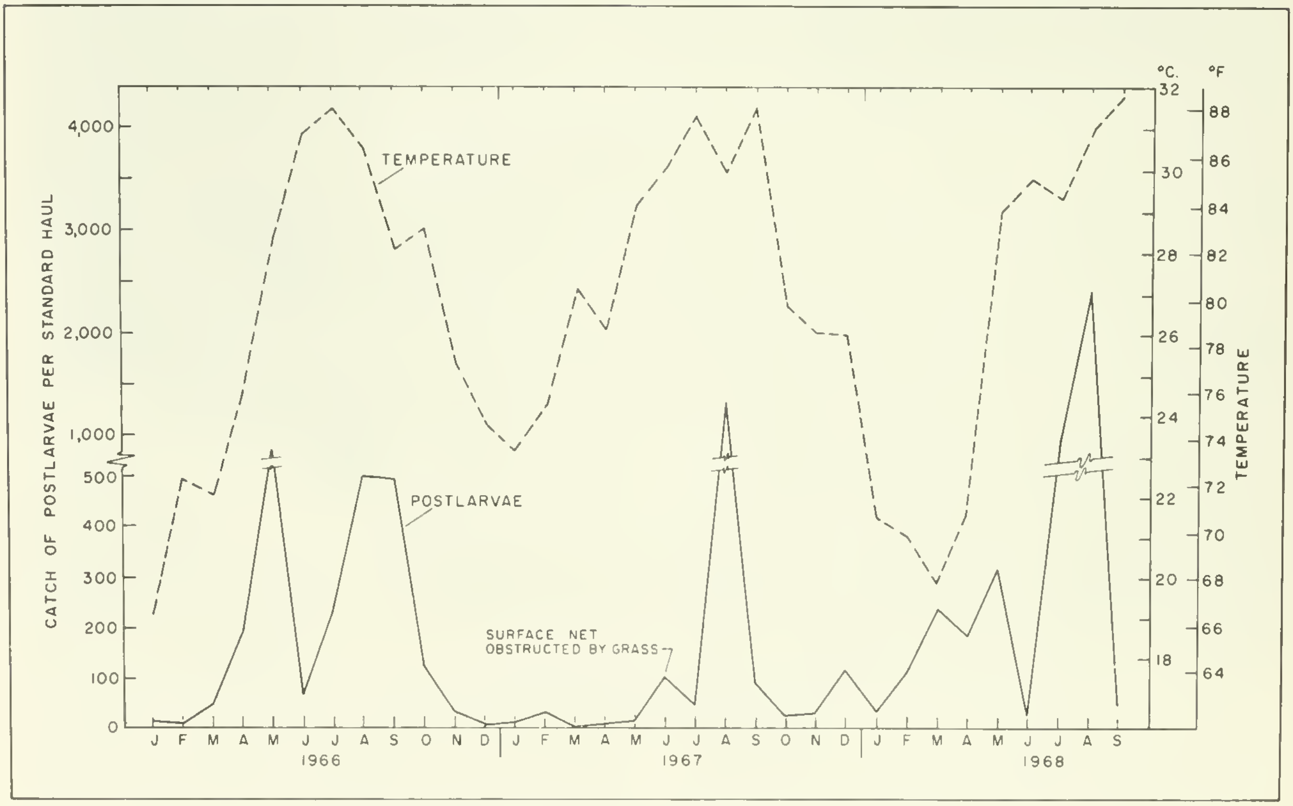

Figure 6.--Seasonal relation between planktonic postlarval shrimp (Penaeus) caught during new-moon periods and water temperature at Whale Harbor Channel, Fla., 1966-68.

situations, additional sampling or analysis will be necessary to define certain aspects of these statistics such as the size distribution of landings and the effects of changes in fishing gear on our estimates of fishing effort.

Richard A. Neal, Acting Program Leader

Predicting Shrimp Abundance

Research was conducted to develop indices of shrimp abundance at three locations: offshore, at the entrance to Galveston Bay, and in the Bay. We attempted to obtain data on the spawner-recruit relations of white shrimp.

Offshore index.--In the winter of 1968-69, we completed studies designed to resolve the question of whether large numbers of postlarval brown shrimp remain burrowed in offshore sediments during periods of low temperatures. If such is the case, it may be possible to predict commercial supplies of brown shrimp from offshore abundance indices of postlarvae several months before postlarvae immigrate into the bays. Trips were made weekly through the winter to collect plankton and benthos from near-shore waters in depths of 4 to 15 m. (2 - 8 fathoms) off Galveston, and our regular sampling with a beam trawl continued in Galveston Entrance (table 4). We concluded that postlarvae were not abundant enough offshore in November and December to enable us to establish an index of abundance before they move into the bay.

We also sought postlarvae during two cruises completed along a track that extended from 7 m. (4 fathoms) off Galveston to 51 m. (28 fathoms) off Freeport, Tex. An average of 0.05 postlarvae per tow was taken in 108 five-minute bottom tows, and an average of 0.33 postlarvae per tow was taken in an equal number of tows made at higher levels. The sled used for bottom tows strained about 100 $m.^3$ of water per 5-minute tow. The catches of shrimp were too low for us to establish a reliable index of abundance.

Table 4.--Monthly average catch of postlarval brown shrimp in two areas by two types of gear, 1968-69, Biological Laboratory, Galveston, Tex.

Month	Near-shore Gulf (sled)		Galveston Entrance (beam trawl)	
	Tows (10-minute)	Shrimp per tow	Standard tows	Shrimp per tow
	Number	Number	Number	Number
November.	14	0.1	4	2.5
December.	78	1.2	1	0
January..	15	11.2	3	11.3
February.	42	10.6	8	55.3

Index at Galveston Entrance.--An automatic plankton pump was installed on a platform near Galveston Entrance to sample postlarval shrimp as they enter Galveston Bay. It is now set to pump continuously for 20 minutes each hour. The sampler has functioned well, but we have not solved completely the problems of preserving the collections as they are taken. Samples were deposited originally in a Formalin bath by a conveyor operating below the pump outfall. The conveyor was unsatisfactory and was replaced with a nylon-webbing-lined chute that transports the collections to the Formalin bath after each pumping cycle.

To evaluate catches made with the pump, we compared them with catches of postlarvae made twice weekly at Galveston Entrance with a small beam trawl (fig. 7). Because of the obvious differences between catches, we will continue both methods of sampling until it can be determined which is most representative.

In conjunction with the development of a more accurate measure of the abundance of postlarval shrimp, we completed vertical distribution studies at the pump site to determine the depth at which immigrating postlarvae were most numerous. Water depth is about 5 m. (16 ft.) at the sampling site. Figure 8 shows the number of postlarval brown and white shrimp collected at each depth during 49 day and 23 night collections made during flood tides in an 18-month period. The depth chosen for the position of the pump intake was 1.8 m. (6 ft.).

Juvenile index.--We continued our weekly collection of catch and effort data from Galveston Bay bait-shrimp fishermen. These data are used to make an index of abundance of juvenile shrimp on the nursery grounds. The total weight of bait shrimp harvested in 1968 from Galveston Bay was 1,102,600 pounds (500 metric tons). About 65 percent of this catch was white shrimp. Analysis of bait statistics revealed that large numbers of white shrimp remained in Galveston Bay through the winter.

Figure 9 shows the estimated annual catch of bait shrimp in weight and value from Galveston Bay for the last 10 years. The retail price of live shrimp remained at $2.00 per quart between 1956 and 1966. In 1967, however, the price was raised to $2.50 in all but two areas of the bay system. By early 1968, 14 dealers in the Galveston-Texas City area charged $3.00 per quart. The price of dead bait has changed little over the past several years and fluctuates between $0.50 and $0.75 per pound.

Spawner-recruit relations.--We have evidence of a relation between the abundance indices of postlarval brown shrimp and those of adults a few months later, but we do not know the relations between adult white shrimp

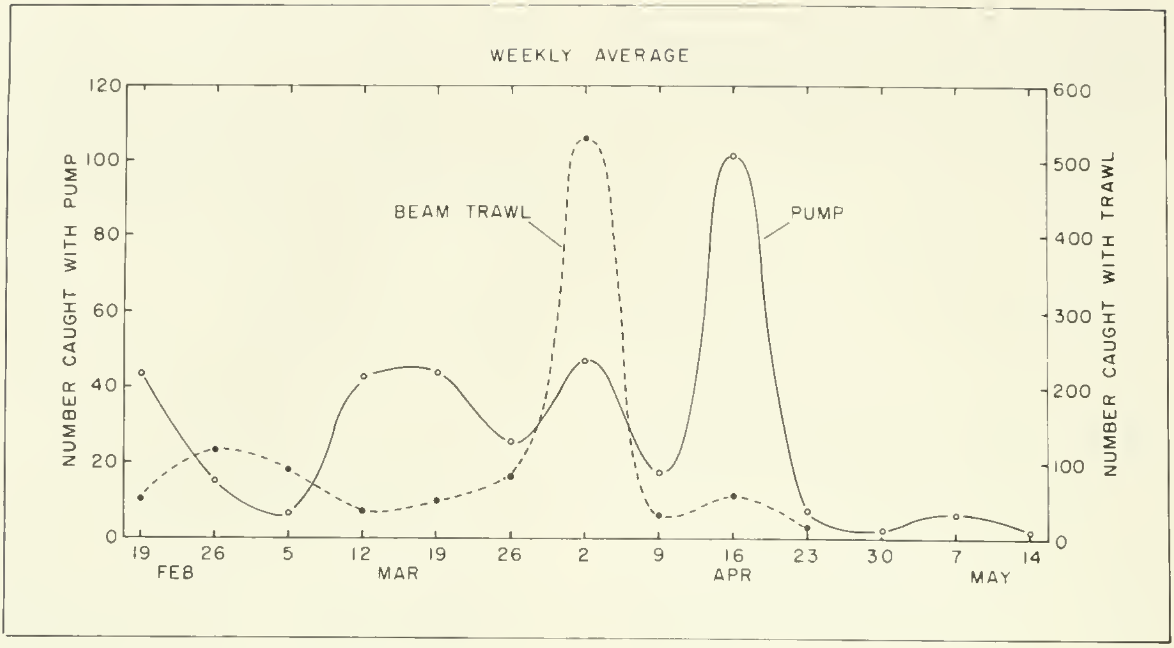

Figure 7.--Indices of abundance of postlarvae at Galveston Entrance, February-May 1969.

abundance and abundance of white shrimp postlarvae. To obtain more information on the spawner-recruit relations of white shrimp, we began to sample landings from the Gulf waters adjacent to Galveston in April 1969. Daily interviews also were obtained from fishermen in the Gulf. In addition, random samples of the white shrimp landed were measured, and stages of sexual development were recorded for females so that the spawning population could be defined precisely. We tested several methods of distinguishing stages of maturity.

Kenneth N. Baxter, Project Leader

Population Dynamics

As an approach to the recommendation of methods for optimal utilization of existing penaeid shrimp resources, we focused our attention on two problem areas. The first was that of defining the time to begin harvesting shrimp if maximum value of landings is to be realized from a population. The second was to describe the long-term effects of different levels of fishing intensity on shrimp stocks.

Timing of harvest.--We have made several refinements in our methods of estimating growth and mortality rates used to determine optimum timing of harvest. One refinement was in the marking methods used for shrimp. We completed our comparison of two methods used most successfully to mark shrimp individually at the Galveston Laboratory. In Biloxi Bay, Miss., small brown shrimp, marked with either Niagara sky blue and a numbered internal tag or a small Petersen disk tag, were released into the fishery. The proportion of shrimp marked with Petersen disks that was recovered was higher than the proportion of stained shrimp recovered. The difference in recovery rates, however, was not apparent until the fourth week (fig. 10). Growth of the stained shrimp during weeks 4 through 8 was more rapid than that of those marked with the Petersen disk (fig. 11). Because few marked shrimp were recaptured after the eighth week, we could not compare growth rates for shrimp at large for longer periods.

An experiment was made to determine if stable strontium could be used to mark white shrimp permanently. Strontium has been used successfully for marking scale and bony tissue of fish by feeding diets that contain a strontium supplement. White shrimp held in aquaria were used to compare the following treatments: (1) shrimp fed prepared food with no strontium supplement; (2) shrimp fed prepared food with a supplement of strontium lactate (7.7 g. strontium lactate per 100 g. of food); (3) shrimp fed prepared food (no strontium supplement) in sea water containing 177 p.p.m. (parts per million) of strontium.

Samples of shrimp and exuviae were removed regularly and checked by flame-emission spectrophotometry for strontium content during the 40-day experiment. Shrimp assimilated significant amounts of strontium from the food and the water but lost a large portion of it when they molted. The strontium apparently accumulated in the exoskeleton but not in other parts of the body. Because most of the acquired strontium is lost during the molt, this method of marking is not satisfactory for our work.

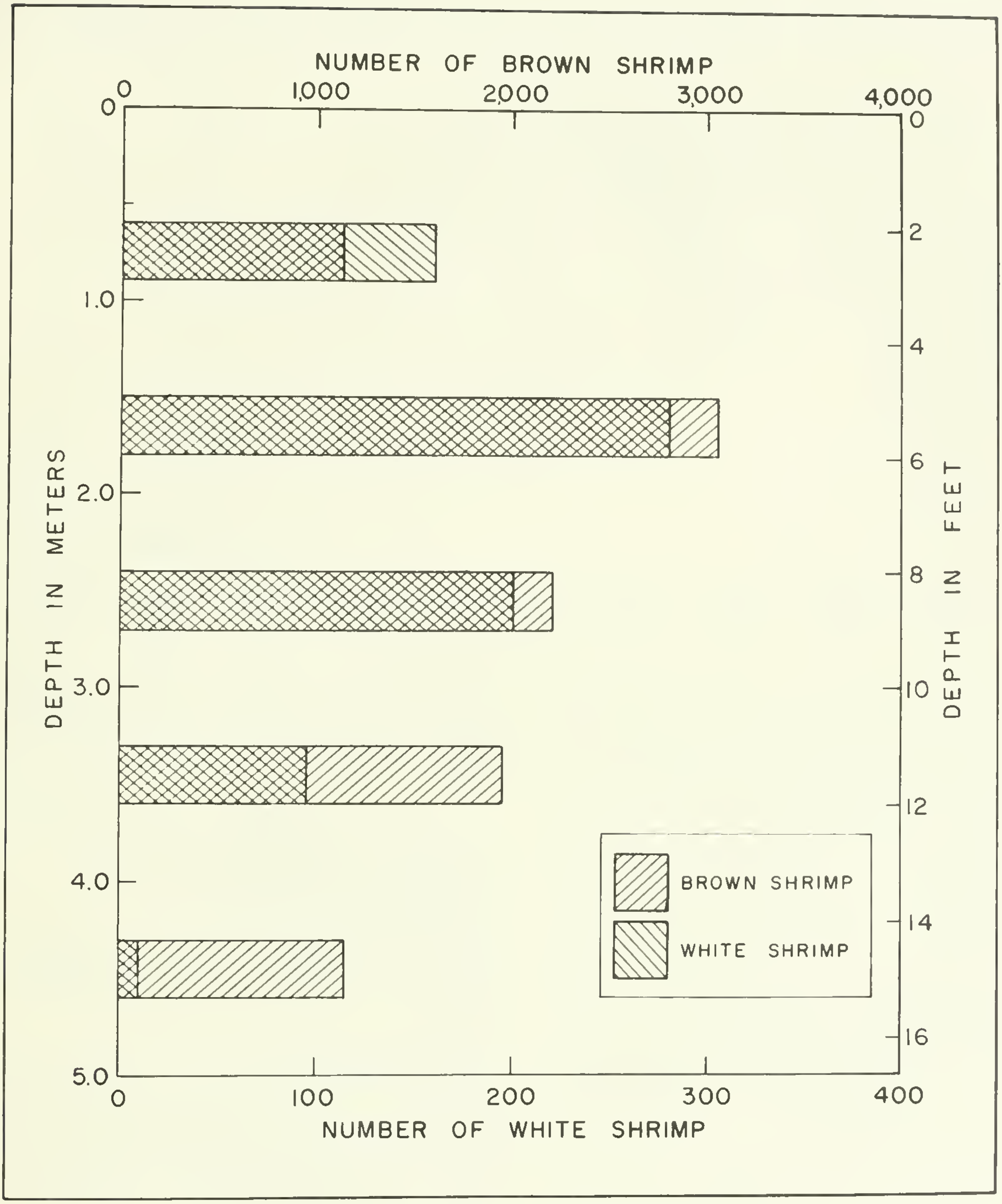

Figure 8.--Depth distribution of postlarvae of brown and white shrimp in 5 m. (16 ft.) of water in Bolivar Roads, Galveston, Tex.

