FISHERY RESEARCH
[B]IOLOGICAL LABORATORY, GALVESTON

FISCAL YEAR 1964

[U]NITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

BUREAU OF COMMERCIAL FISHERIES

CIRCULAR 230

UNITED STATES DEPARTMENT OF THE INTERIOR

Stewart L. Udall, *Secretary*

John A. Carver, Jr., *Under Secretary*

Stanley A. Cain, *Assistant Secretary for Fish and Wildlife*

FISH AND WILDLIFE SERVICE, Clarence F. Pautzke, *Commissioner*

BUREAU OF COMMERCIAL FISHERIES, Donald L. McKernan, *Director*

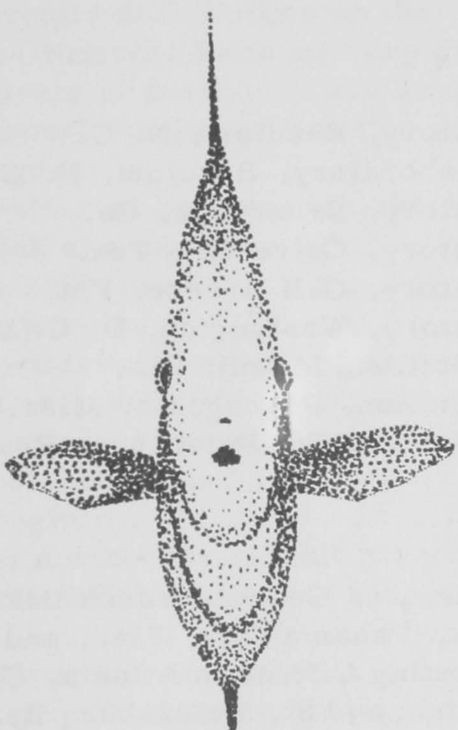
BIOLOGICAL LABORATORY, GALVESTON, TEX.

FISHERY RESEARCH

for the year ending June 30, 1964

Milton J. Lindner, Director

Joseph H. Kutkuhn, Assistant Director



Contribution No. 207, Bureau of Commercial Fisheries
Biological Laboratory, Galveston, Tex.

Circular 230

Washington, D. C.
August 1965

CONTENTS (Continued)

REPORT OF THE DIRECTOR

Milton J. Lindner

The purpose of this section is to point out some of the research highlights that were developed during the year. These are treated in greater detail, in the sections following this one, by the scientists who developed them. Not to be forgotten is the fact that this is an annual progress report, and much of the material it contains is necessarily of a preliminary nature.

Seasonal abundance of larvae, deduced from plankton collections, indicates that brown shrimp, *Penaeus aztecus*, spawn throughout the year in depths between 25 and 60 fathoms. There are, however, two periods of increased spawning -- one during late spring and early summer and the other from early fall through early winter. The greater abundance of larvae appears to be produced in the second period. Ovarian studies, in general, confirm these observations and also show that brown shrimp do not regularly spawn in depths less than 7½ fathoms.

Vertical distribution studies showed that when the water column was stable (thermocline extant) planktonic penaeids were encountered most frequently at and below mid-depths, with the younger stages tending to be nearer the bottom than the older. The distribution of each stage extended towards the surface just prior to or at dark. When there was considerable vertical mixing, planktonic stages were more homogeneously distributed throughout the water column and there was no evidence of diurnal migration.

Brown shrimp, on three occasions, were reared to postlarvae from eggs spawned in the laboratory. These mark the first successful efforts to rear brown shrimp under artifical conditions.

Research on pink shrimp, *P. duorarum*, indicates year-round spawning and that spawning intensity and larval abundance are affected by both absolute temperature and changes in temperature. The greatest numbers of postlarval pinks enter

Buttonwood Canal, Fla., on flood tides, at night, during new moons. Juvenile pinks, however, leave the canal in greatest numbers on ebb tides, at night, during new and full moons. They leave throughout the year but there are periods of major exodus. Three happened in 1963. They occurred in January, April, and September.

The roles played in the life and habits of shrimp by temperature and salinity are being explained by laboratory and field research. Laboratory experiments with postlarval and juvenile white, P. setiferus, and brown shrimp indicate that temperature affects growth patterns to a greater degree than salinity. Salinity and temperature tolerances may change with age. Temperature affects growth by changing the molting rate but not the increment per molt. Molting frequency is the same for white and brown shrimp when individuals of similar length are held at the same temperature. The molting frequency of both species increases with temperature.

Preliminary survival experiments suggest that postlarval brown shrimp survive low temperatures better than whites, but that white shrimp postlarvae survive high temperatures better than browns. Perhaps this observation may help explain why we find the bulk of postlarval brown shrimp always entering the estuarine nursery areas well in advance of the white. The entry of brown postlarvae begins in late winter or early spring when estuarine waters are relatively cool.

Temperature and growth relations are also evident from field data. Growth rates of juvenile browns, based on the largest individuals in samples from Galveston Bay, ranged from less than 0.1 mm. per day when water temperatures were under 68° F. (20° C.) to 3.3 mm. per day at temperatures of 77° F. (25° C.) and higher.

Invasion of Galveston Bay by brown shrimp postlarvae was rapid. They spread throughout the entire bay within about 2 weeks of their first appearance in large numbers at the entrances. Mounting evidence continues to indicate, however, that the shorelines and, in particular, the marsh zones are the principal nursery areas for postlarvae and early juveniles.

Another year of data strengthens our belief that crop prediction may be achieved by postlarval count. Again, as in previous years, numbers of brown postlarvae taken at Galveston Entrance bore a direct relation to the subsequent abundance of juveniles in Galveston Bay.

Four mark-recapture experiments were performed to determine migration, growth, and mortality patterns in brown, white, and pink shrimp. A study on loss of marked animals recaptured but not returned yielded an estimate of only 3 percent.

An experiment was performed to determine whether the biological stain FCF fast green, which becomes fixed in the gills, might affect growth by impairing oxygen uptake. The results indicated no difference in oxygen consumption between stained and unstained shrimp.

Discarded shrimp can be an important factor in resource utilization. A study conducted on the Tortugas pink shrimp grounds demonstrated that between September 1963 and July 1964 an estimated 11 percent by weight of the total catch was discarded at sea.

Preliminary results indicate that significant numbers of marketable shrimp escape from trawls with larger-than-average meshes, whereas only a few escape through the meshes of nets commonly used by the shrimp fleet. These studies also suggest that selective action of cod-end meshes varies with length of tow. With the same mesh, more small shrimp escape during a 2- than a 1-hr. tow. Additionally, the research shows that fishing power of nets is increased by increasing mesh size.

Analyses of bathythermograph casts from the northwestern Gulf of Mexico demonstrate that the waters, over those portions of the continental shelf we are studying, are isothermal from top to bottom during late fall and winter. Thermoclines begin to form in early spring and are most pronounced from June through August. How these phenomena affect shrimp, we do not yet know.

STAFF

Milton J. Lindner, Laboratory Director
Joseph H. Kutkuhn, Assistant Laboratory Director

Biological Laboratory at Galveston, Tex.
Field Stations at Miami, Fla., and Pascagoula, Miss.

Shrimp Biology Program

J. Bruce Kimsey	Program Leader	Galveston
Thomas J. Costello	Head, Field Station	Miami
Donald M. Allen	Biologist	Miami
William C. Renfro	Biologist	Galveston
Robert F. Temple	Biologist	Galveston
David L. Harrington	Biologist	Galveston
Harry L. Cook	Biologist	Galveston
Clarence C. Fischer	Biologist	Galveston
Harold A. Brusher	Biologist	Galveston
Carlton H. Furr	Fishery Reporting Specialist	Galveston
Kenneth W. Osborn	Biologist (transferred 9/63)	Galveston
Aubrey A. LaFrance	Aid (transferred 7/63)	Galveston
Carl E. Wood	Aid (resigned 1/64)	Galveston
Imogene A. Sanderson	Technician	Galveston
M. Alice Murphy	Technician	Galveston
Ann D. Seward	Aid	Galveston
C. Stewart Law	Aid	Galveston
Johnny L. Ledford	Aid	Miami
John H. Tweedy	Aid (Intermittent) (res. 4/64)	Miami
Richard L. Aaron	Aid (Intermittent) (res. 4/64)	Miami
Don E. Kozacek	Summer Aid	Galveston

Shrimp Dynamics Program

Richard J. Berry	Program Leader	Galveston
Edward F. Klima	Biologist	Galveston
Kenneth N. Baxter	Biologist	Galveston
Ray S. Wheeler	Biologist	Galveston
Charles E. Knight	Biologist (transferred to Galveston 3/64)	Houma
Thomas W. Turnipseed	Biologist	Morgan City
James M. Lyon	Biologist	Aransas Pass
Joseph A. Benigno	Biologist (transferred to Galveston 9/63)	Pascagoula

Shrimp Dynamics Program (continued)

John B. Hervey	Biologist	Galveston
Charles R. Frith	Biologist (transferred 10/63)	Brownsville
Robert C. Benton	Biologist (transferred to Freeport 6/64)	Key West
James H. Hudson	Biologist	Key West
Larry M. Wiesepape	Aid (transferred 10/63)	Galveston
Frank Marullo	Aid	Galveston
Robert C. Haas	Summer Aid (resigned 8/63)	Galveston
Frank N. Moseley	Summer Aid (resigned 9/63)	Galveston
Frederick D. Miller IV	Summer Aid (resigned 9/63)	Galveston
James B. Reynolds	Summer Aid (resigned 8/63)	Galveston
John A. McDonald	Summer Aid (resigned 9/63)	Galveston
Edward S. Halpert	Summer Aid	Galveston
Robert M. Blade	Summer Aid	Galveston
Randall W. Bland	Summer Aid	Galveston

Estuarine Program

Charles R. Chapman	Program Leader	Galveston
Richard A. Diener	Biologist	Galveston
Cornelius R. Mock	Biologist	Galveston
Jack C. Parker	Biologist	Galveston
Edward J. Pullen	Biologist	Galveston
Robert D. Ringo	Biologist	Galveston
Gilbert Zamora, Jr.	Technician	Galveston
William Laming	Technician	Galveston
Genevieve Adams	Statistical Clerk	Galveston
Thomas W. Ates	Summer Aid (resigned 9/63)	Galveston
Edward I. Bault	Summer Aid (resigned 8/63)	Galveston
William T. Ladnier	Summer Aid	Galveston

Industrial Fishery Program

Joseph H. Kutkuhn	Program Leader	Galveston
Donald Moore	Biologist	Galveston
Charles M. Roithmayr	Biologist	Pascagoula
Leslie Osborne	Aid	Pascagoula