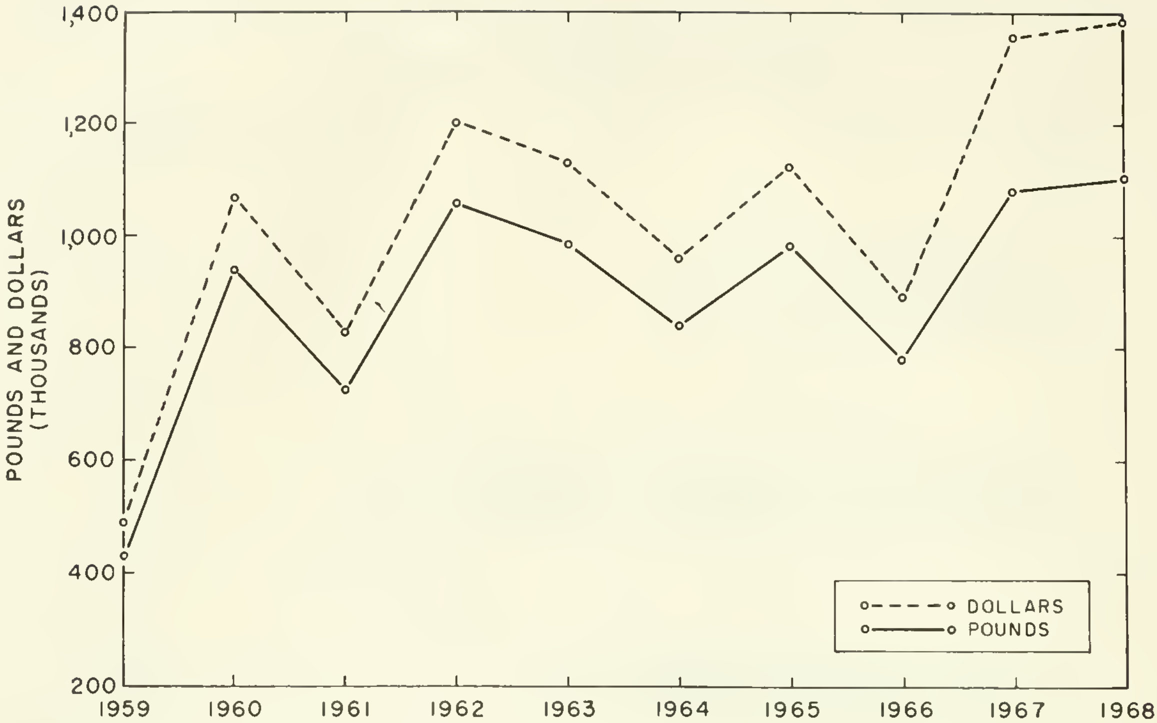

Figure 9.--Estimated weight and value of bait shrimp catch from Galveston Bay, Tex., 1959-68.

Effects of fishing intensity.--To approach the second problem, we have expanded our use of the commercial landing statistics. Recent changes in the size and efficiency of fishing vessels have been so large that effort statistics over the last 12 years are not comparable. To standardize the effort statistics, we calculated the relative fishing power of numerous shrimp vessels (defined as the ratio of a boat's catch per unit of effort to that of a standard boat fishing the same area at the same time) and described the relations between this statistic and various vessel characteristics. During our initial study, we computed the mean power factors for 211 commercial shrimp vessels in the Tortugas fishery in January and February 1965. We examined the data to find possible relations between fixed, measurable characteristics of the vessels, such as length, horsepower, and weight, and the power factors.

The most significant relation was between power factors and vessel length (fig. 12). A subsequent study of 33 vessels fishing in statistical area 19 off the Texas coast in August and September 1967 indicated that the relation between power factors and vessel length did not differ significantly (at the 95-percent level) from that calculated for the Tortugas fishery. With these relations we plan to standardize our effort data so that data on catch per unit of effort are comparable from year to year despite changes in the size of vessels. Changes in catch per unit of effort from year to year can then be examined critically to evaluate the effects of long-term changes in fishing intensity.

Richard A. Neal, Project Leader

The Growth and Distribution of Juvenile Pink Shrimp in the Estuaries of Everglades National Park

Studies were begun on the growth and distribution of pink shrimp in the Whitewater-Coot Bay estuary of Everglades National Park in July 1968.

Distribution.--We studied the four main basins in Whitewater Bay and established trawling stations in each. We selected eight stations so that each area had within it a shallow and a deep trawling location (fig. 13). Odd-numbered stations were in water 0.7 to 1.1 m. (2.5 - 3.5 ft.) deep, and the even-numbered ones were in water 1.7 to 2.1 m. (5.5 - 7.0 ft.) deep.

Regular monthly sampling with a modified 2-m. (6.6-ft.) roller frame trawl began in September 1968. We scheduled trawling trips near the time of the new moon and included 2 nights of sampling at each station. Seven trawl drags each about 100 m. (330 ft.) long were made on each station visit. For each drag the trawl was pulled for 1.5 minutes at a standard

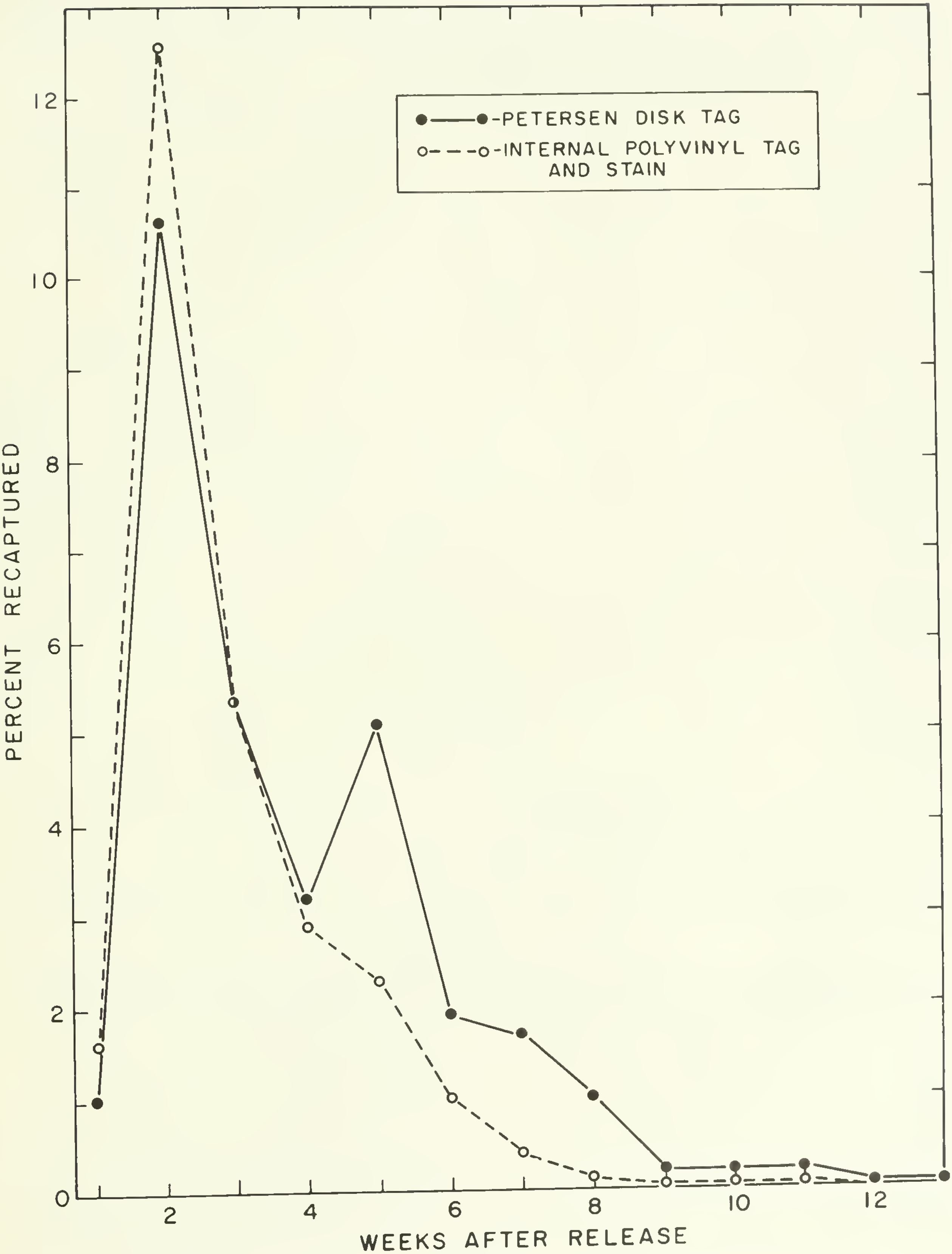

Figure 10.--Weekly percentage of brown shrimp recaptured, Biloxi Bay, Miss., 1968-69.

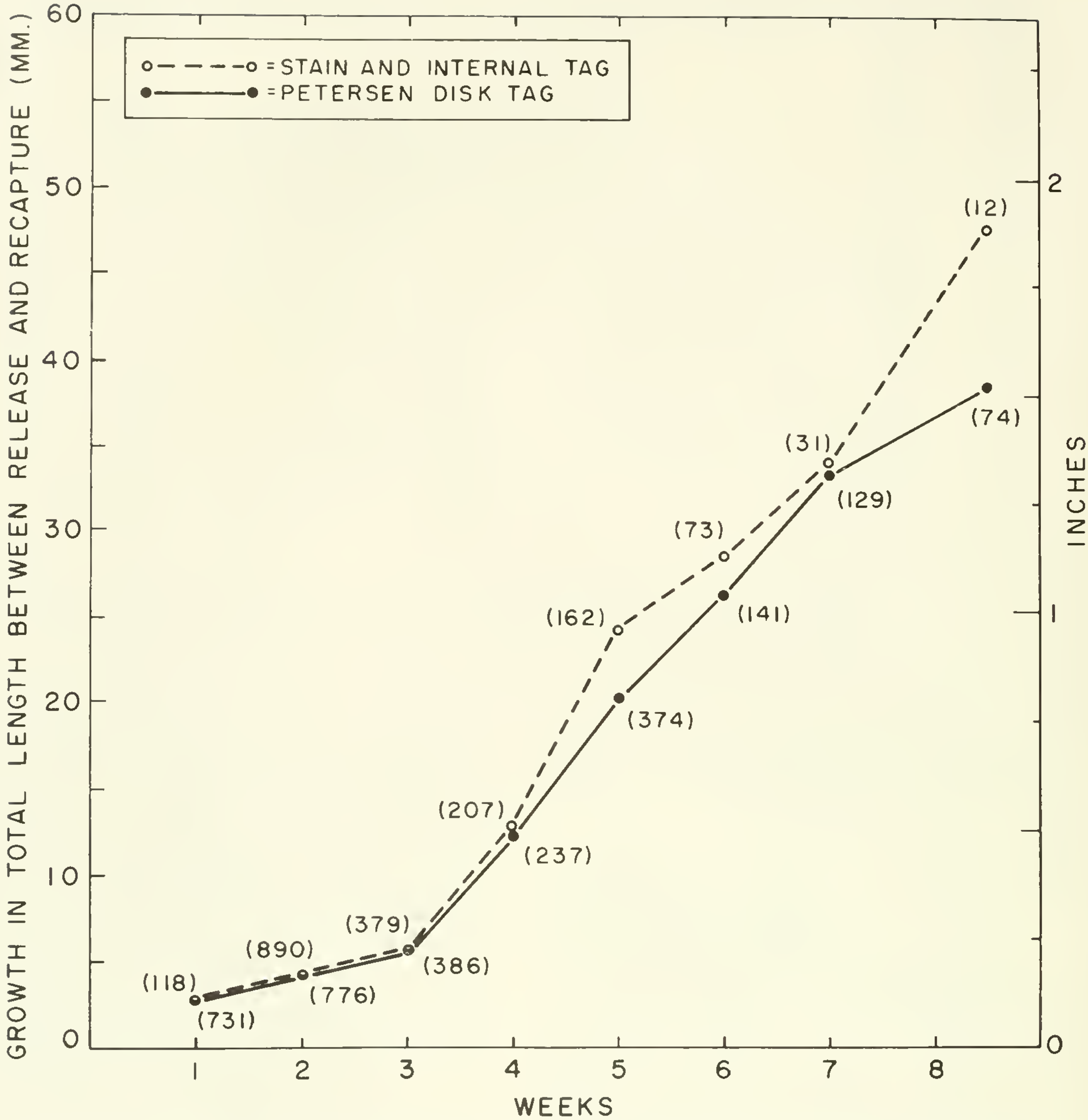

Figure 11.--Growth of brown shrimp marked with Petersen disk tags or with stain and internal polyvinyl tags by weekly periods between release and recapture, Biloxi Bay, Miss., 1968-69 (number recaptured in parentheses).

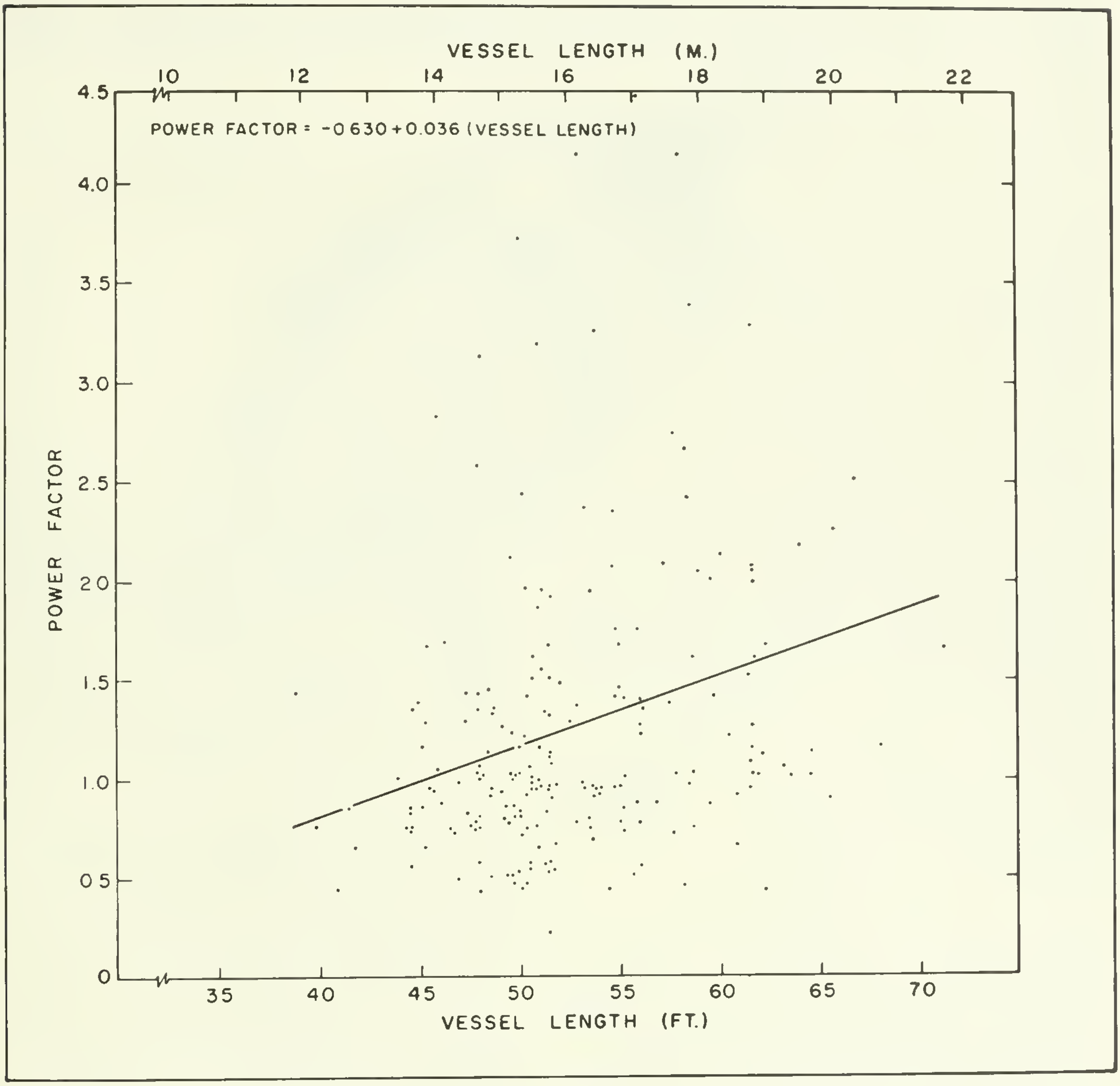

Figure 12.--Relation between fishing-power factors and vessel length for 211 shrimp vessels fishing on the Tortugas grounds in January and February 1965.

speed. In the first 10 months we collected 2,240 samples, each representing the catch from about 100 m.^{2} (1,070 ft.^{2}) of bottom.

Table 5 summarizes by station and month the catch data for the samples collected through April. Abundance trends at individual stations varied somewhat, but in general, relative abundance decreased during the 8-month period. Exceptions to this trend were at stations 5 and 6. A marked but temporary increase in abundance occurred at these stations in December and to a lesser extent at station 7. Abundance declined at all but one of the remaining four stations in the eastern portion of the Bay, and stations 3 and 4 showed a reduction of more than 50 percent between November and December.

These data suggest a movement of shrimp from the inner basins of the Bay westward during the fall and winter. This movement and the general decline in abundance are consistent with the findings of earlier research which has shown emigration of juveniles out of the estuary and low rates of recruitment in the winter.

A logarithmic transformation was applied to the catch data (table 5) to overcome the problem of unequal variances among stations.

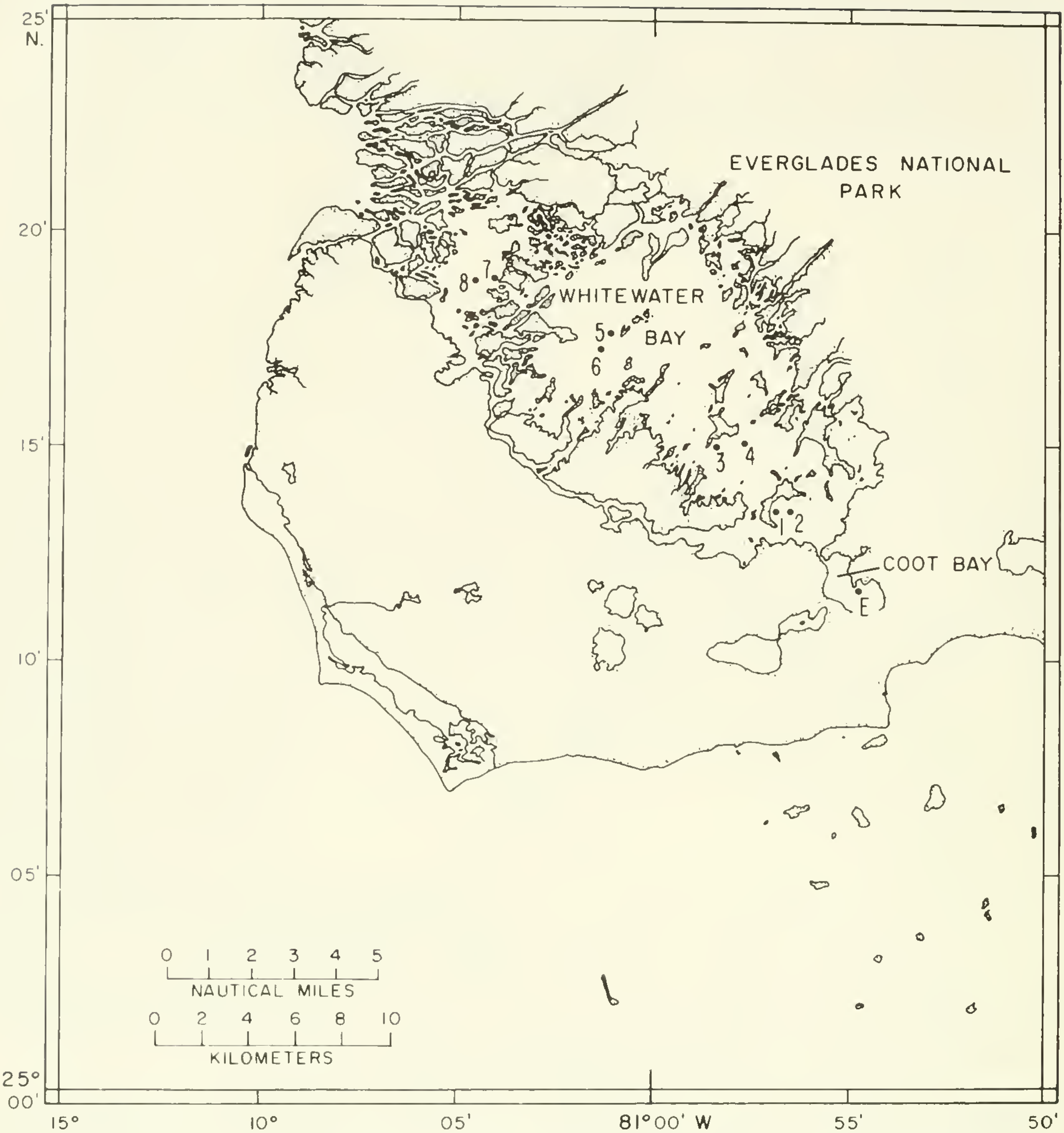

Figure 13.--Whitewater Bay estuary in Everglades National Park, Fla., with the location of the trawling stations and the enclosure (E) in Coot Bay.

Table 5.--Pink shrimp in monthly trawl catches from eight stations in Whitewater Bay, September 1968 to April 1969

Month	Stations								Total
	1	2	3	4	5	6	7	8	
	Number								
Sept. .	78	96	1,545	1,656	1,483	1,888	805	174	7,725
Oct....	48	102	768	989	1,614	1,585	782	257	6,145
Nov....	35	57	720	833	813	1,461	480	213	4,612
Dec....	52	36	307	393	1,768	1,918	544	140	5,158
Jan....	23	26	170	432	1,314	1,379	317	47	3,708
Feb....	19	60	313	179	1,401	1,013	396	73	3,454
Mar....	6	28	227	144	1,073	1,011	626	49	3,164
Apr....	6	11	126	82	272	490	628	128	1,743
Total	267	416	4,176	4,708	9,738	10,745	4,578	1,081	35,709

Analysis of variance of the transformed data for the eight stations indicates highly significant differences in the geometric mean catches among months and among stations. Differences among months reflect a general seasonal decline in abundance over the 8-month period.

Differences in the geometric mean catches among stations are apparently related positively to the kinds and density of the vegetative cover. Stations 5 and 6 with extensive vegetative cover had significantly larger catches of shrimp than those stations with less cover.

Growth.--We studied growth of pink shrimp in the estuary by holding a population of shrimp in a 0.1-hectare (1/4-acre) enclosure in Coot Bay and sampling it at weekly intervals. The site for the enclosure (marked E in fig. 13) was selected in an area normally inhabited by shrimp and where conditions within the enclosure could be maintained as closely as possible to the natural environment.

We completed the enclosure in late October and stocked it with 20,000 postlarval pink shrimp caught in Buttonwood Canal on October 30. Samples of about 200 shrimp were taken each week with plankton nets. From October 30 through April 17 (24 weeks) the average carapace length (the distance from the orbital notch to the posterior edge of the cephalothorax) of the shrimp increased from 1.8 to 15.6 mm. (0.1 - 0.6 inch) (fig. 14). Shrimp collected on April 17 were 6.5 to 21.4 mm. (0.3 - 0.8 inch) carapace length.

After the seventh week and until the end of the experiment, temperatures in the enclosure were recorded continuously with a Ryan thermograph. Weekly averages ranged from 19.9° C. (68° F.) in mid-March to 24.4° C. (76° F.) in late March; the average value for the experiment was 21.7° C. (71° F.). Salinity in the enclosure ranged from 4.9 p.p.t. in early November to 21.7 p.p.t. in late March. The average salinity for the experimental period was 14.5 p.p.t.

The summer growth experiment (now underway) was started on May 27 when an estimated 19,500 postlarvae were captured in Buttonwood Canal and placed in the enclosure. Inspection of the early samples suggests that shrimp growth was considerably faster in the summer.

C. P. Idyll and B. J. Yokel
Project Leaders

Institute of Marine Sciences,
University of Miami
(Contract No. 14-17-0002-279)

ESTUARINE PROGRAM

Analysis of past data was completed during the fiscal year. Manuscripts entitled "Hydrographic survey of the Galveston Bay system, Texas, 1963-66" and "Relative abundance, seasonal distribution, and species composition of demersal fishes of Louisiana and Texas, 1962-64" are almost ready for submission to the Technical Editors.

Publications released since July 1, 1968, were: "Hydrographic observations from the Galveston Bay system, Texas, 1958-67," "Use of dorsal carinal spines to differentiate between postlarvae of brown shrimp, Penaeus aztecus Ives, and white shrimp, Penaeus setiferus (Linnaeus)," "Hydrological conditions in Clear Lake, Texas, 1958-66," and "Channelization and spoiling in Gulf coast and South Atlantic estuaries."

Program personnel gave considerable attention during the year to assessment of the probable effects of water-development activities. This responsibility was fulfilled by completing short-term investigations in connection with the Federally planned as well as private water-development projects. We worked in

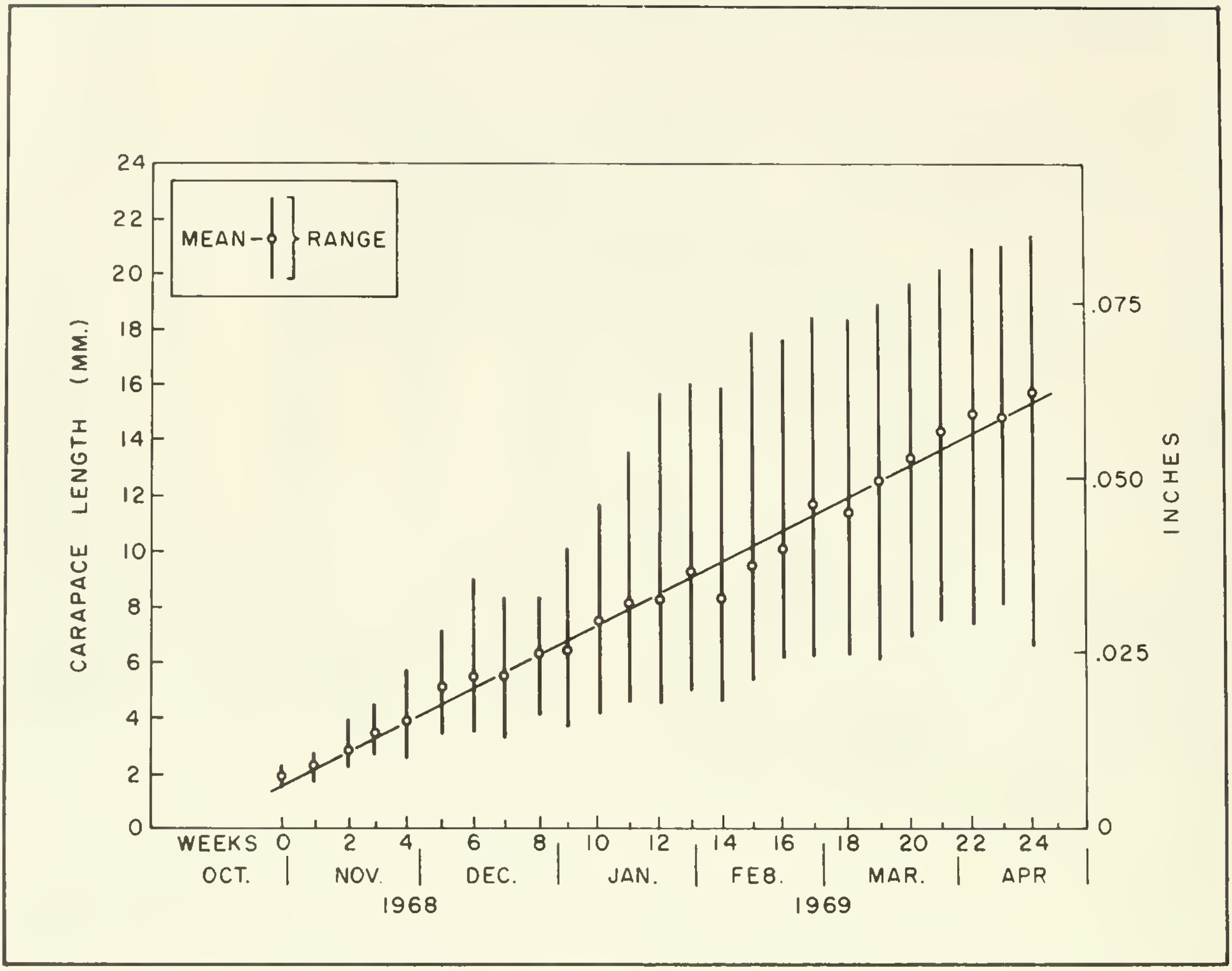

Figure 14.--The range and mean size of pink shrimp taken in weekly samples from the enclosure in Coot Bay, Everglades National Park, from October 1968 to April 1969.

close coordination with BSFW (Bureau of Sport Fisheries and Wildlife) and the Texas Parks and Wildlife Department.