Experimental Biology Program

David V. Aldrich	Program Leader	Galveston
Zoula P. Zein-Eldin	Biochemist	Galveston
Don S. Godwin	Biologist (transferred 11/63)	Galveston
George W. Griffith	Biologist	Galveston
Roger M. Friedberg	Aid (resigned 9/63)	Galveston
Linda A. Edwards	Aid	Galveston
James A. Supej	Aid	Galveston
Robert E. Trist	Summer Aid (resigned 8/63)	Galveston
Vernon Lee Rainey	Summer Aid	Galveston

Chemistry and Sea-Water Laboratories

Kenneth T. Marvin	Supervisory Chemist	Galveston
Raphael R. Proctor	Chemist	Galveston
Larence M. Lansford	Technician	Galveston
Larry L. Elam	Aid (resigned 11/63)	Galveston
James Wallett	Aid	Galveston

Library

Stella Breedlove	Librarian	Galveston

Technical Services

Ruth W. Yanch	Secretary	Galveston
Petronila C. Prado	Clerk-Stenographer	Galveston
Margie L. Watson	Clerk-Stenographer	Galveston
Daniel Patlan	Office Draftsman	Galveston
Nellie P. Benson	Clerk-Stenographer (part-time)	Miami
Laura M. Hermann	Museum Technician (Natural Science)	Galveston

Administration and Maintenance

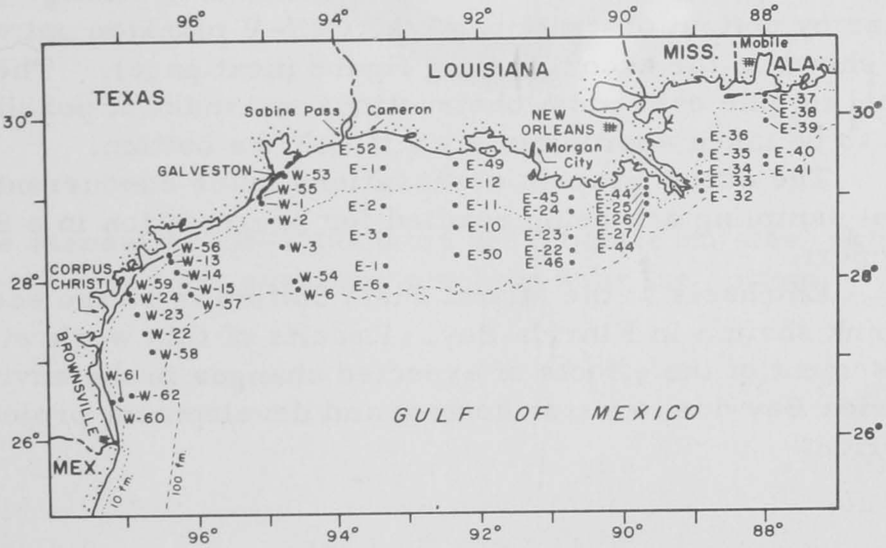
Raymond H. Niblock	Administrative Officer	Galveston
Corinna L. Denbo	Purchasing Agent	Galveston
Glo S. Baxter	Administrative Clerk	Galveston
Elizabeth C. Kilian	Clerk-Stenographer	Galveston
Alvin M. Reynolds	Storekeeping Clerk	Galveston
Peter M. Villarreal	Maintenance Foreman	Galveston
Tidas C. Alcorn	Maintenanceman	Galveston
Robert L. McMahon	Maintenanceman	Galveston

SHRIMP BIOLOGY PROGRAM

J. Bruce Kimsey, Program Leader

The Shrimp Biology Program is primarily concerned with the distribution, abundance, and the ecology of commercially important shrimps of the Gulf of Mexico, during life history stages when they inhabit the marine environment of the continental slope. Biological material and measurements of environmental factors are obtained systematically during regularly scheduled cruises of a chartered research vessel.

The distribution of sampling stations in the northwestern Gulf was modified in early 1964 when 10 stations east of the Mississippi River Delta were eliminated. Some of the sampling procedures were also changed. No shrimp ovaries were collected, and no routine releases of drift bottles and seabed drifters were made after December 1963. A Gulf-V sampler was mounted on a sled for collecting plankton near the bottom. Except for the above, sampling operations remained the same, and at each station a 45-ft. shrimp trawl was towed for 1 hr., a 20-min. tow was made with a Gulf-V plankton net, and salinity and temperature measurements were taken at standard depths.



Station pattern used by the Shrimp Biology Program, 1963-64. The 10 stations east of the Mississippi River Delta were discontinued after December 1963.

The poor rate of return from commercial trawlers of routinely released seabed drifters has limited the usefulness of these devices for describing bottom currents. In 1963, a system of releasing seabed drifters only in areas where the shrimp fleet was expected to concentrate during the following 30 to 90 days was tested and found to approximately double the rate of return. Drift bottles were released with the seabed drifters for comparative purposes. The results of releases between August and December 1963 showed surface and bottom currents at 15- and 25-fathom stations in the waters off central Texas to be generally in the same direction during August and November-December, but in opposite directions during September. The direction of drift at both surface and bottom was variable at stations in water shallower than 15 fathoms.

Using seabed drifters, a study of bottom currents on the Tortugas trawling grounds was carried out in cooperation with the Univ. of Miami. Drift bottles were supplied and returns processed in a cooperative study of surface currents in the Strait of Yucatan with the Florida State Board of Conservation.

Investigation of the general distribution and abundance of planktonic-stage shrimp continued as before, being supplemented with special studies on vertical distribution and seasonal occurrence of shrimp larvae and postlarvae on the bottom. Since it has not been feasible to collect plankton near the bottom because of damage to the sampling gear by bottom obstructions, the Gulf-V plankton net was modified as shown in the accompanying figure (next page). The skis permit the net to ride over most obstructions and make it possible for samples to be taken approximately 1 ft. off the bottom.

The oceanographic observations made concurrently during biological sampling are being readied for presentation in a Special Scientific Report.

Emphasis at the Miami Field Station is on the ecology of juvenile pink shrimp in Florida Bay. Results of this work will permit an assessment of the effects of expected changes in the environment of Florida Bay due to water control and development projects in south Florida.

The standard Gulf-V plankton net mounted on steel skis and used for sampling plankton near the bottom.

Distribution and Intensity of Shrimp Spawning Activity

From January 1961 through December 1963, almost 200,000 penaeid shrimp representing 13 species were collected systematically on the continental shelf of the Gulf of Mexico between Brownsville, Tex., and Mobile, Ala. Objectives of this extensive sampling activity include determination of the reproductive status of the various species with respect to season and area, and description of their seasonal and areal distributional patterns in terms of environmental factors such as temperature and salinity. Emphasis has been and continues to be placed on shrimps of commercial importance, but information on noncommercial varieties is being obtained as well.

In this study, conclusions regarding the degree and (seasonal) pattern of spawning activity in a particular stock of shrimp are based upon the general stage of ovarian development, as determined microscopically, in adult shrimp sampled from that stock over a fairly long period of time. A comprehensive report which treats analytically the biological material collected and processed for cytological examination during 1961 and 1962 is nearing completion. Some of its conclusions are as follows:

Brown shrimp do not regularly spawn in areas much shallower than about 10 fathoms. At 15 fathoms, however, spawning occurs from March-April through November-December, with the largest number of "ripe" females being found in late summer. Spawning activity is evident the year round between 25 and 60 fathoms and appears to be most intensive during the fall.

White shrimp spawn almost exclusively at depths less than 20 fathoms. In the zone paralleling the $7\frac{1}{2}$-fathom contour, spawning continues from spring to early fall. Females collected from 15 fathoms in the winter and early spring are usually more advanced in ovarian development and probably begin to spawn several weeks earlier than those at $7\frac{1}{2}$-fathoms.

William C. Renfro, Project Leader
Harold A. Brusher

Rearing and Identifying Shrimp Larvae

At comparable stages of development, the larvae of penaeid shrimps are very similar and at times exhibit practically no differences between species. For example, *Penaeus* larvae occurring in the plankton of the northwestern Gulf of Mexico cannot yet be distinguished specifically and must therefore be treated as a single unit. To obtain full benefit from studies of the early life histories of commercially important shrimps, accurate differentiation of larvae is necessary. The presence or absence of specific differences at each larval stage cannot be ascertained until the larval development of the various species is known. Accordingly, this project has focused most attention on rearing penaeid larvae of known parentage and describing their developmental stages in great detail.

The young of penaeid shrimp pass through three larval stages (naupliar, protozoeal, and mysis) before becoming postlarvae. On three occasions, larvae hatched from eggs spawned by captive brown shrimp were reared to postlarvae. On one occasion each, larvae of two rock shrimps, *Sicyonia dorsalis* and *S. brevirostris*, were reared to (first) protozoeae. Eggs were also obtained from pink shrimp and *Trachypeneus similis*, but hatching did not occur. During periods when ripe penaeid shrimp were not available, larvae of other marine forms, such as caridean shrimps, crabs, and nudibranchs, were reared in an effort to improve upon established rearing procedures. Throughout every rearing trial, specimens of all stages of both penaeid and nonpenaeid larvae were preserved for descriptive purposes. Following is a brief discussion of the methods found to be most successful in rearing brown shrimp larvae.

Upon their arrival at the laboratory, ripe female shrimp which, hopefully, will yield viable eggs are placed in Fiberglas aquaria (one shrimp per aquarium) holding 80 liters (84.6 qt.) of water each. Water from the open Gulf with a salinity of from 36‰ to 38‰ is used most frequently, but water from Galveston Island's East Lagoon (28‰) has also been used successfully. Prior to use, the water is filtered through a cellulose filter which has a pore size of 5 microns. During the rearing process, the water is not recirculated, but is well aerated by means of compressed air.

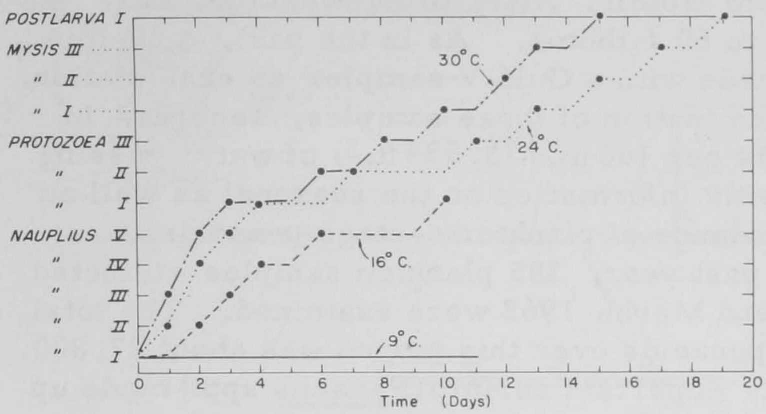
Antibiotics are used only during spawning and hatching and are not added until evening because the brown shrimp spawns at night. When spawning, the shrimp apparently discharge metabolites which greatly enhance the growth of small micro-organisms. The antibiotics do not eliminate these micro-organisms but significantly retard development of their populations for at least 48 hr., thereby allowing time for the eggs to hatch and the larvae to be isolated. Good results have been obtained with a combination of sodium penicillin G and dihydrostreptomycin sulfate in concentrations of 50 international units/ml. and 50 micrograms/ml., respectively.