We also spent considerable time on the Gulf of Mexico Estuarine Inventory in cooperation with the Gulf States Marine Fisheries Commission. Material under the headings "Geology," "Fish and Wilflife Resources," and "Vegetation" were completed for all seven of the Texas estuarine systems. The Texas Parks and Wildlife Department offered much needed assistance in supplying data and information.

Studies were begun on Galveston Island to determine ecological differences between a natural estuarine area and adjacent areas altered by channelization, bulkheading, and landfilling for housing sites. From each area we took samples of fishes, crustaceans, benthic organisms, and plankton, plus concurrent hydrological measurements, during a 24-hour period every other week. Also, the growth and setting rates of the American oyster, basic productivity of phytoplankton, and stomach contents of selected finfish species were compared between the two areas.

Richard J. Hoogland, Acting Program Leader

Evaluation of Engineering Projects and Estuarine Data

The western Gulf coast is experiencing exceptional economic growth, and many estuarine areas are being destroyed or altered extensively. The effects of water-resource development on fish and wildlife resources have received some national recognition, and legislation has been enacted to provide a means for considering fish and wildlife aspects in all Federally planned and Federally authorized water-development projects. Implementation of this legislation authorized and obligated the U.S. Fish and Wildlife Service to assist and cooperate with other Federal, State, and public or private interests in planning the development of our water resources. Our primary goal is to assure that estuary-dependent fishery resources receive consideration and protection.

To achieve our goal we assisted BSFW Division of River Basin Studies by reviewing each of the Federally planned as well as privately planned projects that might have affected the estuarine zone in the western Gulf. When warranted, we recommended measures to reduce adverse effects and changes and thereby improve the environment for fishery resources. We obtained assistance from other BCF scientists, economists, and statisticians and used all available sources of information to develop the best possible contribution to the Fish and Wildlife Service report on each proposed project. Table 6 lists the number, type, and general location of applications for private construction projects reviewed during the fiscal year. Project personnel also contributed to and reviewed drafts of 33 BSFW reports on private and Federal projects.

An example of the time spent by project personnel is the review of a permit application for construction of a steam electric generating plant on the shore of Cox Bay, Tex. The proposed power station would be constructed on an 81-hectare (200-acre) tract on the north shore of Cox Bay (fig. 15). The initial installation would be a 240-megawatt unit with a subsequent unit tentatively sized at 450 megawatts.

The company proposes to take water from the Matagorda Ship Channel turning basin to dissipate the heat in the generating system. The cooling water would be discharged into a stilling basin and then through a dredged channel into Cox Bay. Spoil dredged from the discharge channel would be placed along the entire east bank of the channel.

Cooling-water requirements for the first unit would be about 350 c.f.s. (cubic feet per second), and the second unit would need an additional 650 c.f.s. Expected temperature rise between the points of intake and discharge would be in excess of 4.5° C. (8° F.) under 60-percent load capacity.

Valuable estuarine habitat potentially affected by the proposed power station could include a small portion of Lavaca Bay, Cox Bay, and lower Huisache Cove. These areas amount to more than 2,023 hectares (5,000 acres). Operation of the proposed plant would have damaging effects in the form of: physical displacement of habitat associated with dredging and spoil deposition; perversion of water circulation patterns resulting in disruption of nutrient distribution and animal migration routes as well as accelerated erosion, siltation, and turbidity; introduction of polluted waters into unpolluted habitat; physical loss of animals into the plant intake; and thermal disruption of the environment.

The above-mentioned general points were reported to the U.S. Army Corps of Engineers via the U.S. Department of the Interior Regional Coordinator. Later, the Corps of Engineers notified the applicant of the Department of Interior's objections and recommendations. The applicant was then questioned as to his willingness to revise plans to meet Interior recommendations and instructed either to submit revised plans for further consideration or state in writing why any of the recommendations are unacceptable.

To date (40 days from above-mentioned notice) the power company has not responded

Table 6.--Number, type, and location of proposed private construction projects in the coastal areas of the northwestern Gulf of Mexico that were reviewed during fiscal year 1969

Location	Mineral development: With channel dredging	Mineral development: Without channel dredging	Navigation channels	Bulkheading and fill, or shoreline work	Other[1]	Total
	Number					
Sabine Lake	0	0	0	0	1	1
Galveston Bay	7	10	3	16	23	59
Matagorda Bay	3	7	1	2	11	24
San Antonio Bay	3	6	1	0	6	16
Aransas-Copano Bay	11	14	1	8	16	50
Corpus Christi Bay	4	11	2	6	17	40
Laguna Madre	10	6	4	4	11	35
Gulf of Mexico	0	88	0	3	29	120
Rivers and streams	0	2	9	102	93	206
Total	38	144	21	141	207	551

[1] Such as pipelines, wharves, piers, bridges, and jetties.

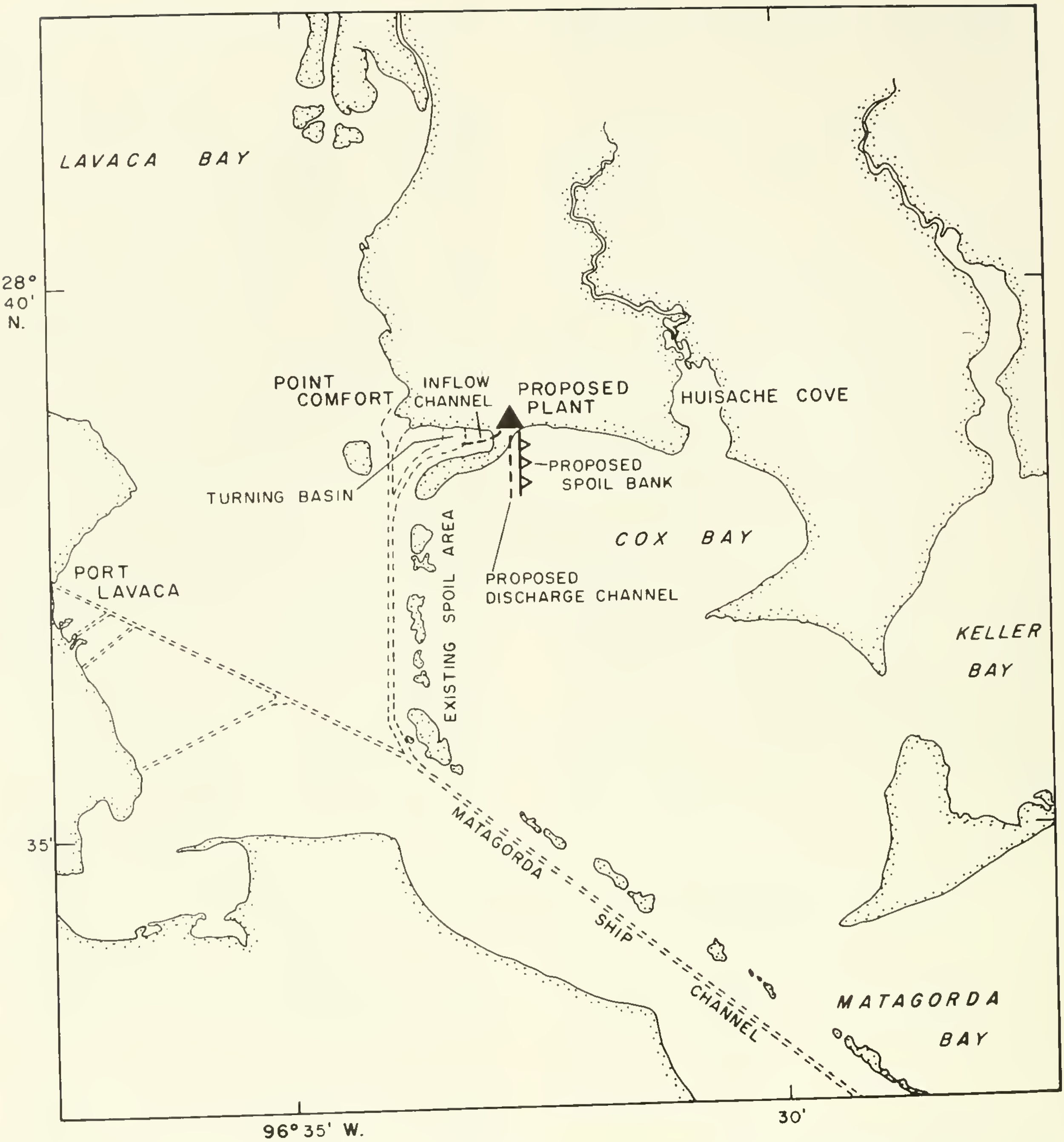

Figure 15.--Proposed site of steam electric generating station, Cox Bay, Tex., 1968-69.

to the Corps correspondence; the permit is still pending.

Model tests of Galveston Bay hurricane protection plans.--Our last annual report mentioned that the model study (Waterways Experiment Station, Vicksburg, Miss.) by the U.S. Army Corps of Engineers demonstrated that essentially no change in tidal ranges resulted from either the "Alpha" or "Gamma" barriers. The data indicated that the Gamma barrier would concentrate contaminants in upper Galveston and Trinity Bays, particularly during low fresh-water inflow. The Corps indicated that this condition could be corrected and has since returned to model testing this fiscal year. Its aims are to correct the restricted water circulation by relocating openings in the hurricane protection structure. Results of these tests have not been released to date.

Evaluation of estuarine data.--The complexity of the large developments and the number of smaller projects made it difficult to treat easily each proposal in sufficient detail. Our goals, however, were made simpler by our organizing and distributing new and existing information. We performed these services by means of an inventory of the Texas estuaries.

This past year we continued to prepare the area-description portion of the inventory for the Texas Gulf coast. We obtained data from sources such as topographic maps and navigation charts, stream discharge records, oyster lease statistics, meteorological data, ... While compiling these data, we learned many facts about Texas estuaries that were not widely known. Three examples illustrate this point.

1. Although the extent of shoreline developments in the Texas estuaries has aroused anxiety over the possible effects on fish and wildlife resources, the total area involved has not been fully determined. It now is known, however, that about 47 percent of the shore of Sabine Lake has been altered primarily by channelization, spoil placement, bulkheading, and filling for industrial and residential developments. Conversely, about 3 percent of the Laguna Madre, which is relatively inaccessible, has been disturbed by human encroachment.

2. One of the most serious forms of man-made changes in the estuary results from domestic, industrial, and agricultural effluents. For a long time local interests have known about polluted waters (i.e., waters closed to shellfishing) in Texas estuaries, but these data were never widely published. The percentage of polluted (or unapproved) waters in the various estuarine systems of Texas ranges from 100 percent in Sabine Lake to about 10 percent in the Laguna Madre system.

3. Over 250 significant reservoirs are situated on rivers which flow through Texas before emptying into estuaries of the Gulf of Mexico. These reservoirs are in Colorado, New Mexico, Texas and Louisiana and the Mexican States of Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas. The construction of a reservoir usually brings a change of volume, a reduction of seasonal fresh-water inflow into the estuaries, and ultimately a general deterioration of estuarine habitat.

Richard J. Hoogland, Project Leader
Richard A. Diener

Ecology of Western Gulf Estuaries

Studies were planned and initiated to determine how landfill housing developments affect the ecology of natural marsh areas. We selected this type of modification for study because it is one of the greatest threats to the continued existence of natural marshes. Little is known about the effects of housing developments on the ecology of an area, how the alterations might be made so that destruction of an estuary will be minimal, or how, once an area has been altered, it might be rehabilitated.

After we reached an agreement with the developers and landowners, we selected for study the resort housing development (fig. 16) of Jamaica Beach on the west end of Galveston Island, Tex. The housing project is the largest and has the most complex canal system of any in the area. The project was developed by dredging, filling, and bulkheading a natural marsh area, and it is bordered on each side by extensive natural marshlands.

Specific aims of our research were to compare the abundance and size of the dominant organisms, environmental features, and the setting and growth of oysters in the natural and altered areas.

Abundance and size of organisms.--We began biological and environmental sampling in March 25, 1969, and took samples every 2 weeks. We analyzed only the information from four collections through May 6; therefore, the results are preliminary. Samples were collected during the day (between 9:00 a.m. and 2:00 p.m.) and night (between 9:00 p.m. and 2:00 a.m.) within the same 24-hour period. About 3 hours were required to sample at all stations. The order of the stations at which samples were taken was random.

Figure 16 shows sampling stations, and table 7 gives information describing each station.

Biological samples were taken in a trawl that had an opening of 0.6 by 3 m. (2 by 10 ft.) and a stretched mesh of 28 mm. (1.1 inches) in the body and 16 mm. (0.6 inch) in the codend. The trawl was towed at each station for 200 m. (660 ft.) at a speed of about 2 knots. We

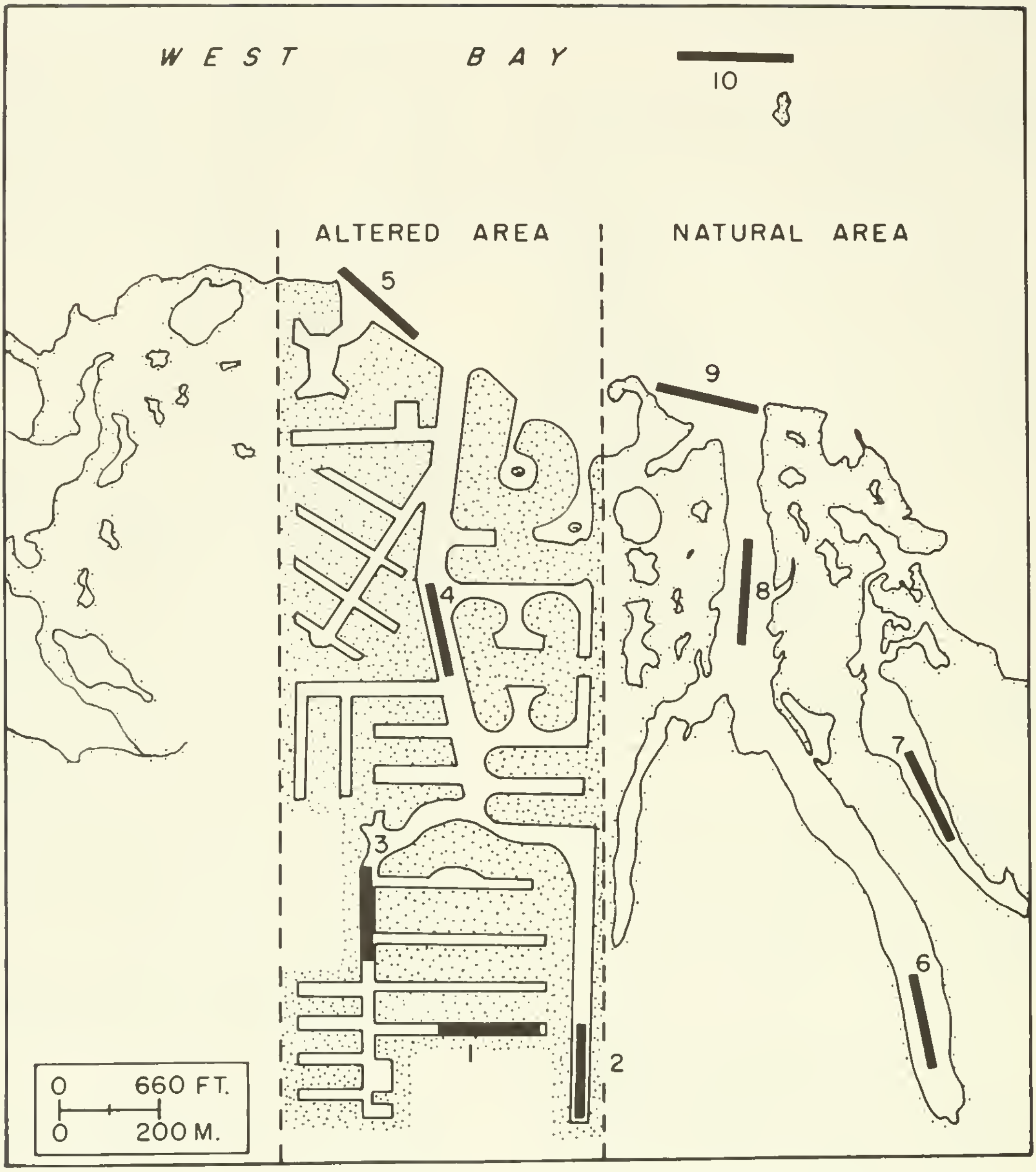

Figure 16.--Study area and sampling locations in the Jamaica Beach housing development and vicinity, Galveston Island, Tex., 1968-69.

counted individuals of each species caught and measured them to the nearest 0.5 cm. (0.2 inch)--tip of snout to tip of caudal fin for fishes, tip of rostrum to tip of telson for shrimp, and carapace width for crabs.

Water samples collected with the biological samples were taken at 30 cm. (12 inches) above the bottom at each station. We measured the water temperature immediately after sampling. We froze or preserved the samples so that we could measure the other variables later in the laboratory.

The trawl took 41 species of finfish and crustaceans. Four of the 41 species were caught only in the altered area and 9 species were caught only in the natural area.

Figure 17 shows the 10 species caught in greatest abundance (all stations combined). Six of these 10 species represented 96.1 percent of the total catch. Spot Leiostomus xanthurus; large-scale menhaden Brevoortia patronus; brown shrimp; and Atlantic croaker Micropogon undulatus are commercially valuable. The bay anchovy Anchoa mitchilli, and grass shrimp, Palaemonetes sp., are important as food for commercial and sport fish. Six of the 10 species were most abundant in the natural area.

Table 7.--A brief description of the 10 sampling stations in the Jamaica Beach area, Tex., 1968-69

Area and station	Depth (mean low tide)		Bottom compactness	Submerged vegetation	Adjacent to			Distance from shoreline of open bay (approximate)	
					Marsh	Open bay	Bulkhead		
Altered	M.	Feet						M.	Feet
1	1.6	5.2	low	- [1]	-	-	x [2]	1,500	4,920
2	2.6	8.5	low	-	-	-	x	1,500	4,920
3	2.2	7.2	low	-	-	-	x	1,100	3,608
4	1.4	4.6	low	-	-	-	x	450	1,476
5	1.3	4.3	low	-	-	x	x	0	0
Natural									
6	0.5	1.6	low	x	x	-	-	1,300	4,264
7	0.2	0.6	medium	x	x	-	-	750	2,460
8	0.4	1.3	medium	x	x	-	-	300	984
9	0.5	1.6	high	-	x	x	-	0	0
10	1.0	3.3	high	x	-	x	-	800	2,624

[1] - = absent or no.
[2] x = present or yes.

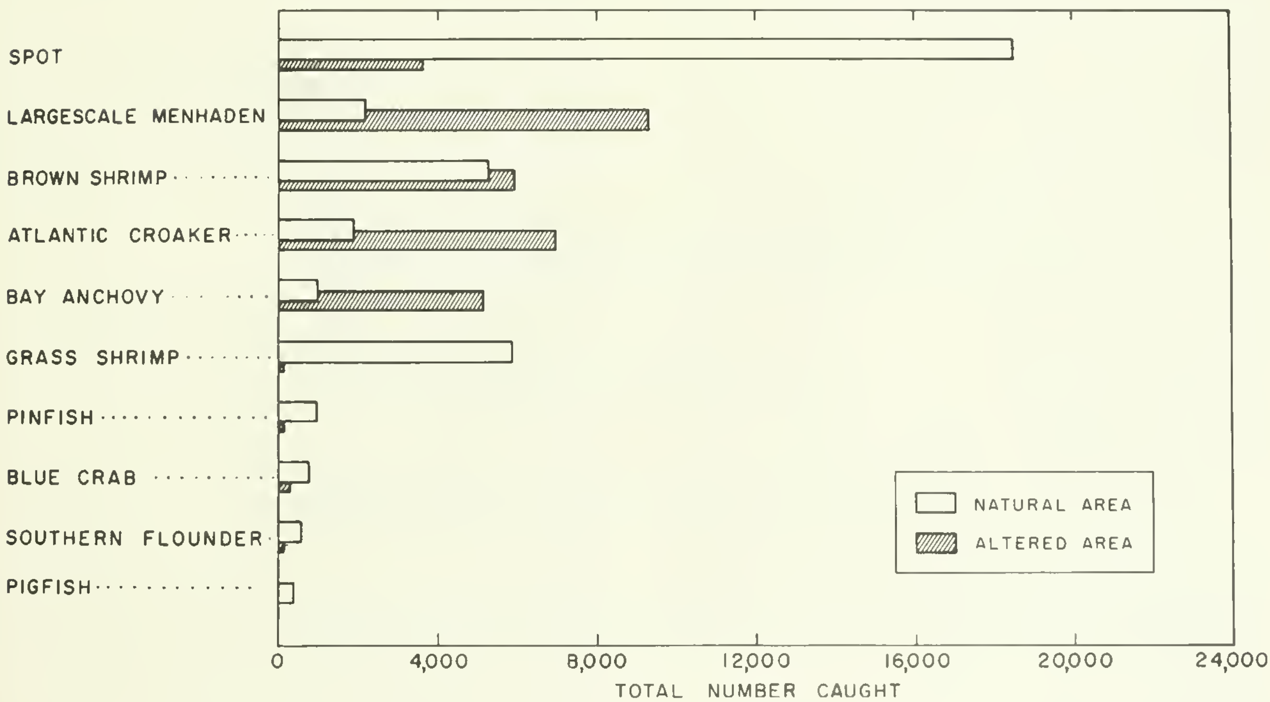

Figure 17.--The 10 most abundant species caught in the trawl and comparisons of their abundance in the natural and altered areas, Jamaica Beach area, Tex., 1969.

We analyzed data on the four species that were the most abundant to compare differences in abundance between stations and between day and night tows (fig. 18). Mean total lengths of these species also were compared between natural and altered areas (fig. 19).

Spot were much more abundant and slightly longer in the natural than in the altered area. In the natural area, spot concentrated at stations bordered by marsh vegetation and were caught in greatest abundance at the stations farthest from the bay (fig. 18). Catches in the open bay (station 10) were similar to those in the altered area. The largest catches in the altered area were made in a small canal (station 1) remote from the bay. Differences between day and night catches appeared random when all stations were considered.

More largescale menhaden were taken in the altered than in the natural area, but average lengths were slightly greater in the natural area. Differences in abundance were not consistent, however, when we compared catches from individual stations. In general, the stations farthest from the bay--2, 3, 6, and 7--had the highest catches, regardless of the area. More menhaden were caught at night than during the day at all stations except station 1. Differences may possibly be explained by the ability of menhaden to escape the trawl during the day.

Brown shrimp were slightly more abundant in the altered than in the natural area; mean lengths of shrimp in the two areas were similar. Except for the low catches at station 2, differences in abundance were not great between stations. Greater catches were made at night than during the day at 7 of the 10 sampling locations. Apparently, the shrimp burrowed in the day and were not as vulnerable to the trawl as they were in the night when they were on or above the bottom.

Atlantic croaker were considerably more abundant in the altered than in the natural area, but mean lengths were similar in the two areas. All stations in the altered area produced high catches, whereas in the natural area, only station 6 produced high catches. A tentative explanation for this distribution is that Atlantic croaker prefer areas with a soft bottom. Day catches did not differ from night catches when all stations were considered.

Environmental comparisons.--Data for each hydrographic variable measured in this study were compared to determine variations between natural and altered areas, and between stations (fig. 20).

Water temperature and salinity were similar between areas and stations.

Average values of oxygen were generally higher, and fluctuations greater, in the natural than in the altered area. These general differences may reflect the station depths in the two areas. The average sampling depth was 1.5 m. (5 ft.) in the altered area and 0.3 m. (1 ft.) in the natural area. Photosynthesis and tidal action probably were the primary causes of the oxygen concentrations in the natural area, whereas tidal action and vertical mixing were the primary causes of the concentrations in the altered area.

The natural area had slightly higher average values of phosphorus than the altered area. The lowest values recorded in the altered area were at station 5, and the highest values recorded in the natural area were at station 10. Phosphorus values fluctuated independently between stations and showed no general trend within areas.

Concentrations of Kjeldahl nitrogen varied between stations and between areas. Average values were lowest at stations 4, 5, and 10, which were near or in the open bay. Intermediate values were at stations 1, 2, 3, and 9, and the highest values were at stations 6, 7, and 8. Highest average values observed in the natural area may have been caused by freshwater drainage from the adjacent land or the interchange of waters (tides) between bayou and marsh.

Nitrite values varied between areas and stations; lowest concentrations were at the stations farthest from the bay. The bay was either the major source area for nitrite or basic productivity was lower in the offshore water and the large populations of plankters in the inshore areas utilized more of the available nitrite.

Carbonate alkalinity varied between areas and stations. Values were highest at the inshore stations of the altered and natural areas and decreased bayward. These concentrations may have been affected by drainage of fresh water from the surrounding land or to the variations in biological activity between stations.

Growth of oysters in natural and altered areas.--In February we began a study designed to compare the setting and growth rate of oyster spat, and the growth rate of unattached juvenile oysters in a natural and an altered marsh. For setting and growth studies we placed asbestos spat collectors and trays in the natural area (station 6) and adjacent to a bulkhead (station 1) in the altered area.

To measure the set and growth of oyster spat, we placed three pairs of plates (32 $cm.^2$ or 5 $in.^2$) in the natural area and four in the altered area. These plates were placed at mean low-water level and at 0.3-m. (1-ft.) intervals to the bottom on a suspended rack on February 20, 1969. We replaced the spat collectors every 2 weeks, and examined those that were removed for oyster spat. No oysters had set by May 14.

We determined the growth rates of juvenile oysters in each area by using transplanted oysters from the 1968 spatfall in Galveston

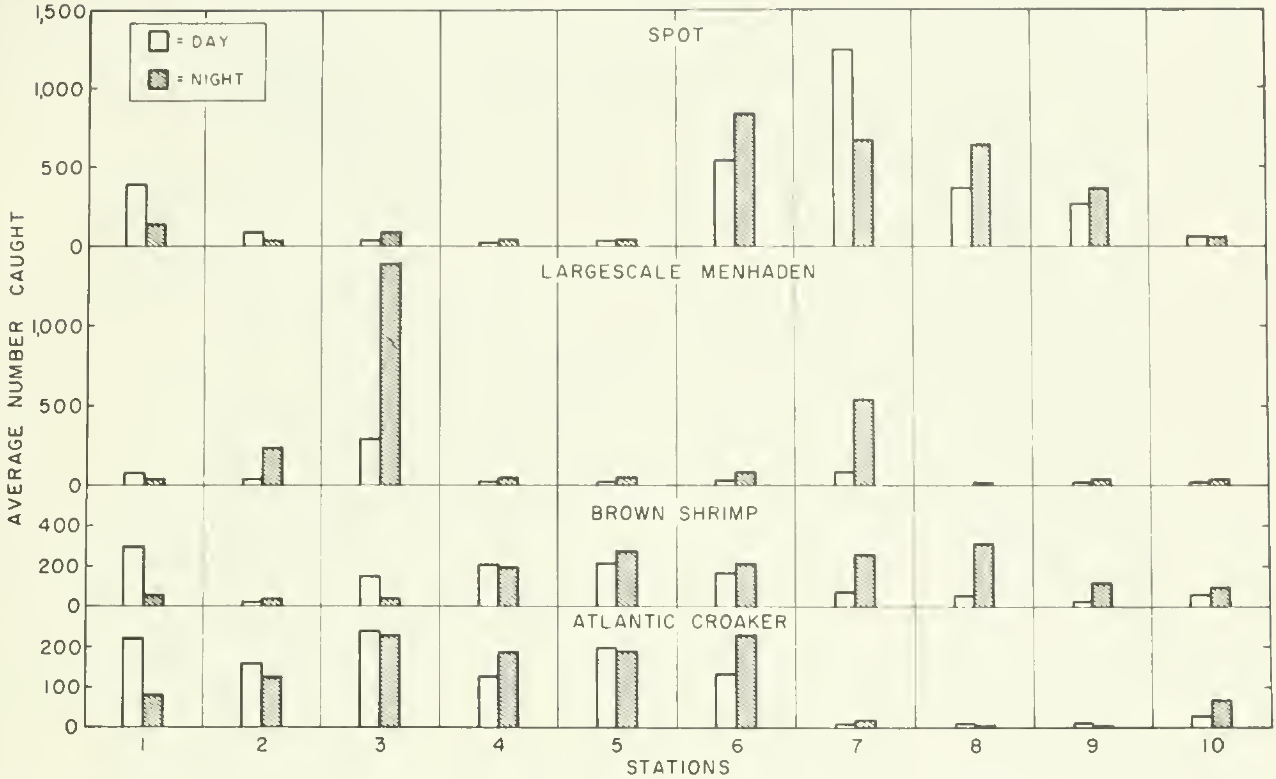

Figure 18.--Mean number of the four most abundant species of finfish caught in relation to station location and time of day, Jamaica Beach area, Tex., 1969.