Brown shrimp larvae are relatively hardy and not prone to injury if handled gently. After hatching, the nauplii are carefully siphoned out of the large spawning aquaria and caught on a stainless steel screen, usually suffering no perceptible damage in the process. They are then placed in 250-ml. (8.4 oz.) beakers, each holding about 100 ml. (3.4 oz.) of rearing medium which is changed daily. Thirty nauplii can be easily maintained in each beaker. When the larvae reach the protozoeal stage, however, their numbers are reduced to 10 per beaker.

Development of a suitable medium in which to rear the larvae has been difficult, as varying results have been obtained with the same type medium in different rearing experiments. Attempts to rear the larvae in unenriched sea water have been unsuccessful, whereas best results have been obtained using "B_5" or "Miquel's" medium with soil extract. It is noteworthy, however, that pereiopods of larvae reared in the B_5 medium retain their exopods when molting to postlarvae. If these "abnormal" postlarvae are maintained in B_5, the exopods remain through at least six molts, but if they are placed in unenriched offshore water, the exopods are shed at the first molt. Similarly, when third-mysis larvae which have been reared in the B5 medium are placed in unenriched offshore water, they molt into normal postlarvae.

A diatom, Skeletonema sp., is used as food for the protozoeal stages; and brine shrimp, Artemia sp., for the later stages.

Temperature greatly affects the growth of the larvae. Temperatures of 28° to 30° C. (82° to 86° F.) are now regarded as the most suitable for laboratory culture of brown shrimp larvae. The most rapid development from time of hatching to first postlarva was 12 days at 29° ± 1° C. Larvae will metamorphose at lower temperatures, but development is slower. The accompanying graph illustrates the results



Growth of brown shrimp larvae at four different temperatures.

of a rearing trial designed to assess the effects of temperature on larval growth. The experiment was initiated with active first nauplii that were hatched at 23.5° C. (74.3° F.). Larvae held at 9° C. (48° F.) were relatively inactive, exhibiting only feeble movement of their appendages while resting on the bottom. In each individual, the yolk was gradually absorbed starting posteriorly leaving what appeared to be an empty space within the body. Appendage movement could still be detected when the rear third of the body was completely void. Those nauplii held at 16° C. (68° F.) were not as active as those kept at higher temperatures, with only a few moving about at any given time. In contrast, all larvae held at 24° and 30° C. (75° and 86° F.) maintained themselves in the water column.

In all rearing trials to date, salinity has been kept above 34‰. As a result, we have no information on what effect a lower salinity might have on rate of development. Eggs, however, have been observed to hatch in water of lower salinity.

Brown shrimp nauplii and protozoeae are positively phototropic and, when reared under an overhead light source, swim to the surface where they may become trapped by the surface tension and die. Their survival is increased by supplying light laterally or rearing them in the dark.

Harry L. Cook, Project Leader

Distribution and Abundance of Shrimp Larvae

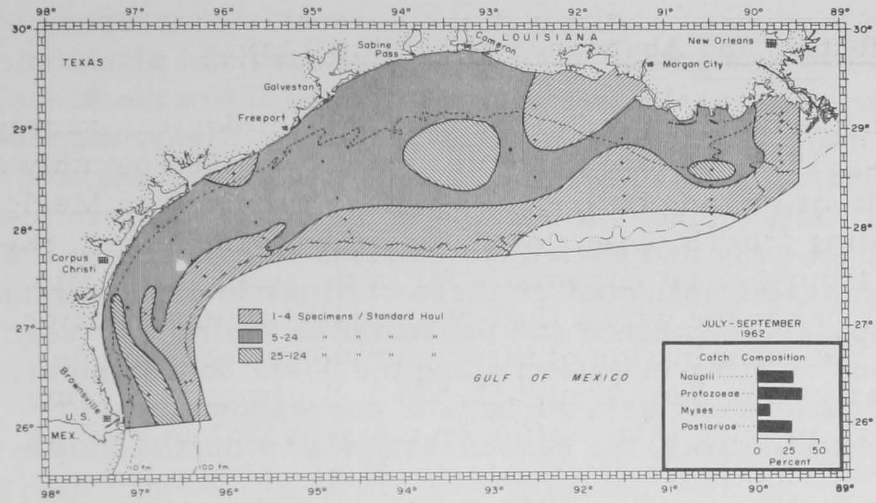
With the continuation of the extensive biological survey initiated in January, 1962, plankton samples were collected monthly at predetermined stations on the continental shelf of the Gulf of Mexico over an area extending from Mobile, Ala., to Brownsville, Tex. Station depths ranged from 4 to 60 fathoms. As in the past, a 20-min., "step-oblique" haul was made with a Gulf-V sampler at each station. Data derived from the examination of these samples, recorded in terms of the number caught per 100 $m.^3$ (3,534 $ft.^3$) of water passing through the sampler, provide information on the seasonal as well as areal distribution and abundance of planktonic-stage penaeids.

During the past year, 385 plankton samples collected between September 1962 and March 1963 were examined. The total catch of planktonic-stage penaeids over this period was about 27,800. The young of commercially important shrimp (Penaeus spp.) made up 20 percent of the catch with noncommercial forms, namely, Trachypeneus spp. (47 percent), Sicyonia spp. (24 percent), Solenocera spp. (7 percent), and Parapenaeus spp. (2 percent), making up the remainder.

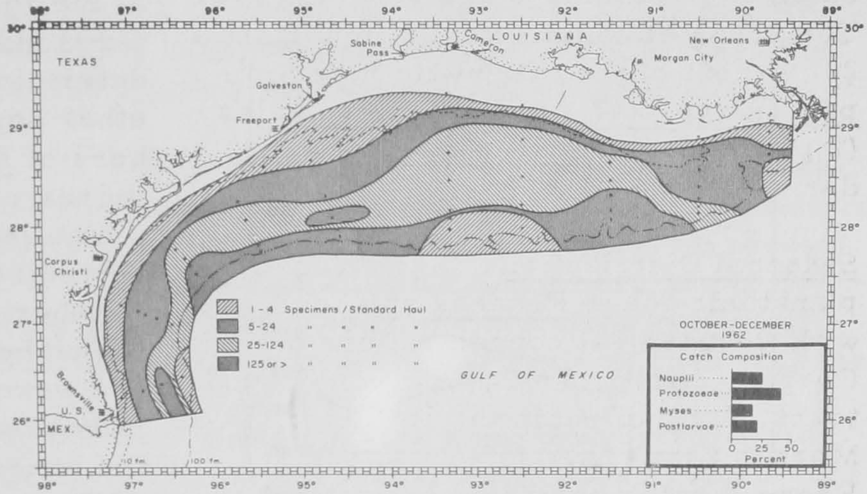
Seasonal Distribution During the period July-September 1962, planktonic-stage Penaeus spp. occurred throughout the sampling area, with the greatest concentrations being evident between Brownsville and Corpus Christi, Tex., in a zone bounded by the $7\frac{1}{2}$- and 15-fathom contours; south of Sabine Pass, Tex., (15-25 fathoms); and southeast of Morgan City, La., (15-25 fathoms). Approximately 65 percent of the Penaeus catch consisted of nauplial and protozoeal stages, indicating considerable spawning activity during this 3-mo. period.

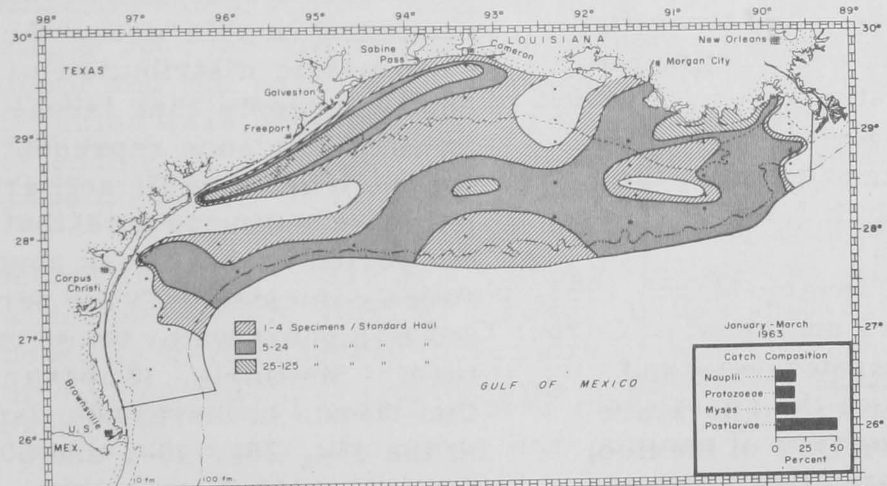
Although restricted for the most part to waters beyond the $7\frac{1}{2}$-fathom curve, planktonic stages of Penaeus spp. occured over the entire sampling area during the period October-December 1962. Greatest concentrations were observed east of Brownsville (25 fathoms) and south of Galveston (35 fathoms). The large numbers of nauplial and protozoeal stages found in the plankton hauls (approximately 65 percent of the total catch for the period) indicated continued spawning activity at this season.

In January-March 1963, planktonic stages were not encountered in waters southeast of Corpus Christi. Moreover, the zone of greatest concentration shifted to the shallower waters of an area which extended along the coast from central Texas to Louisiana. A decrease in the numbers of nauplial and protozoeal stages entering the samples indicated that spawning activity decreased during this period.

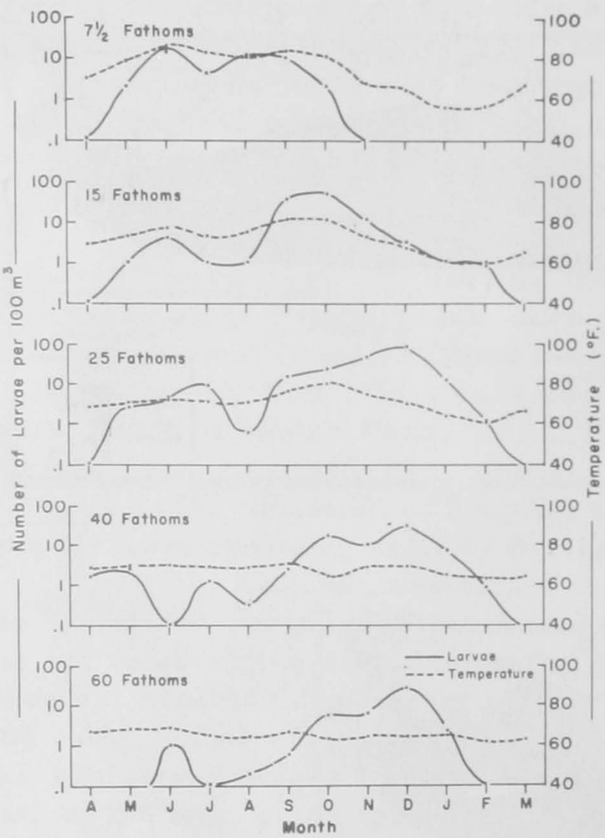


Distribution of planktonic-stage Penaeus in the northwestern Gulf of Mexico during the period July 1962 to March 1963.