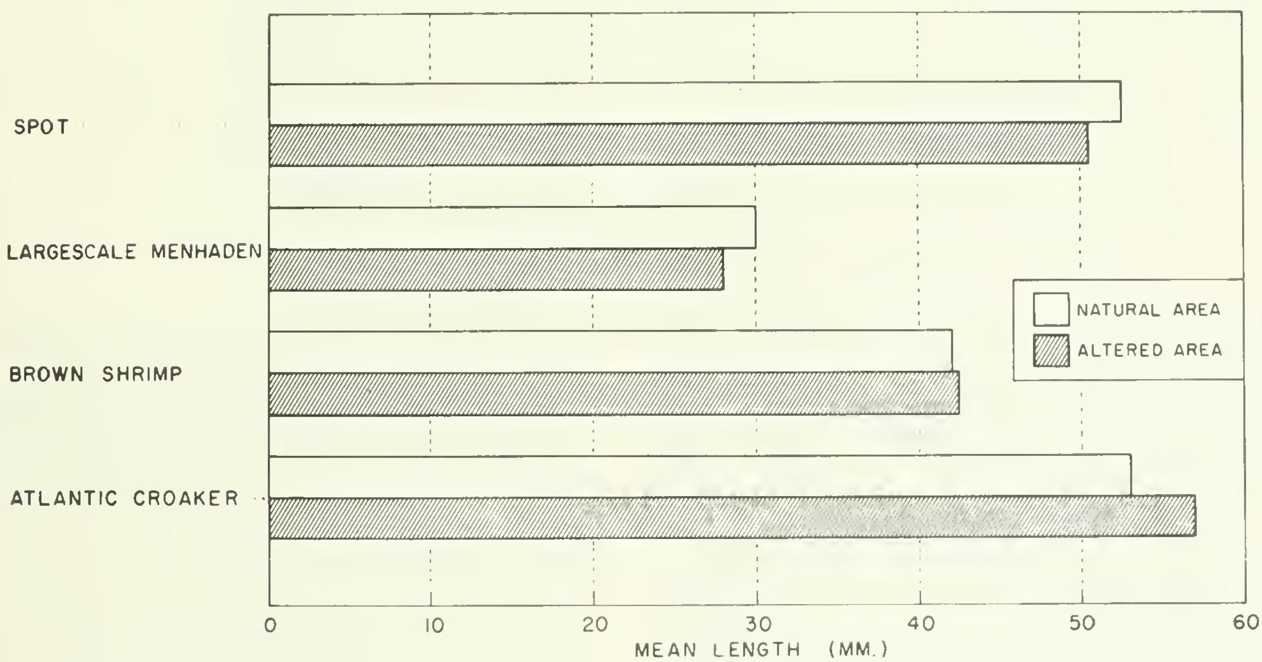

Figure 19.--Comparisons of mean length of four species of finfish between altered and natural areas, Jamaica Beach area, 1969.

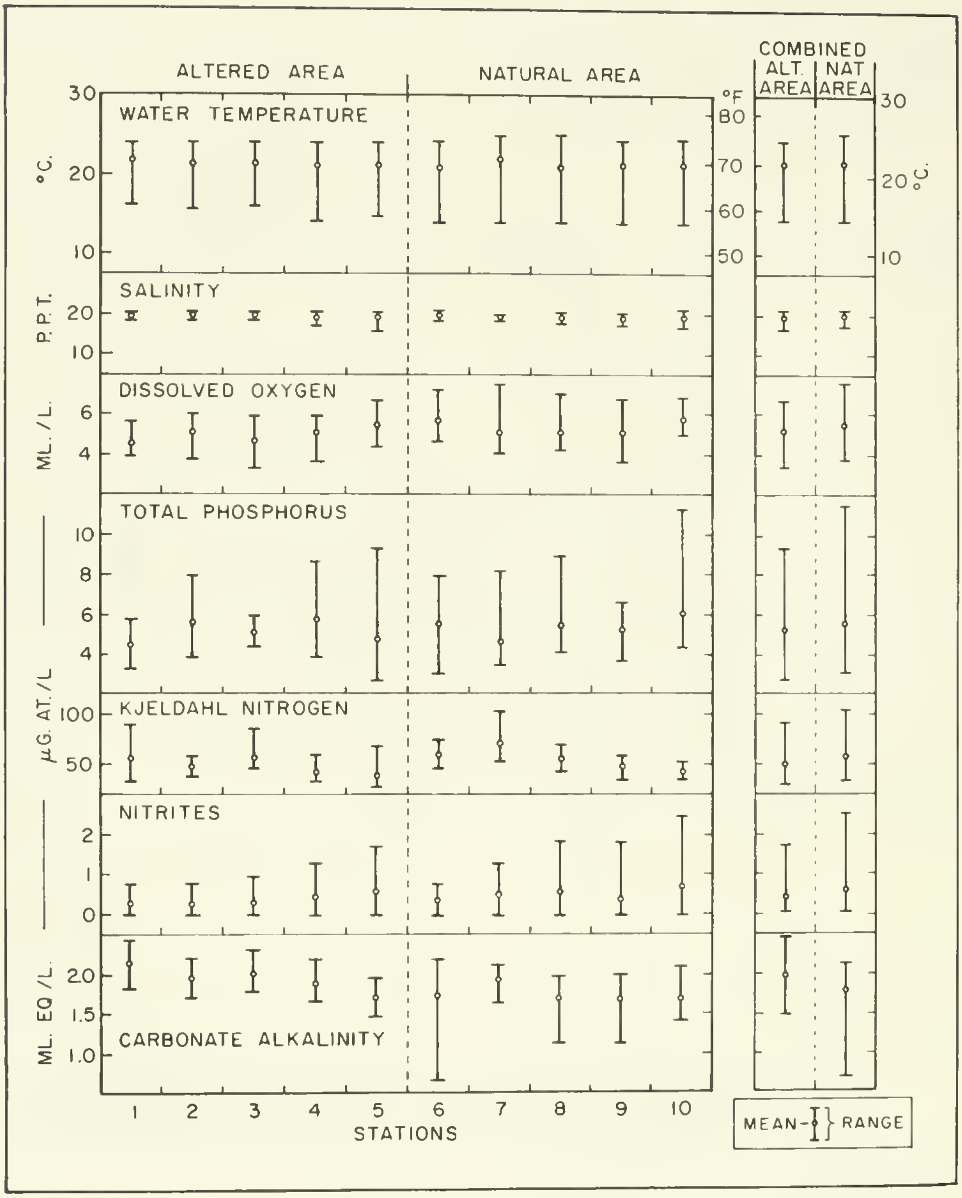

Figure 20.--Range and mean value of each hydrographic variable measured, by station and for stations combined by area, Jamaica Beach area, Tex., 1969.

Bay. On February 20, we placed two trays of oysters 0.3 m. (1 ft.) below mean low water in each area. Each tray was partitioned into 18 squares. The oysters were sorted into eight groups; each group had a shell length range of 5 mm. before being placed in trays. Lengths of groups ranged from 25 to 29 mm. to 60 to 64 mm., and four oysters of a size group were placed in each partition. Every size group was represented by at least eight oysters at each station. Every 2 weeks we replaced any dead oysters with live oysters of the same length and a similar shell configuration. Shell length for each oyster was recorded monthly and weight was recorded bimonthly. We analyzed only the lengths because the oysters had been weighed only twice.

The lengths of the oysters in each size group increased more rapidly in the natural area than in the altered area during the 3-month period (fig. 21). Growth in both areas, however, was probably determined to a large extent by the seasonal temperature increase from a low of 12° C. (54° F.) in the first month to a high of 28° C. (82° F.) in the third month. Salinity apparently had little or no effect on oyster growth as concentrations varied no more than 2 p.p.t. between the two areas.

The difference in oyster growth between the two areas may be explained by the relative

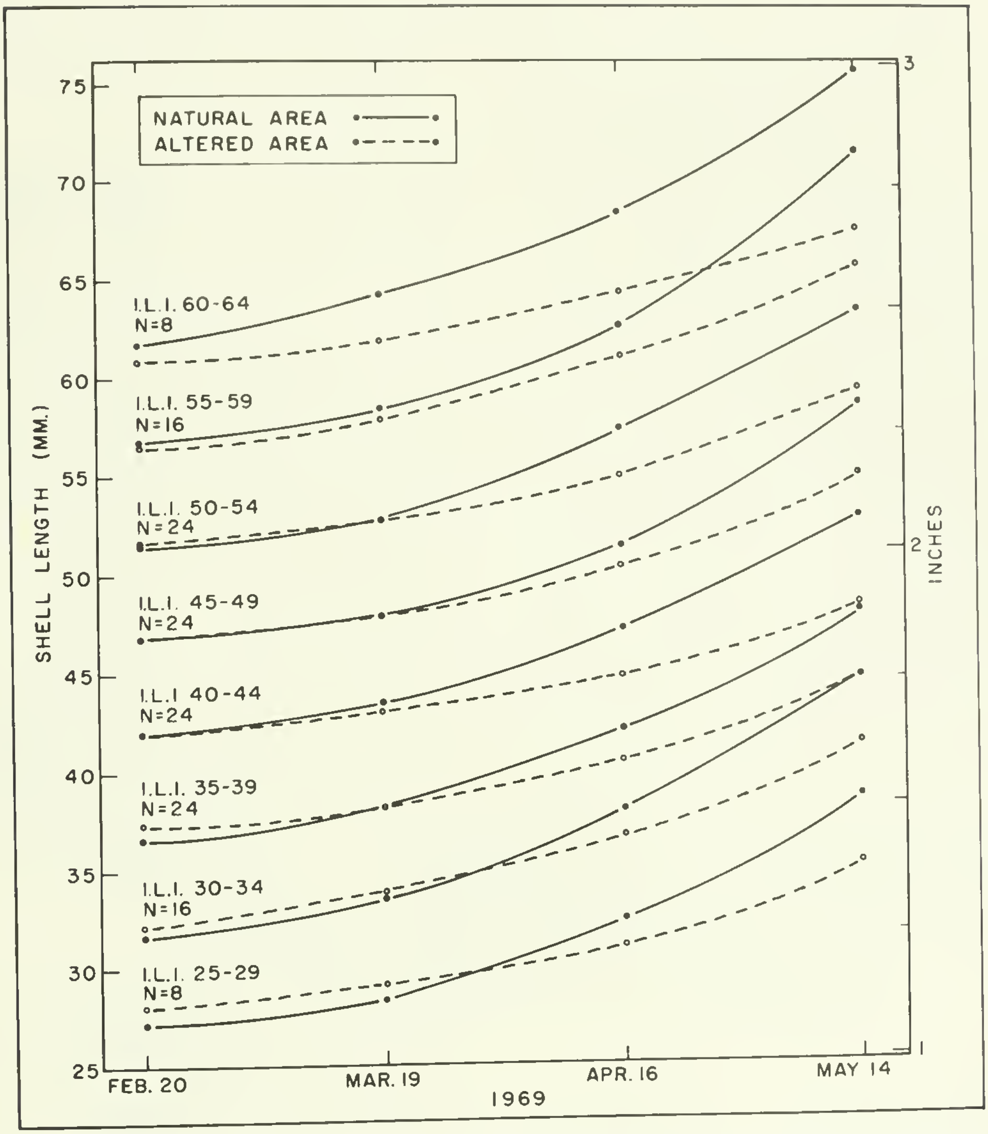

Figure 21.--Growth of juvenile oysters in natural and altered areas. ILI is initial length interval in millimeters, and N equals the number of oysters placed in each area, Jamaica Beach area, Tex. 1969

sizes of the populations of the resident oysters. A sizable population of oysters in the altered area was attached to the bulkheads, whereas few oysters were present in the natural marsh, apparently because of the lack of a suitable setting surface. Experimental oysters in the natural marsh may have less competition for food than those in the altered area.

W. Lee Trent, Project Leader
Edward J. Pullen
Donald Moore

GULF OCEANOGRAPHY PROGRAM

We continued to process and analyze benthic, hydrographic, and biological information collected from the Gulf of Mexico and Yucatan Strait during the 1966-68 cruises of the R/V GERONIMO. We emphasized the development of methods to evaluate the quality of these data so that we can describe the topography and sediments of the sea floor over the Continental Shelf, and the character and changes in the overlying water in the areas of the shrimping grounds.

A chart of the bottom topography of the Continental Shelf south of Tampa Bay, Fla., is in preparation. We completed the southern portion of the map, which includes the shrimping grounds in the area of the Dry Tortugas, and are plotting the properties of the sediments.

Our hydrographic data were processed by computers at the NASA Mississippi Test Facility, Bay St. Louis, Miss. Station profiles of temperature, potential temperature, and density were plotted, and factors of the dynamics of the currents computed. From our study of the data collected in the northwestern Gulf, it is now apparent that the main offshore circulation influences the currents over the western shelf. Also, the exchange of water below 1,000 m. (3,282 ft.) between the eastern and western Gulf exerts a dominating influence on the circulation in the western Gulf.

We plotted the distribution and abundance of the principal zooplankton taxa in the Gulf, and are studying their relation to the major oceanographic features of the Gulf.

An intensive oceanographic survey in the vicinity of the Yucatan Strait was planned with the R/V Oregon II to provide "ground truth"--surface features measured and photographed simultaneously--for photographs that will be taken during the Apollo 7 mission in October. We selected this area for several reasons: the currents that enter the Gulf through the Strait, the upwelling that extends over the Yucatan shelf, and the supplemental information that was obtained on previous cruises of the R/V Geronimo. We did not achieve all our objectives because of adverse weather, but we did obtain some hydrographic and benthic data that provided additional information on the southeastern Gulf.