Seasonal Trends in Abundance Although the seasonal occurrence and peaks in abundance of *Penaeus* spp. larvae (as distinct from planktonic stages which include postlarvae) varied between transects in the areas off Brownsville and immediately west of the Mississippi River, the differences were so minor that it was felt advantageous to combine all data on a depth-zone basis. Since alterations in the station pattern involving elimination of the 35- and 45-fathom stations were made in 1963, data obtained from material collected at these stations in 1962 were, for comparative purposes, combined and presented as being representative of conditions existing in waters along the 40-fathom contour. The accompanying figure illustrates, along with corresponding average monthly water temperatures, the seasonal trends by depths in larval abundance.



Abundance of *Penaeus* larvae and corresponding bottom temperature in the northwestern Gulf of Mexico, April 1962 to March 1963.

The abundance trend at the $7\frac{1}{2}$-fathom stations differed markedly from those determined for waters in other depth zones. The numbers of *Penaeus* spp. larvae increased in May, maintained a high level during June-September, and decreased in October. During the period November-February, no larvae were caught at the $7\frac{1}{2}$-fathom stations. Although at the present time it is impossible to differentiate between the larval stages of the three commercial species of *Penaeus* occurring in this area, the bathymetric distribution of adults suggests that larvae in this depth zone represent for the most part *P. setiferus*. It is interesting to note that the period of their peak abundance coincided with the period of highest water temperature. Similarly, it appears that trends in larval abundance at the 15-, 25-, 40-, and 60-fathom stations represent, for the most part, those of the brown shrimp, *P. aztecus*.

In waters overlying the other four depth zones, i. e., 15, 25, 40, and 60 fathoms, the seasonal abundance trends were comparable. In each zone there were two periods of larval abundance, one in the late spring or early summer, and another extending from early fall to early winter. Penaeus spp. larvae were considerably more abundant during the second period than during the first. Although heightened larval abundance in waters 15 and 25 fathoms deep occurred at progressively later dates, the peaks observed at stations located in 25, 40, and 60 fathoms were concurrent.

At the 15-fathom stations, seasonal trends in bottom temperature and larval abundance coincided closely. In waters of greater depth, however, this apparent relation did not exist. This observation suggests that in the shallower waters, spawning and larval abundance are related to the absolute temperature or to the rate of temperature change, whereas in deeper waters where the bottom temperature remains relatively stable throughout the year, larval abundance merely reflects the species' normal pattern of reproduction.

Vertical Distribution Short research cruises were made in June, July, September, and November, 1963 in an attempt to describe diurnal changes in the vertical distribution of planktonic stages of penaeid shrimps. At a station 50 miles south of Galveston where water depth approached 20 fathoms, plankton samples were collected systematically with a Clarke-Bumpus sampler at 4-hr. intervals at each of three depths, namely, 1, 10, and 19 fathoms.

During the first three cruises when temperature profiles indicated a vertically stable water mass, catch data grouped over all stages indicated that planktonic penaeids most frequently concentrated at and below mid-depth. Analysis by developmental stage indicated that protozoeal stages occurred most often near the bottom, mysis stages near the bottom and at mid-depth, and postlarval stages at mid-depth and the surface. In addition, short-term changes in depth distribution were observed for the various planktonic stages, with each extending its distribution into the surface layer either just prior to or after the advent of darkness.

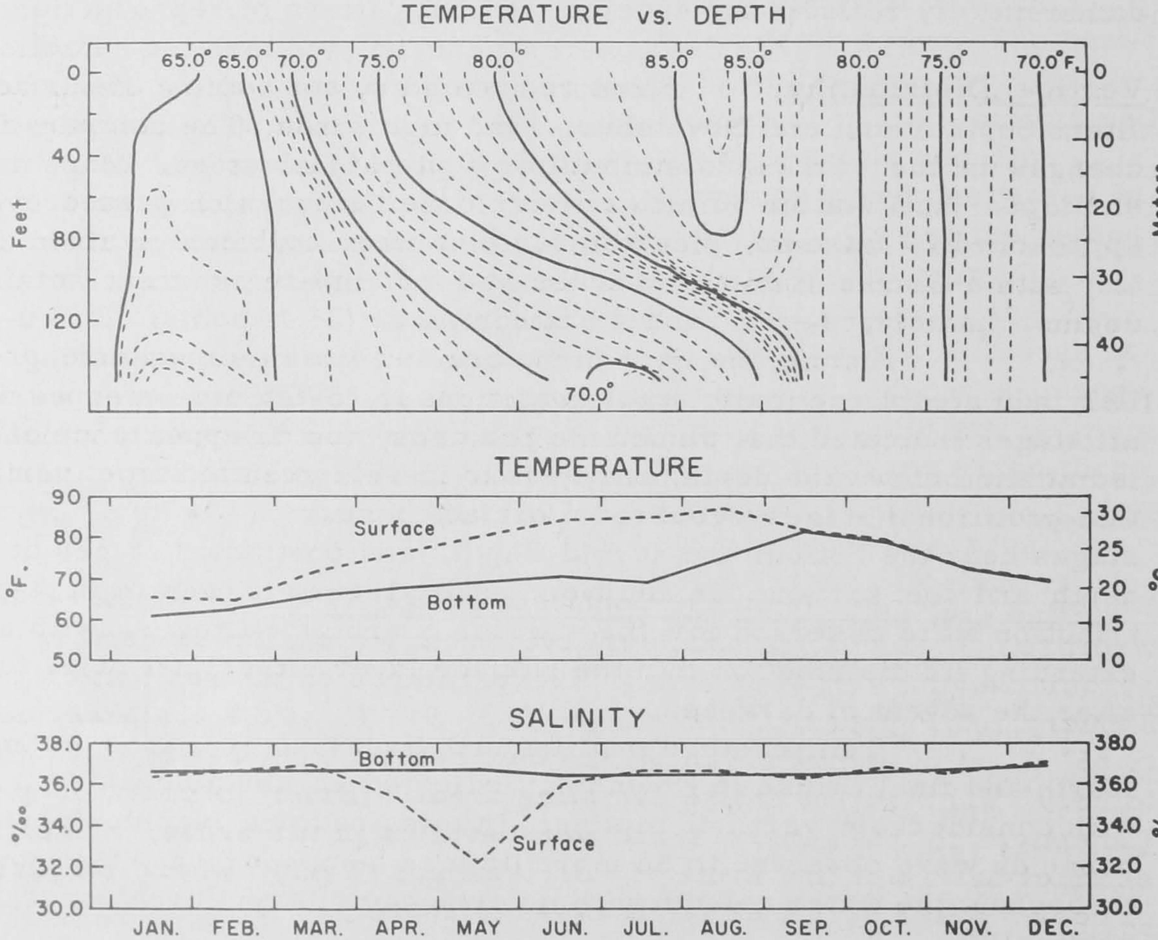
Temperature profiles and visual observations during the fourth and final cruise in November indicated an unstable water mass with considerable vertical mixing. In this instance planktonic-stage penaeids were observed to be more or less homogeneously distributed throughout the water column with no evidence of any diurnal migration vertically.

Robert F. Temple, Project Leader
Clarence C. Fischer

Oceanographic Observations on the Continental Shelf of the Northwestern Gulf of Mexico

Physical oceanographic measurements and meteorological observations are made in conjunction with monthly biological sampling operations at predetermined stations on the continental shelf of the northwestern Gulf of Mexico. (See chart on p. 7.)

Water temperatures are obtained by means of a bathythermograph cast which is made while the vessel is stopped at each sampling station. The instrument's slides are processed and photographed at the laboratory where approximately 1,000 bathythermograms, covering the period August 1962 to June 1964, are on file. In addition to the bathythermograph cast at each station, water samples are obtained at standard depths with Nansen bottles. The samples are taken to the laboratory where salinity determinations are made. Approximately 4,000 samples have been processed.



Seasonal distribution of sea temperature and salinity at lat. 28°18' N. and long. 94°16' W. (25 fathoms, south of Galveston, Tex.) in the Gulf of Mexico, 1963.

Temperature vs. Depth A serial plot of sea-temperature profiles illustrates the seasonal progression of isotherms, depth of thermocline, and time of overturn at each station. An example of such a plot, depicting the thermal conditions which existed in coastal waters of comparable depth, i.e., 20-30 fathoms, over the same period of time, is given in the accompanying figure.

It is evident that distinct thermal conditions prevail within the water column during the different seasons of the year. After initial surface warming in the spring, subsequent mixing caused a similar but slower warming at progressively greater depth, thus producing a negative gradient. The resulting thermocline was most prominent during late June, July, and August, and descended from a depth of about 40 ft. in June to about 90 ft. in August. Following the overturn in September, the water column remained completely isothermal but cooled gradually until the end of the year. In late winter the water column was nearly isothermal.

Overturns are generally caused by either the establishment of thermal convection currents created by the cooling of surface waters, or the occurrence of storms and high winds. The comparatively early overturn at the 25-fathom station south of Galveston, Tex., in 1963 is attributed to the effects of Hurricane Cindy which passed over the Texas coast on September 16-17. Bathythermograms obtained in late September and early October showed a complete overturn at all oceanographic stations along the same contour (25 fathoms) off Louisiana. In contrast, no major storms occurred in this area during 1962, and completely isothermal conditions in 25-fathom water were not observed until mid-November. The decay and disappearance of the thermocline above the 25-fathom contour in 1962 resulted from vertical convection due to the cooling of surface water.

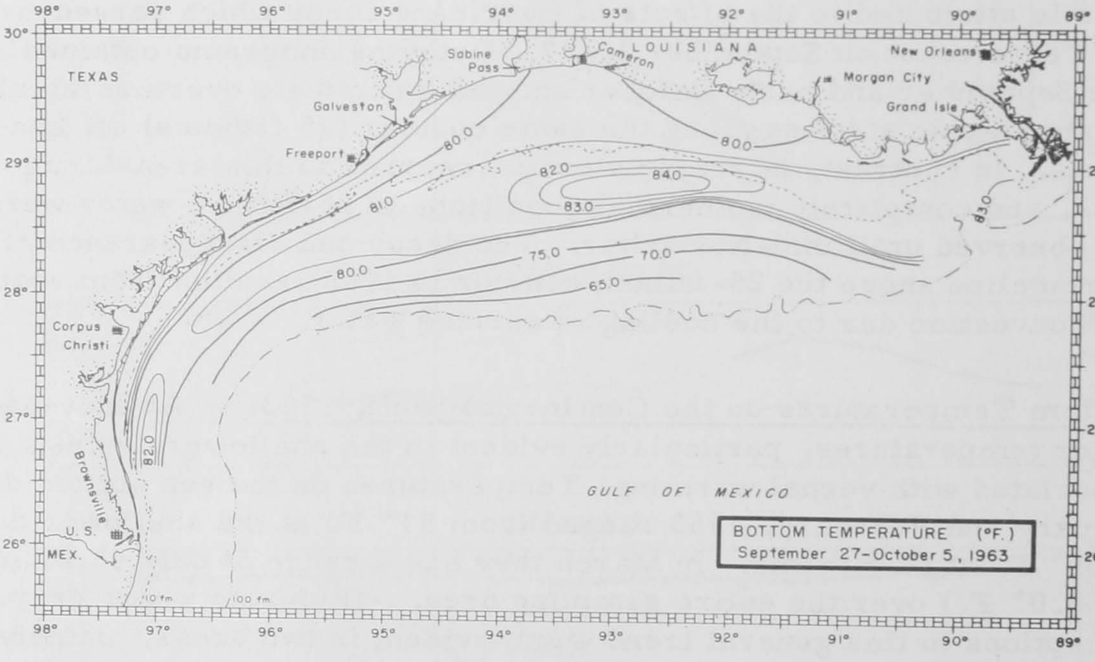
Bottom Temperatures on the Continental Shelf, 1963 An increase in water temperatures, particularly evident in the shallower depths, was associated with vernal warming. Temperatures on the sea bottom during January and February, 1963 ranged from 51° F. at the shallower depths to 65° F. at 60 fathoms. In March they had a range of only 4° F. (64.0° to 68.0° F.) over the entire sampling area. (Refer to chart on p. 7.) Exceptions to this general trend were evident in two areas, namely, south of Galveston and south of Port Aransas (Tex.), where tongues of cooler water persisted fairly close to shore.

During the next two months the bottom temperature regime slowly reversed itself, i. e., warmer temperatures occurred at the shallower depths. In late April and early May, the 75° F.-isotherm paralleled the Texas coast at a mean depth of 12 fathoms. Waters off Louisiana remained somewhat cooler, however, with the 70° F.-isotherm arching well shoreward of the 10-fathom curve. In late May the 75° F.-isotherm moved closer to the Louisiana coast and the bottom temperature at 12 fathoms off Texas decreased slightly. As this reversal was not preceded by a reduction in air (hence surface) temperature, it is assumed that cooling along the Texas coast resulted from advective processes involving the cooler offshore waters.

Examination of bottom isotherms for June revealed a sharp temperature gradient with values ranging from 84.0° F. in the shallower areas near shore to 64.0° F. at 60 fathoms.

Except for an intrusion of cold offshore water which compressed the isotherms off Texas in August, the distribution of bottom temperature in July and August was much the same as in June.

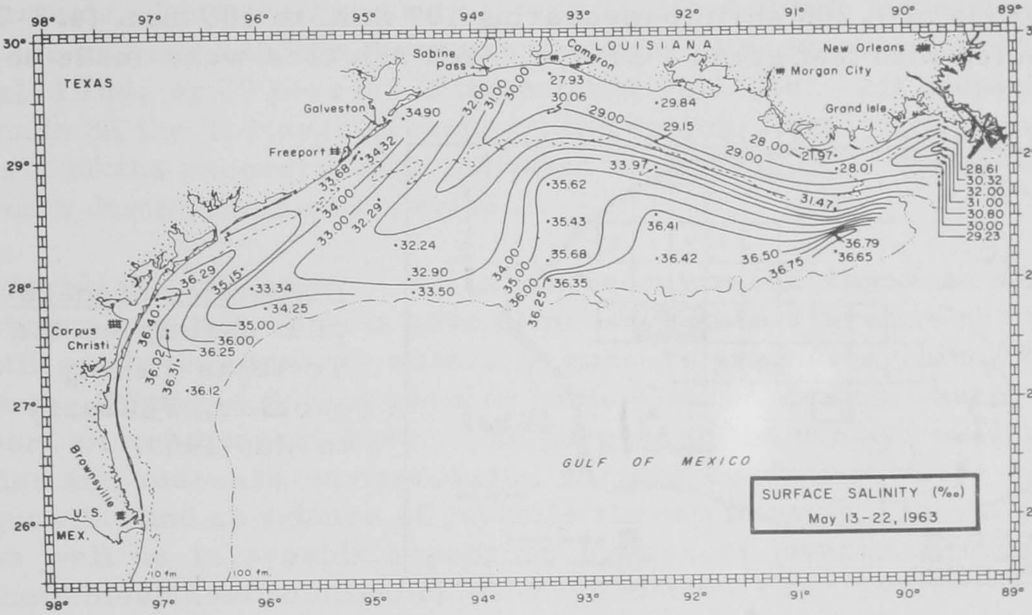
In late September, an isolated patch of 84.0° F. water occurred at 15 fathoms off western Louisiana. (See accompanying figure.) During the same period, the 81.0° F.-isotherm closely paralleled



The distribution of bottom temperature on the continental shelf of the northwestern Gulf of Mexico during late September and early October 1963.

most of the Texas coast where it adjoined near lat. 27°30' N. an extension of slightly warmer (82.0° F.) water from the south. This condition prevailed through October with little variation.

Salinity The distribution of salinity throughout the sampling area exhibits pronounced seasonal differences which reflect variations in the amount of water discharged by the Mississippi River and other freshwater drainage systems. For example, the accompanying figure, based on measurements obtained in mid-May 1963, illustrates the influence of the Mississippi's discharge on the salinity regimen of near-shore waters off Louisiana and eastern Texas.



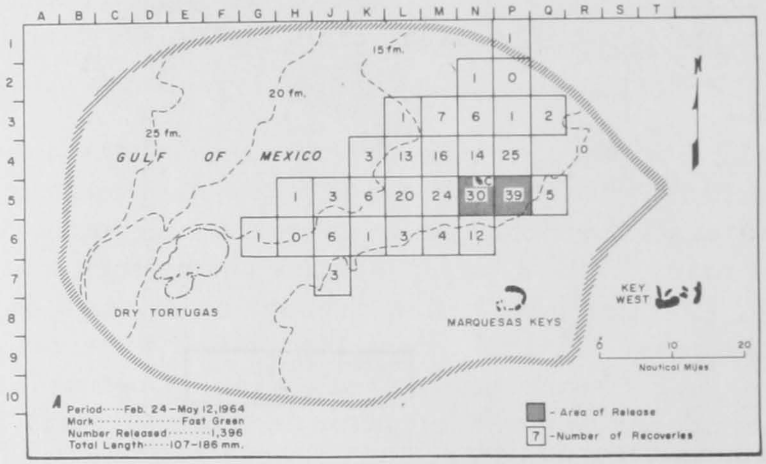
The distribution of surface salinity on the continental shelf of the northwestern Gulf of Mexico from May 13-22, 1963.

David L. Harrington, Project Leader

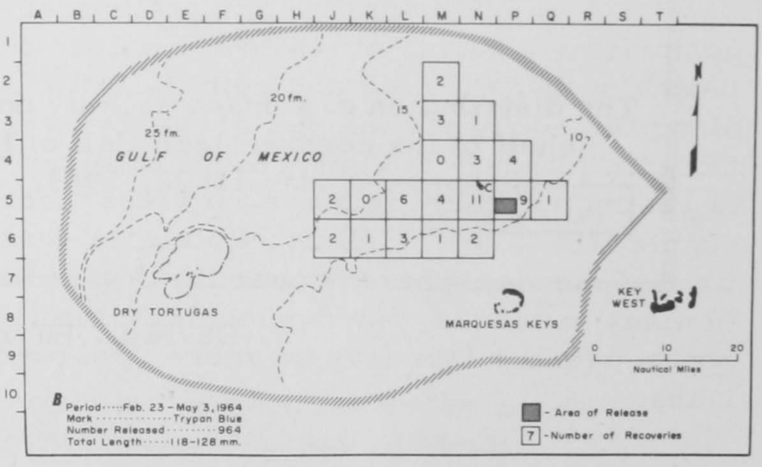
Pink Shrimp Life History

Previous research by the Bureau of Commercial Fisheries in south Florida waters has served to outline the geographic distribution of pink shrimp fished commercially in the Tortugas-Sanibel area. More recent investigations have been concerned with their rates of growth and mortality.

Mark-Recapture Experiments This year, an additional mark-recapture experiment was undertaken to secure supplemental information regarding (1) rates of fishing and natural mortality in the Tortugas pink shrimp stock, (2) rate of growth, and (3) pattern of dispersal. Between February 23 and 24, 2,360 marked shrimp were released on the Tortugas fishing grounds. One group of 964 shrimp ranging in total length from 118 mm. to 128 mm. (4.6-5.0 in.) were marked with Trypan blue dye, while another group of 1,396 shrimp measuring 107 mm. to 186 mm. (4.2-7.3 in.) were injected with fast green FCF dye. All releases were made on the



Dispersion of marked pink shrimp on the Tortugas fishing grounds, February to May 1964.



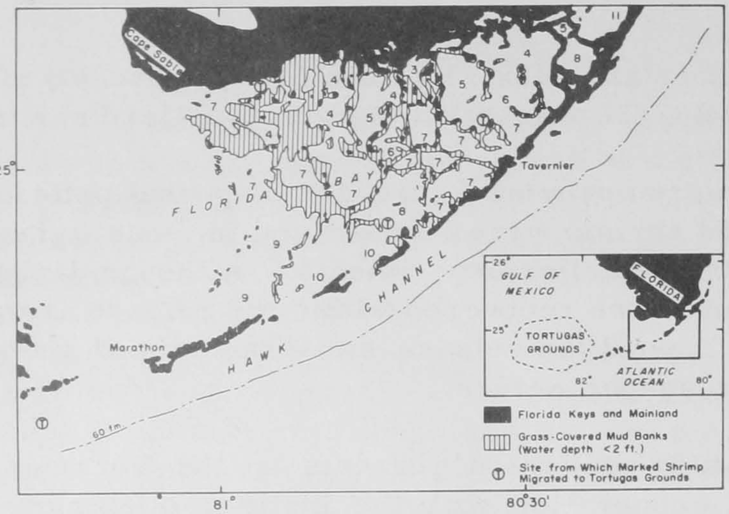
bottom by means of a special release box. By June 5, 67 (7 percent) of the blue-stained shrimp and 307 (22 percent) of the green-stained shrimp had been recovered.

Shown in the accompanying figure, the dispersal patterns of the two groups of marked shrimp were similar and in close agreement with results obtained from earlier experiments. Although large percentages of marked shrimp were recovered within the release areas, those individuals recovered beyond the release sites had moved westward and northwestward into deeper waters.