The analysis of oceanic features seen in photographs taken during manned spaceflights continued to demonstrate that the view from space is valuable to fishery research. Oregon State University and Seaonics International, Inc., made additional studies under contract.

John R. Grady, Program Leader

Reconnaissance Survey

This study is designed to provide information on sediments throughout the Gulf of Mexico and the oxygen and nutrient content in the overlying waters. In this fiscal year we limited our analyses of water samples to those from the southeastern Gulf.

Bottom sediments.--We completed the analyses of particle size of marine sediments collected on the Continental Shelf and upper slope east of the Mississippi River Delta including the Florida and Yucatan Strait during the 1967-68 cruises of the R/V Geronimo. Sediments on the shelf were collected principally with a van Veen grab, and those on the lower slope were taken with a short, open-barrel, gravity corer of 38-mm. (1.5-inch) inside diameter. The upper centimeter of the samples was taken for analyses; half was stained with Rose Bengal to identify living organisms. Sediment sizes were treated graphically and statistically to provide a means for investigating properties of the bottom sediments and their distribution.

This year we began analyses of the total organic carbon and carbonate content of the surface sediments. This information will be used to estimate the percentage of organic matter present. Carbon analyses were made by combustion in an induction furnace, and the carbonate was calculated from the difference between the total carbon and the carbon that remained after treatment with a weak acid. Results were obtained and tabulated for sediments east of the Mississippi River.

We are determining the colors of the sediments by comparing them with color chips of the Munsell System. We also are studying the source of color, almost completely biogenic carbonate on the southern Florida Shelf, and its relation to the distribution of sediments and the physical processes now acting in the area.

We separated the microfauna from sediments (essentially the coarse fraction) collected from the western slope of the Yucatan Strait and sent subsamples to O. L. Bandy at the University of Southern California. Identification and frequency distributions of the foraminifera were completed. A number of samples from the deepest water contained ancient shallow-water faunas and lithic debris with a distinct shiny patina mixed in with Recent planktonic and benthic assemblages. Shallow-water faunas also were found on the northern Florida Shelf. Specimens of Globorotalia punticulata padana, an index of lower or middle Pliocene, were found in two samples.

We are preparing for publication a chart of the topography on the commercial shrimping grounds of southern Florida and the distribution of sediments in the vicinity of the Dry Tortugas (fig. 22). The bathymetric chart covers about 25,100 km.^{2} (9,700 square nautical miles) and is contoured at 1-m. (3.3-ft.) intervals on a Mercator projection. This map provides a sufficiently detailed base upon which the type and properties of the sediments can be plotted in their relation to bottom topography.

Configuration of the bottom was obtained from soundings provided by the USCGS (U.S. Coast and Geodetic Survey) from recent hydrographic surveys. Numerous enclosed basins and mounds of irregular shape and minor relief, typical of a limestone bottom, are shoreward east of the 37-m. (122-ft.) isobath. This relict surface that is undergoing little deposition contrasts with the relatively smooth bottom that slopes gently west to the edge of the Shelf. The slope is about 1 m. (3.3 ft.) per mile to a depth of 77 m. (254 ft.), 263 km. (142 nautical miles) west of Cape Sable.

Knolls or moundlike features in a linear north-south arrangement fringe the edge of the shelf. Calcareous algae dredged from their surface indicate that they are reef structures.

Figure 22.--Bottom topography of the principal shrimping area in the vicinity of the Dry Tortugas, Fla., 1968-69. Relief is contoured at 1-m. (3.3-ft.) intervals on a Mercator projection.

Other mound and basin features at greater depths mark old strandlines and indicate a stillstand of the ancient prograding sea. Profiles that show topographic relief across the area were prepared from echo-sounding traces made during cruises of the R/V Geronimo.

Waters in the southeastern Gulf.--During the cruise of the R/V Oregon II in October, we collected 342 water samples from the southeastern Gulf. Dissolved oxygen content of the water was determined aboard ship; concentrations of phosphate-phosphorus and silicate-silicon were determined in the laboratory.

We completed the analysis of dissolved oxygen and nutrient contents of samples collected during cruises 12, 16, and 20 of the R/V Geronimo in the Gulf and Yucatan Strait. We analyzed 6,742 samples. We are now plotting these data and examining their quality by several methods. Particular emphasis is being placed on a study of dissolved oxygen and temperature in the areas of strong and persistent upwelling in the Straits of Florida and the Yucatan Strait. Populations of plankton are dense in each area.

John R. Grady, Project Leader

Circulation Dynamics

The amount of data and extensive coverage of the Gulf of Mexico accomplished during the

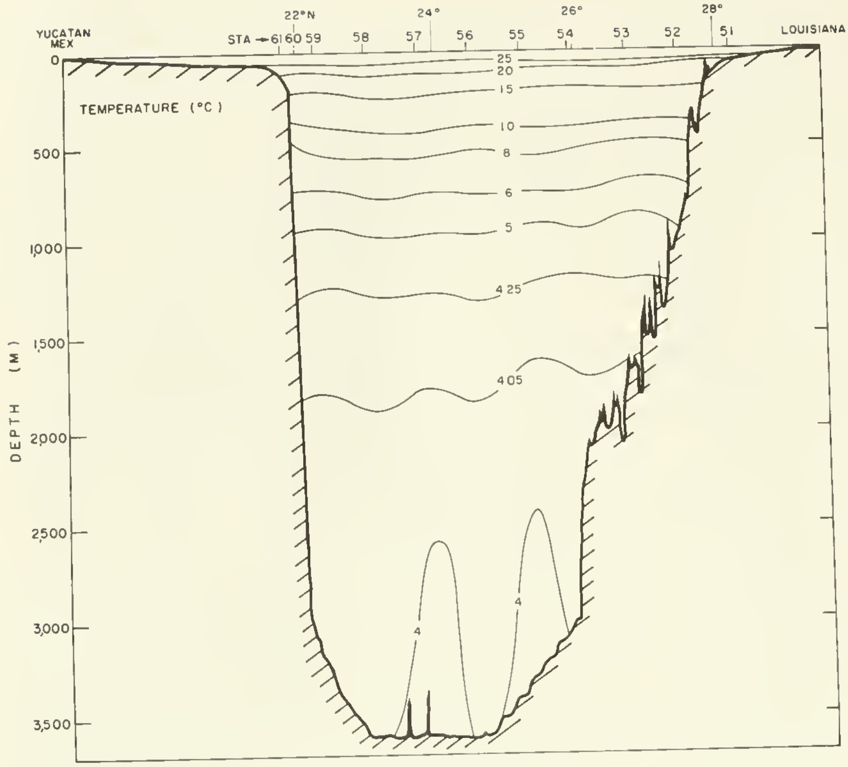

Figure 23.--Temperature cross section from cruise 16, R/V Geronimo, in the Gulf of Mexico, August to October 1967, based on potential temperature for $\leq 6^{\circ}$ C. (40° F.).

hydrographic cruises of the R/V Geronimo were so large that our principal concern has been to analyze this information and to formulate plans and basic questions that should be answered for future operations. The R/V Geronimo cruise data, supplemented by data from other hydrographic operations in the Gulf, permit us to detail the general features and conditions that prevail in the waters of the Gulf and, to some degree, the variations that occur with time.

The data from these cruises were put into the computers of the NASA Mississippi Test Facility, Bay St. Louis, Miss., to produce station profiles of temperature, salinity, potential temperature, and density (σ_t) and to compute factors for dynamic analysis of the water circulation. This information is now used for quality analysis of the data and worked up into cross sections (figs. 23, 24, and 25).

A technique for determining the level of no motion for geostrophic current computations was developed and is now being tested. The concept is to examine the relative divergence by comparing temperature profiles for two adjacent stations. Figure 25 is an example of the geostrophic velocities computed by this technique. Because that portion of the Gulf to the west of this section is totally enclosed by land, the net volume transport through the section should be zero. The gross volume transport was computed as 43 million $m.^3/sec.$; the net transport was 0.31 million $m.^3/sec.$, or about only 0.7 percent in error. The usual method for computing geostrophic currents is to assume that the level of no motion lies at the deepest level of observation. If such a method were used for the data in figures 23, 24, and 25, the pronounced deep currents (maximum value of 6.9 cm./sec. between stations 57 and 58) could not be detected. In this particular section, more than half the volume transport is effected in the waters below 1,000 m. (3,300 ft.).

We have learned from the data collected during the R/V Geronimo cruises that the regions of the Yucatan Strait and the central Gulf are of main importance to the oceanography of the Gulf. A major leg of the Gulf Stream system enters the Gulf through the Yucatan Strait. This flow produces a strong looping current in the eastern Gulf, and the exchange of water in the central Gulf between this loop current and the western Gulf apparently determines the conditions that prevail in the waters of the western Gulf. For future operations, therefore, primary interest should be given to the waters of the Yucatan Strait and the central Gulf, particularly off the shelf break along the northern edge of the Campeche Shelf of the Yucatan Peninsula.

During cruise 3 of the R/V Oregon II (October 8-18), we completed 14 of the intended

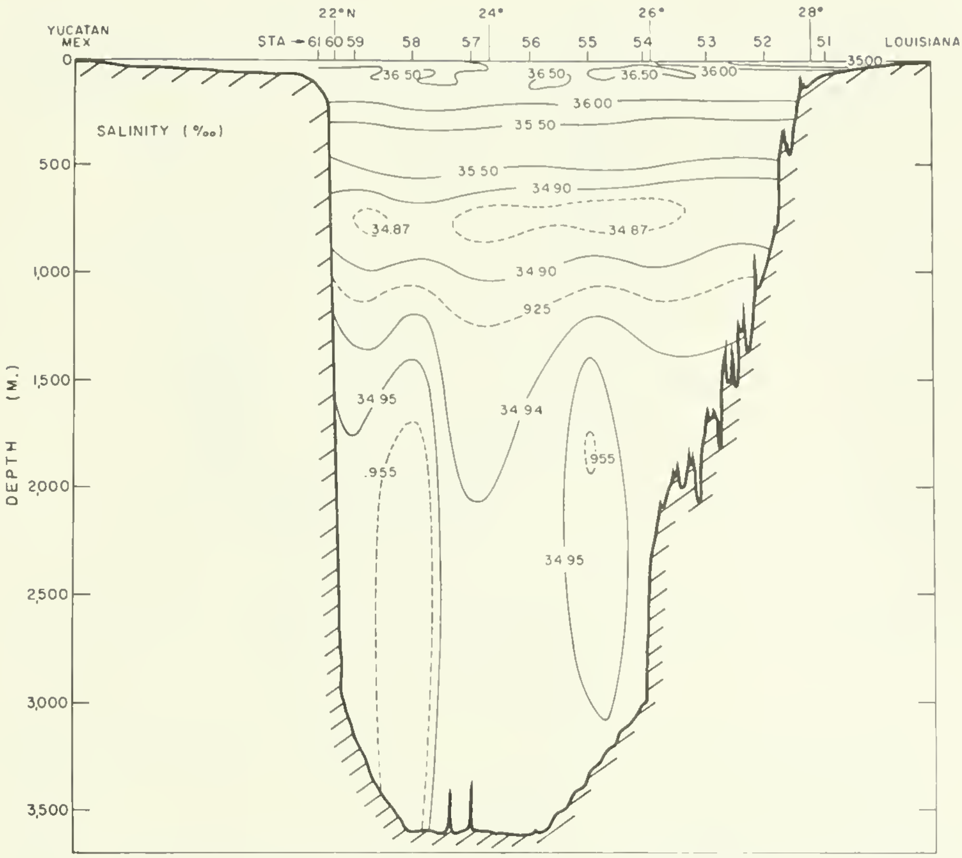

Figure 24.--Salinity cross section from cruise 16, R/V Geronimo, in the Gulf of Mexico, August to October 1967.

67 hydrographic stations in the southeastern Gulf-Yucatan Strait area (Hurricane Gladys prevented completion of the cruise). The data from this cruise were analyzed, and although few stations were occupied, the information will be useful in supplementing the data from the R/V Geronimo cruises.

Hydrographic data for the upper 1,200 m. (3,960 feet) from various cruises of the R/V Alaminos (Texas A&M University) in the Gulf during 1965-68 were processed to supplement the R/V Geronimo data. This information will provide more detail on time variations of the circulation.

Reed S. Armstrong, Project Leader

Biological Applications

We collected samples of zooplankton at most hydrographic stations occupied during the all-Gulf cruises of the R/V Geronimo and cruise 3 of the R/V Oregon II. We obtained these samples by making vertical hauls in the upper 100 m. (330 ft.) of water with a metered NV-70 net. We counted the 12 most abundant taxa (including fish larvae) and prepared some frequency tables and contour maps to illustrate distributions. We are now studying how the seasonal abundance and distribution of these taxa are related to the water masses, convergences, and areas of upwelling.

The preparation of all data has not been completed, but preliminary plots of the distribution of zooplankton indicate that the highest catch was over the Continental Shelf in the summer of 1967 near the mouth of the Sabine River. More extensive concentrations of organisms, however, were found over the Continental Shelf of the northern Gulf in the winter of 1967. These areas were apparently at and near local sites of upwelling and convergences.