Bottom Currents A study of bottom currents on the Tortugas grounds was undertaken in cooperation with the Institute of Marine Science, Univ. of Miami, to help explain how (planktonic) larval shrimp are transported from offshore spawning areas to inshore nursery grounds. Between February 17 and March 4, 1964, 360 seabed drifters were released on the Tortugas grounds. Recoveries as of June 4 totaled 104, or 29 percent of the number released. All recoveries were made on the Tortugas grounds by the shrimp fleet. Preliminary analysis of the recovery data indicated a general drift to the west and south during the 3-mo. period.

Florida Bay Ecology Mark-recapture experiments with pink shrimp in south Florida have demonstrated that juvenile shrimp which utilize shallow inshore waters as nursery grounds eventually migrate to the Tortugas fishing grounds in the Gulf of Mexico where they support an important fishery. The purpose of the present study is to define and measure environmental factors conducive to the survival, growth, and abundance of juvenile shrimp in south Florida estuaries, as well as to provide abundance indices of juvenile shrimp prior to their movement to offshore fishing grounds.

Florida Bay and peripheral wetlands cover a vast area comprising a series of shallow, semienclosed basins or "lakes." The depths of these lakes vary from 3-10 ft., with the deepest occurring along the southeast margin of the bay where it adjoins the Atlantic Ocean. Although the interchange of water between the ocean and lakes is restricted, there is some exchange through the narrow channels that connect the lakes. Salinity fluctuates seasonally in the northern portions of the bay, whereas near the ocean margins it is relatively stable. In many instances, environmental variations occurring between depth zones within a lake may be more pronounced than differences between lakes.



Florida Bay, an important nursery area for the Tortugas pink shrimp. (Numbers indicate depth in feet.)

To evaluate the effects of these various environmental factors on juvenile shrimp and to obtain seasonal and annual abundance indices thereof, systematic sampling will be conducted in three or four lakes which have distinct salinity-temperature regimes and varying degrees of circulation.

As in most ecological surveys, however, the problem of obtaining adequate biological samples will not be easily surmounted. Conventional fishing gear is not adequate because pink shrimp usually remain buried during the day. The ideal sampling device would be one that would remove all shrimp (or a constant known percentage) from a unit area of bay bottom.

After studying various localities in the Bay with respect to water depth, bottom type, and submerged vegetation, two approaches to the problem of biological sampling are now being considered. One involves enclosing a defined area and, by means of an air-lift assembly, pumping all shrimp from the bottom mud or sand into a screened container at the surface. There is also a possibility that such a method can use, in addition, an electronic impulse to drive the buried shrimp out of the substrate. In the second method, the shrimp are removed from an enclosed area by means of a "drop trap." This procedure may require the use of a repellent or attractant to induce all shrimp to move out of the substrate and into the trap. Such traps could be fished day or night.

Preliminary results obtained from these sampling methods appear to justify their further development and more rigorous field tests prior to beginning a program involving extensive biological sampling in Florida Bay.

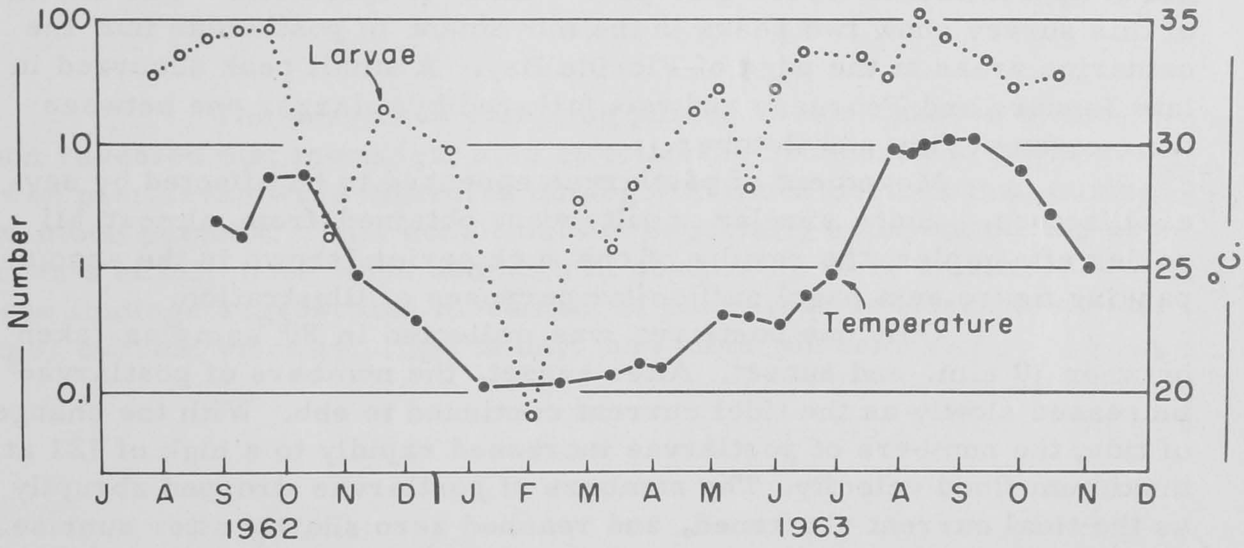
Thomas J. Costello, Project Leader
Donald M. Allen

C. P. Idyll and Albert C. Jones
Institute of Marine Science, University of Miami
(Contract No. 14-17-0002-66)

The Univ. of Miami continued its studies of the abundance and distribution of pink shrimp larvae on the Tortugas Shelf in the eastern Gulf of Mexico. The purpose of this project is to measure seasonal variation in spawning intensity and in survival of larvae.

Plankton samples were collected semimonthly at 10 stations located on a 10-mile-square grid. Two 30-min., "step-oblique" hauls were made at each station with a Gulf-V plankton sampler. During the year, 18 cruises yielding 329 plankton samples were made. Samples were sorted in the laboratory, and the results prepared for electronic processing. Sorting of samples collected during the 1963 cruise was completed, and processing of samples collected in 1964 began.

The 1963 pink shrimp spawning season began in mid-March on the southeastern portion of the fishing grounds, the region in which bottom temperatures were highest. By May, spawning was evident throughout the sampling area (6 to 20 fathoms) and by mid-October, it was largely confined to the northwestern part of the area. Spawning was observed at temperatures below 24° C. (75.2° F.) but generally under conditions of rising temperature such as occur in the spring. Conversely, at temperatures above 24° C. (75.2° F.), spawning intensity was sometimes low under conditions of falling temperature such as occur in the fall. These observations suggest that spawning intensity as well as larval abundance is affected by both the absolute temperature and temperature changes. A more detailed examination of this relation is underway.



Bottom temperature and average number of pink shrimp larvae on the Tortugas fishing grounds.

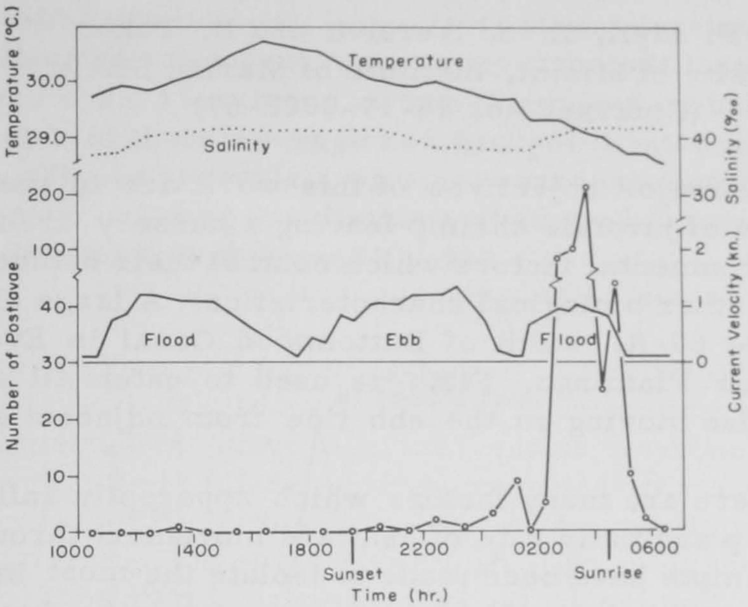
Variability of Larval Counts Information on the variability of the plankton data was gained from a study of the results of paired hauls made in a 10-step-oblique fashion. Such hauls were made successively and in as nearly identical a manner as possible. Statistical treatment of the data showed that the coefficients of variation for estimates of larval density ranged from 1 to 125 percent and averaged 34 percent. In spite of such high haul-to-haul variability, differences in number of larvae between stations and between cruises were significant. In addition, time of sampling did not have a significant effect on the sample catch. In two cases, variability due to time of day was about one-fourth that due to variability between successive samples.

Water Currents in Relation to Postlarval Abundance and Movement
Water currents are important in the transport of planktonic larvae. Previous studies conducted on the Tortugas fishing grounds indicated that resultant currents in this area were generally of small velocity (0.1 knot) and in an offshore direction. In February 1964, the Bureau of Commercial Fisheries and Institute of Marine Science released a number of seabed drifters in the same area to obtain additional information on bottom currents. The study indicated that current drift over the period February-May was about 1 mile per day and was predominantly to the west and south. The lack of any significant onshore drift suggests the possibility that pink shrimp postlarvae actively migrate to estuarine nursery grounds from the spawning area.

The seasonal movement (1962-63) of postlarval shrimp into the nursery areas was surveyed by sampling in Buttonwood Canal, Everglades National Park, with a 3-in. centrifugal pump having an output of approximately 7,575 gal. per 30 min. of operation. The results of this survey show two peaks in the movement of postlarvae into the estuarine areas at the edge of Florida Bay. A small peak occurred in late January and February and was followed by a larger one between the months of July and October.

Movement of postlarvae appeared to be affected by several factors. Since similar results were obtained from almost all series of samples, the results of one such series (shown in the accompanying figure next page) suffice for purposes of illustration.

Only one postlarva was collected in 80 samples taken between 10 a.m. and sunset. After sunset, the numbers of postlarvae increased slowly as the tidal current continued to ebb. With the change of tide, the numbers of postlarvae increased rapidly to a high of 121 at maximum flood velocity. The numbers of postlarvae dropped abruptly as the tidal current slackened, and reached zero shortly after sunrise.



Number of pink shrimp postlarvae per plankton-pump sample from Buttonwood Canal on July 19-20, 1963, together with corresponding data on temperature, salinity, and tidal current.

The results of sampling during various phases of the moon revealed that moonlight also affected the abundance of postlarvae. Fewer postlarvae were collected during full-moon periods than during new-moon periods. This condition was especially apparent during ebb currents at full moon when numbers of postlarvae were markedly low. These findings suggest that movement of postlarvae is affected by tidal stage, current velocity, time of day, and moon phase.

Abundance of Juvenile Pink Shrimp on the Everglades National Park Nursery Grounds

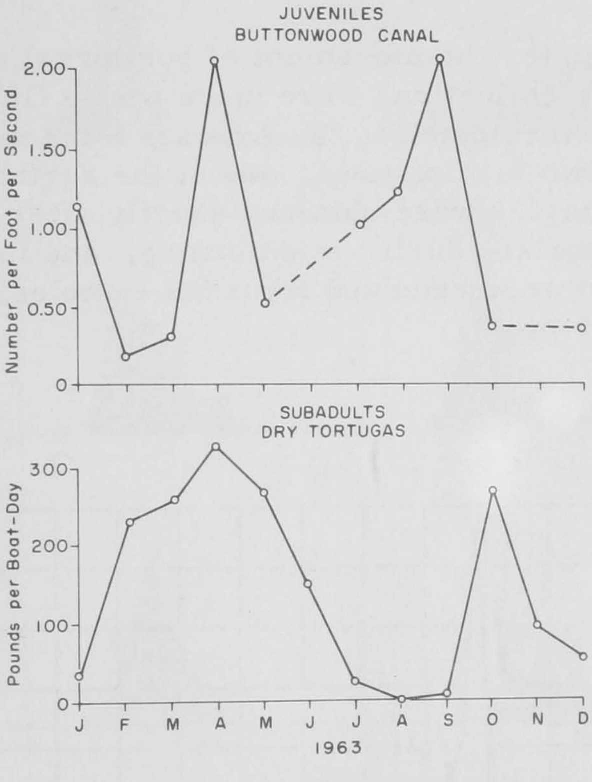
C. P. Idyll, E. S. Iversen, and B. Yokel
University of Miami, Institute of Marine Science
(Contract No. 14-17-0002-67)

The major objectives of this work are to measure the relative abundance of juvenile shrimp leaving a nursery area and to describe the environmental factors which control their numbers, size composition, and other biological characteristics. A large channel net, blocking the entire 60-ft. width of Buttonwood Canal in Everglades National Park near Flamingo, Fla., is used to catch all animals above a certain size moving on the ebb tide from adjacent estuarine areas.

There are many factors which apparently influence the numbers of shrimp and their rate of seaward movement through Buttonwood Canal. Attempts have been made to isolate the most important of these in order to establish a reliable measure of relative juvenile abundance. Results of sampling to date show that two of the more important sources of catch variation are speed of ebbing current and phase of the moon. Other variables which affect the sample catches, such as the time and the magnitude of ebbing tides, are also related to the phase of the moon. In months when samples were collected in ebb currents on or near the new or full moon, the numbers of shrimp they contained were consistently higher than during other moon phases. Current speed is usually higher during new- and full-moon periods, but occasional sampling in tidal currents of comparable speed during quarter- or three-quarter-moon phases did not produce proportionately higher numbers of shrimp.

Now being used as a measure of relative juvenile abundance is the average number of individuals taken during a 30-min. period when the ebbing current exceeds 1 ft. per second, corrected to a standard water velocity. Only those samples taken within 3 days of a new or full moon are used in its calculation. A plot of such measurements for 1963 show that although juvenile shrimp move out of the estuary in abundance in all months of the year, there are distinct seasonal fluctuations. During 1963, peaks in abundance occurred during January, April, and September.

Since sufficient data on the time required for shrimp to appear in commercial catches on the Tortugas grounds after passing through Buttonwood Canal are not yet available, correlations between numbers of juveniles caught in Buttonwood Canal with size of commercial catches offshore are still imperfect. However, the trend in catches of small shrimp (68-headless-count per pound and smaller) taken in depths of less than 15 fathoms on the Tortugas grounds has been examined. A plot of their average catches per boat-day, shown in the accompanying figure, reveals a bimodal seasonal distribution which may be correlated with that of the numbers of shrimp leaving major nursery ground areas through Buttonwood Canal.



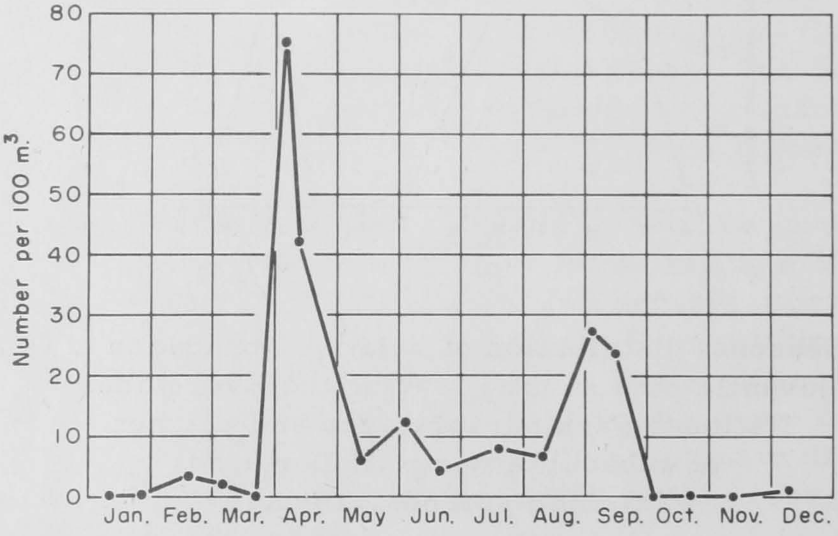
Seasonal distribution of relative abundance of juvenile pink shrimp leaving the Everglades National Park nursery area and catches of subadult shrimp on Tortugas fishing grounds, 1963.

Seasonal Movements of Postlarval and Subadult Shrimp Through Aransas Pass (Texas) Inlet

B. J. Copeland
University of Texas, Institute of Marine Science
(Contract No. 14-17-0002-51)

The Aransas Pass inlet is of vast importance in the life history of penaeid shrimp fished commercially off Texas, since for many miles of coastline it is the only major connection between the shallow bays or nursery areas of the central Texas coast and the spawning grounds in the Gulf of Mexico. A study of the incoming postlarvae and the outgoing juveniles and subadults was conducted between April 1963 and April 1964.

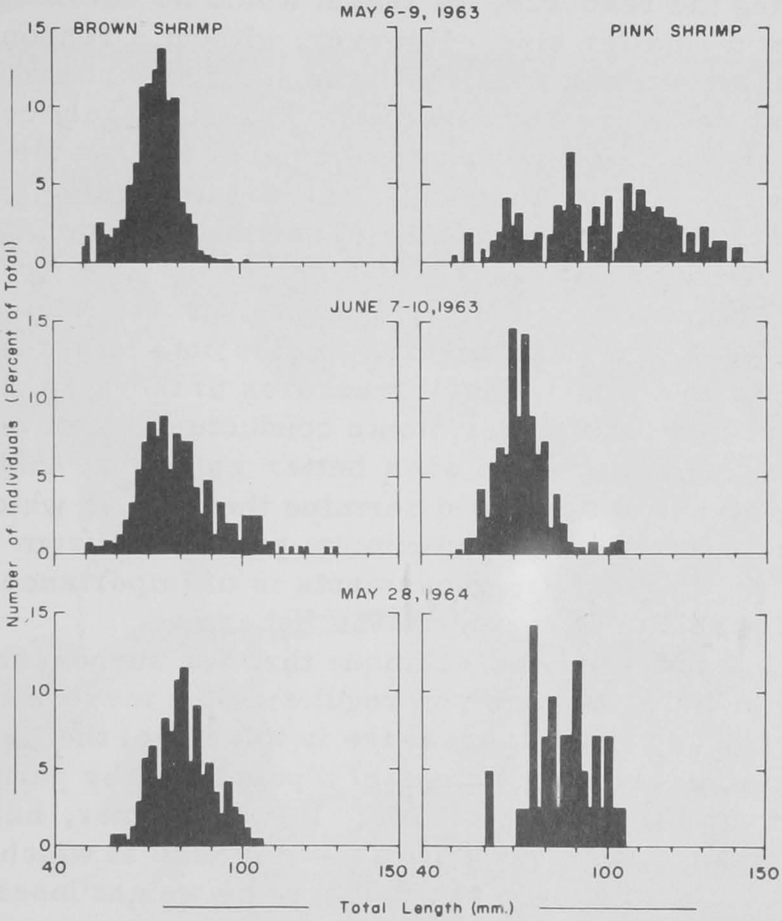
Postlarvae To register the movement of postlarval shrimp into adjoining bays, plankton collections were made with a Gulf-V plankton net at each of three stations located in the Aransas Pass inlet. Sampling consisted of making two 5-min. tows, one at the surface and one just above the bottom. Samples were obtained shortly after sunset, at midnight, just before sunrise, during midmorning, and in midafternoon. All postlarval shrimp were removed from the samples, identified, and counted in the laboratory.



Seasonal distribution of numbers of Penaeus postlarvae entering Aransas Pass inlet (Tex.), 1963.

red in April and August-September, respectively. (See graphs.) They coincided with periods of high tides, which resulted in a net inflow of water from the Gulf, and with periods of heightened productivity in the nearby bays. Temperature observations indicated that in April the waters were gradually warming, whereas during August-September temperatures were decreasing.

Juveniles and Subadults Juvenile and subadult shrimp migrating seaward from the bay nursery grounds through the pass were captured by means of a "tide" trap. Their length frequency distributions are shown in the accompanying graph.



Length frequency distributions of young brown and pink shrimp emigrating through Aransas Pass inlet to the Gulf of Mexico.

It appears that when juvenile and subadult brown shrimp migrate from the bay, their average total length is nearly always the same, namely, 75-80 mm. (2.9-3.1 in.). Because of generally small sample size, the length frequency data presented for emigrating pink shrimp are less significant. The results suggest, however, that although their size range may be quite wide, the majority of pink shrimp average 70-75 mm. (2.7-2.9 in.) total length when leaving the bay system.