Concentrations of zooplankton were large over the Continental Shelves and slopes of eastern Yucatan and southwestern Florida. Although the abundance of zooplankters was generally similar during all cruises, catches were somewhat greater in the winter. Also, the population of zooplankters was dense in

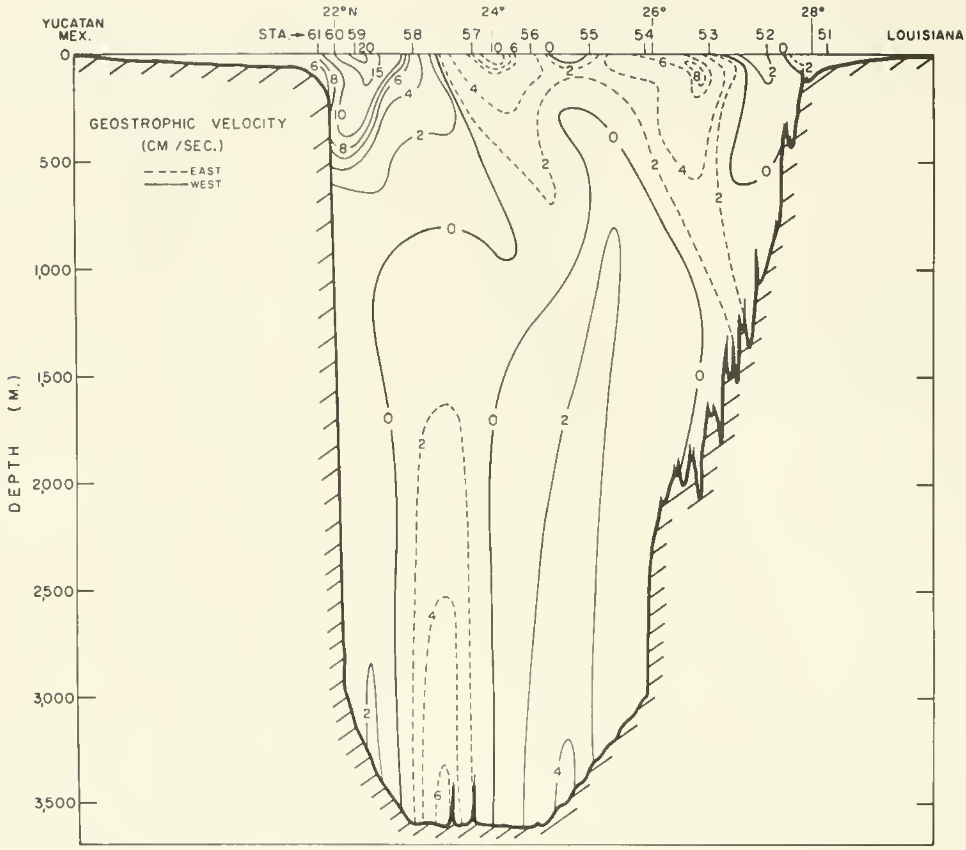

Figure 25.--Geostrophic velocity cross section from cruise 16, R/V Geronimo, in the Gulf of Mexico, August to October 1967.

the winter in the deepest waters between eastern Yucatan and southwestern Florida. This condition apparently resulted from waters near shore being drawn offshore and converging in this area.

Planktonic foraminifera removed from samples taken in the surface waters of the Yucatan Strait were sent to O. L. Bandy at the University of Southern California for study. Species of planktonic foraminifers in the water are to be studied in relation to the distribution and abundance of recent foraminiferal tests in the sediments of the western Strait.

John R. Grady, Project Leader

Space Applications

Evaluation of color photographs taken during the missions of Apollo 7 (October 1968) and Apollo 9 (March 1969) provided more information on oceanographic features, such as eddies, current boundaries, and areas of upwelling. We reviewed and cataloged these photographs.

Applications of lighter-than-air craft to problems of remote sensing at the sea surface were investigated at Goodyear Aerospace Inc., Akron, Ohio. We developed a tentative plan to use blimps in coastal areas in conjunction with ground-truth surveys.

Study of photographs taken during lunar missions of Apollo 8 and 10 revealed that major current systems of the ocean were visible from distances between 74,000 and 259,000 km. (40,000 and 140,000 miles) above the earth. Features such as the Benguela current, Humboldt current, the Canary and Somali upwelling zones were seen with remarkable clarity. These results confirm the utility of such photographs for analyzing seasonal variations in the major circulation systems of the world.

John R. Grady, Project Leader

Remote Sensing of the Pelagic Fishery Environment off Oregon: A Study of Coastal Upwelling and the Columbia River Plume

Oregon State University began a study of the hydrology, plankton, and albacore catches as related to oceanic fronts produced by upwelling

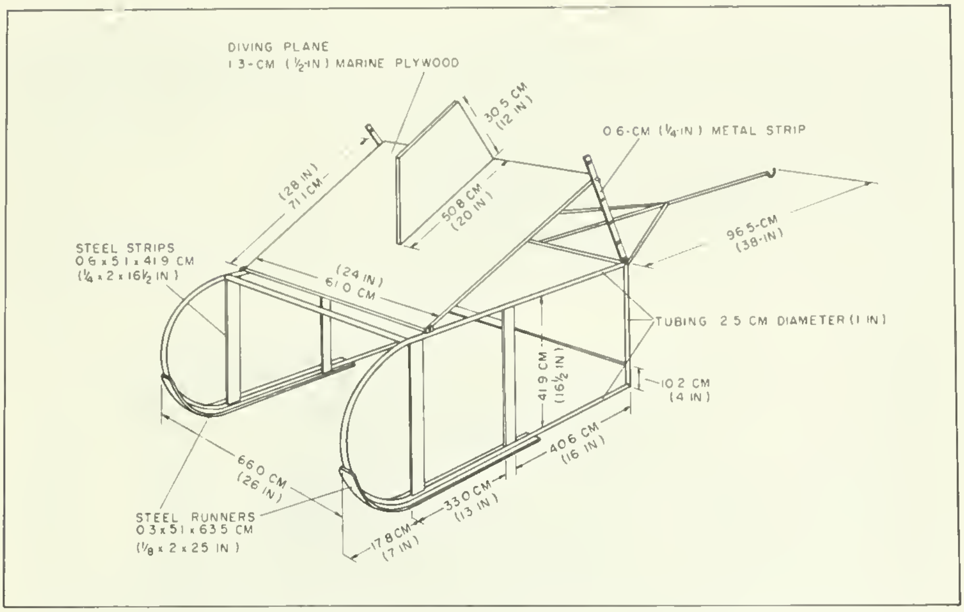

Figure 26.--Framework of benthic sampling sled with approximate dimensions, Gulf of Mexico, 1968.

and the Columbia River Plume. The first cruise to study environmental conditions off Oregon was completed.

William G. Pearcy, Project Leader

Oregon State University
(Contract No. 14-17-0002-333)

Preparation of a Bibliography of Ocean-Surface Features Significant to Fisheries

We prepared a preliminary 78-page bibliography of evaluated references pertaining to sea conditions that restrict fishing, ocean features that delineate high-seas fisheries, and environmental deviations that affect the size of a year-class of fish.

Richard D. Terry, Project Leader

Seaonics International Inc.
(Contract No. 14-17-0002-357)

SPECIAL REPORT: A MODIFIED BENTHIC SAMPLING SLED

To study the distribution of postlarval penaeid shrimp in relation to different types of sediments and to establish indices of postlarval abundance, we modified the quantitative benthic sampler originally described by Macer (1967)[2]. Although the dimensions of our gear (fig. 26) were similar to those of the sampler designed by Macer, modifications included a different opening and closing mechanism; a flowmeter; and two attachments--a roller and a digger bar--designed to disturb the substrate (fig. 27). Because our gear was designed to catch postlarvae in the surface layer of the sediment as well as from the water immediately above the bottom, the net opening was lowered to a position just off the bottom.

Figures 27 and 28 show the design of the opening and closing mechanism. The door is welded to a horizontal shaft that projects 1.3 cm. (0.5 inch) on each side of the box, and both ends of which are secured to support arms. These arms are attached to supports which are welded to the two shoes that are held in position by a guide on each side of the box. In the closed position, the door is held shut by springs connected to each support arm. When the sled is not resting on the shoes, the spring holds them in the lowered position with the door closed. When the sled touches bottom, the shoe is raised and the door opens. If the sled loses contact with the sea floor at any time, the door closes until the sled is again on the bottom in an upright position.

Towing procedures are as follows. To prepare the sled for sampling, we set the diving plane at an angle of about 30°. If the sled is to be towed faster than 3.7 km. per hour (2 knots) or if the sea is rough, the angle may have to be increased to keep the sled on the bottom. The appropriate bottom-disturbing attachment is secured in place, and the flowmeter reading is recorded. A line is then fastened to the sled with a 1.5-m. (5-ft.)

[2]Macer, C. T. 1967. A new bottom-plankton sampler. J. Cons. 31: 158-163.

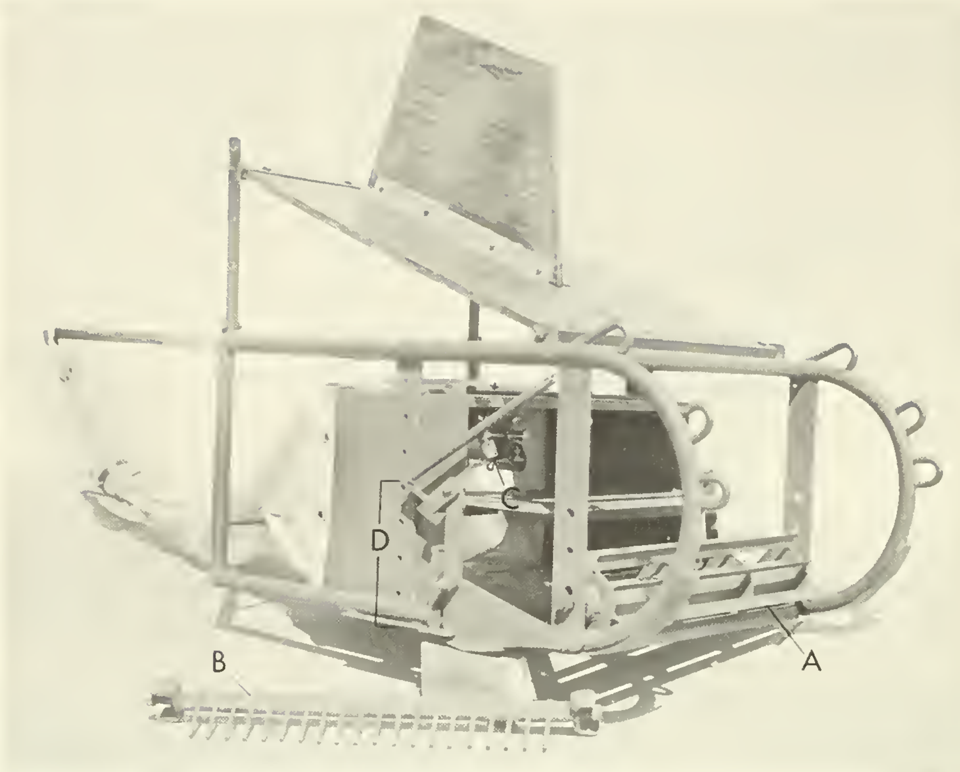

Figure 27.--Modified benthic sampling sled: (A) roller attached in operating position, (B) digger bar, (C) flowmeter, and (D) opening and closing mechanism (door in open position).

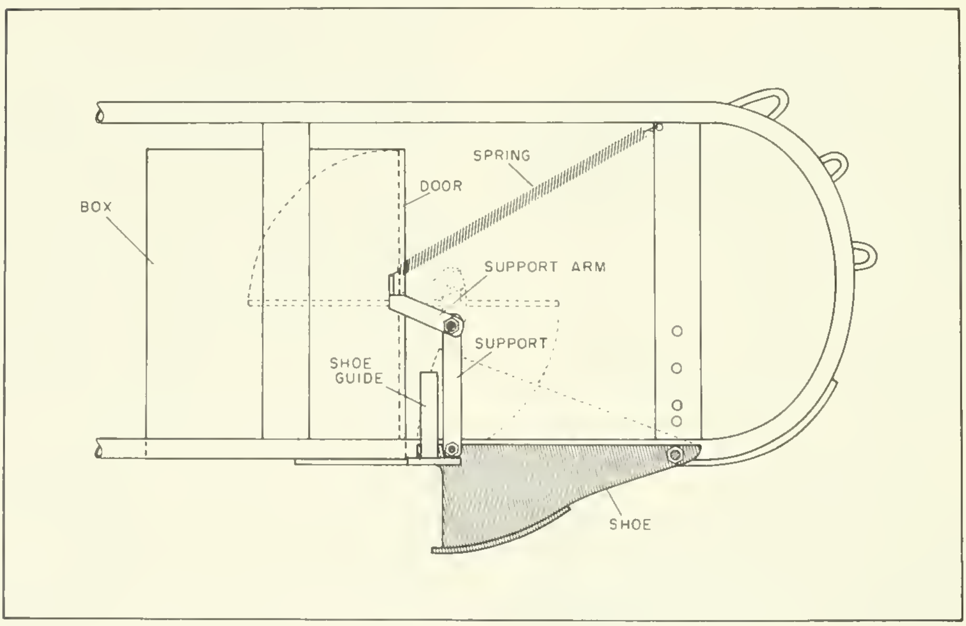

Figure 28.--Opening and closing mechanism of benthic sampling sled.

chain bridle fastened to eyelets on the front of the sled frame (fig. 27). Because of the weight of the sled, we need a hydraulic or rolling winch to handle it aboard a vessel. The proper ratio of towing line to water depth for normal towing speeds (1 - 2 knots) is 3:1.

We made several 10-minute tows at one location to compare catches made with the roller attachment, the digger-bar attachment, and with no attachment. Catches of postlarvae (*Penaeus* spp.) were largest when the roller attachment was used and smallest with no attachment (table 8). We took other animals such as polychaetes, gastropods, pelecypods, coelenterates, echinoderms, and crustaceans in greater numbers when the roller was attached.

The sled with the roller was tested from a 12-m. (40-ft.) research vessel under varying sea conditions. We positioned a series of 10 numbered buoys at 6-m. (20-ft.) intervals parallel to the shoreline in 3 m. (10 ft.) of water. The sampling site was one at which white shrimp postlarvae were known to be abundant. A 10-minute sled tow was made in an offshore direction from each buoy on August 8, 1968, when the seas were 0 to 0.6 m. high (0 - 2 ft.), and from seven of the buoys on August 29, 1968, when the seas were 0.6 to 1.5 m. high (2 - 5 ft.). Similar catches (table 9) on each day and the uniform ratio of brown shrimp to white shrimp each day indicated that the gear functioned well.

With this gear, shrimp researchers can collect quantitative samples from bottoms inhabited by the young of commercial species of penaeid shrimp. Further use of this gear could extend existing knowledge of the life histories of other animals which live in the same areas.

Harold A. Brusher
Frank Marullo

Table 8.--Average catches of postlarvae (*Penaeus* spp.) per 1,000 $m.^3$ during a series of 10-minute tows at the same location with the sampling sled with roller bar, digger bar, and no attachment.

Attachments	Tows	Postlarvae
	Number	Number
Roller...............	2	417
Digger bar...........	2	74
No attachment........	2	6

Table 9.--Catches of postlarval white and brown shrimps per 1,000 $m.^3$ made during sets of parallel tows, Gulf of Mexico, 1968.

Tow	Postlarvae		Tow	Postlarvae	
	Brown	White		Brown	White
	Number	Number		Number	Number
1..............	173	1,463	1	65	4,523
2..............	141	993	2	45	3,620
3..............	131	950	3	12	3,303
4..............	152	1,401	4	40	5,101
5..............	187	1,278	5	12	4,094
6..............	177	1,236	6	18	832
7..............	159	1,025	7	12	3,352
8..............	142	1,401	-	-	-
9..............	132	1,503	-	-	-
10..............	173	1,324	-	-	-
Average number	156.7	1,257.4	-	29.1	3,546.4
Confidence interval at 0.05 level	$\pm$14.4	$\pm$144.5	-	$\pm$19.4	$\pm$1,254.7

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