SHRIMP DYNAMICS PROGRAM

Richard J. Berry, Program Leader

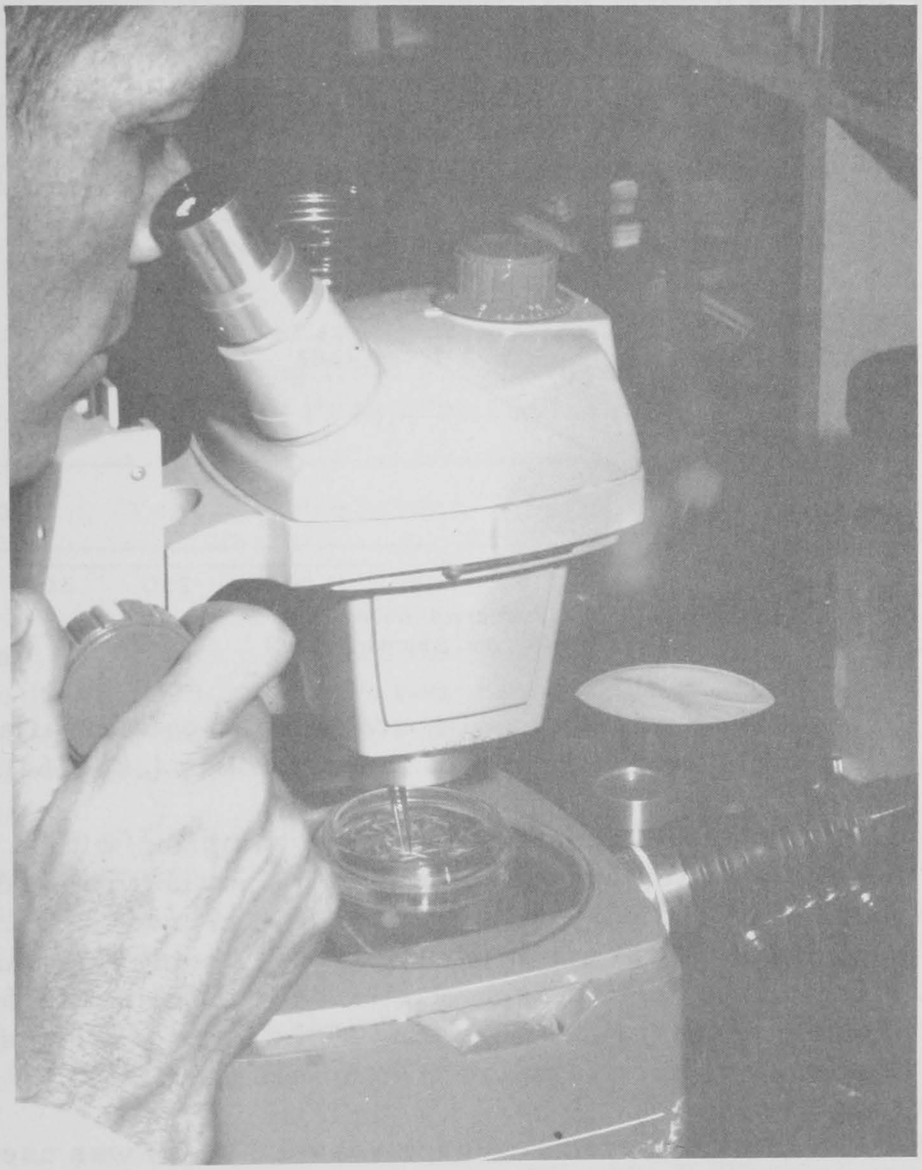
In the same sense that a farm or business must be properly managed if their potential is to be realized, shrimp resources must be used wisely to ensure that high levels of production are maintained. This does not necessarily mean that the harvest of shrimp should be restricted. On the contrary, it is possible that the catch could be increased without harming the resource, or that it would be advantageous to harvest shrimp at a smaller size. However, without a reasonably full understanding of the ways in which both the environment and fishing affect shrimp stocks, decisions about regulations rest largely on opinion. The research of our dynamics program is designed to provide information required to evaluate the effects of fishing and to develop methods which can be used to predict the magnitude of commercial shrimp resources in advance of fishing seasons.

Mark-recapture experiments, using either tags or biological stains as the marking agents, provide data on rates of growth, mortality, and movement. Useful measures of these vital factors have been gained from several experiments conducted recently, and work now being planned will provide even better estimates in the future. Rates of growth and mortality determine the size at which shrimp should be harvested to achieve maximum production from a population. Information concerning movements is of importance in determining the availability of shrimp to the fisherman.

A management technique that has successfully been applied to several fisheries involves regulating the mesh size of fishing gear. The purpose of such a measure is to control the fishing mortality exerted on the young individuals of a population by permitting them to escape through the meshes of nets. In this manner, harvest can be regulated to occur at an optimum size -- the size at which weight gains in the population from growth are balanced by weight losses due to mortality or movement. Whether or not mesh regulations can profitably be applied to shrimp stocks remains an open question, one for which we are seeking an answer through mesh-selectivity studies.

One of the most direct means for obtaining information about the effects of fishing on shrimp stocks is to follow trends in commercial landings. This procedure is facilitated by intensively surveying selected fisheries. Such work is now in an early stage of development but eventually is expected to provide indirect estimates of fishing mortality from measures of fishing intensity and from changes in the size composition of landings.

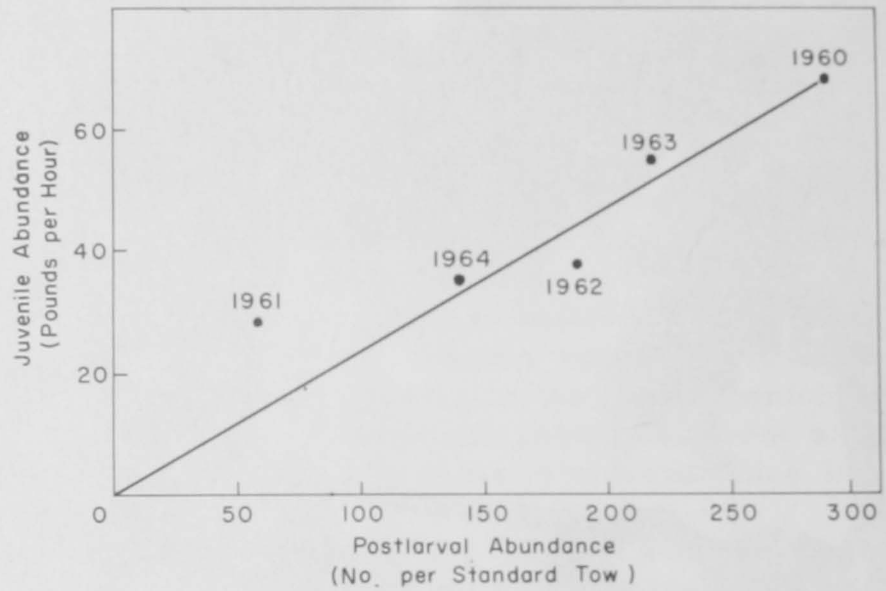
An encouraging degree of success has been achieved in efforts to predict the relative magnitude of offshore commercial brown shrimp production from the earlier abundance of postlarval or juvenile shrimp in estuarine nursery areas. Such studies are now being made at this laboratory as well as at contract agencies in Louisiana and Mississippi. Resulting forecasts can provide valuable advance information to commercial shrimp interests and also add to our knowledge of the survival of various developmental stages in the life of shrimp.



Identifying and counting postlarval shrimp.

Abundance of Postlarval and Juvenile Shrimp

Data on the relative abundance of postlarval and juvenile brown shrimp in Galveston Entrance and Sabine Pass (Tex.) pointed toward a low harvest of brown shrimp along the upper Texas coast during the latter half of the 1964 season. The spring index of postlarval abundance at Galveston showed a 35-percent decline for that for the same period of 1963. Catch-per-unit-of-effort data for juvenile brown shrimp also showed a considerable drop from last year. The accompanying figure shows that the number of brown shrimp postlarvae taken at Galveston Entrance bears a direct relation to the subsequent abundance of juveniles present in Galveston Bay.



Relation between indices of abundance for postlarval and juvenile brown shrimp in Galveston Bay (1960-64).

In mid-March, twice-weekly sampling with a 12-in. Clarke-Bumpus plankton net at two depths in the tidal pass (Bolivar Roads) was begun. The purpose of this work is to investigate patterns of movement of postlarval brown shrimp as they enter the Galveston estuary. In addition, collections were made with a small beam trawl in progressively deeper water beginning at the edges of the pass to determine if postlarvae tend to follow the shoreline during their movement into the bay.

The chartered research vessel GUS III was used to conduct two 72-hr., around-the-clock studies in Galveston Entrance to obtain additional information on the depth distribution and diurnal movements of postlarval brown and white shrimp in the tidal pass. A similar study was conducted near shore at our regular sampling station inside the north jetty during the peak movement of postlarval brown shrimp.

In addition to semiweekly and weekly collections in Galveston Entrance and Sabine Pass, respectively, samples are now being obtained weekly to determine the numbers of postlarvae entering Rollover Pass at Gilchrist (Tex.). Sampling for postlarval shrimp also continues on a weekly schedule at Port Aransas.

The results of three rearing experiments aided efforts to determine the accuracy of our present techniques for identifying postlarval shrimp. These experiments were undertaken in midsummer when it is difficult to separate brown and white postlarvae because of an overlap in their total length. Collections of postlarvae, which included both species, were reared to the juvenile stage in the laboratory. In each instance there was a discrepancy of less than 5 percent between the identification of field-preserved postlarvae and those reared to the juvenile stage in the laboratory.

Juvenile (Bait) Shrimp Bait shrimp production in the Sabine Pass area (Sabine Lake, Keith's Lake, and the Port Arthur Ship Channel) in 1963 was estimated at 78,500 lb. of juveniles taken during 1,282 hr. of trawling, or about 61 lb. per hour. This area yielded nearly twice as many pounds of shrimp per unit of effort as did the Galveston Bay system in 1963. The following table summarizes production from Galveston Bay (2 yr.) and the Sabine Pass area (1 yr.):

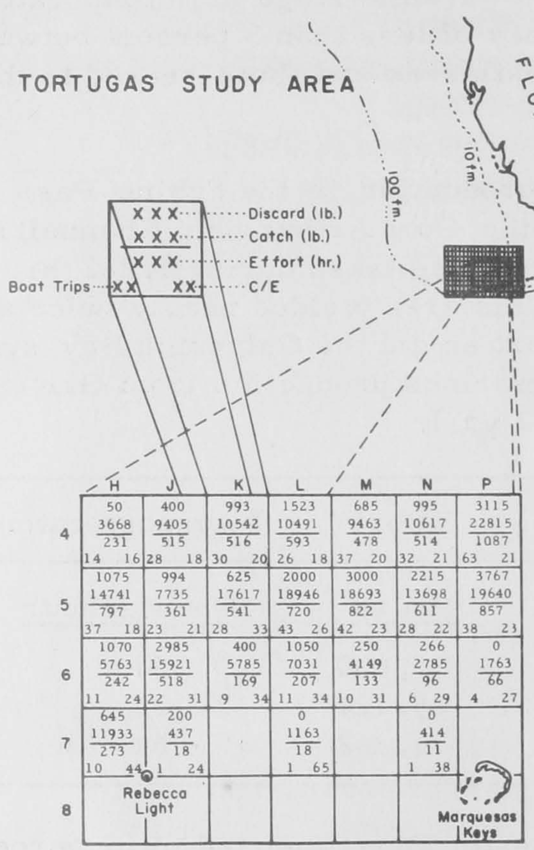
Location	Year	Production	Effort	Average catch
		Pounds	Hours	Pounds/hour
Galveston	1962	1,062,900	33,600	31
Galveston	1963	994,600	29,120	34
Sabine	1963	78,500	1,282	61

The 1963 bait-shrimp catch from Galveston Bay consisted of 61 percent white and 38 percent brown shrimp. The remaining 1 percent was made up of Trachypeneus spp. and pink shrimp. The Sabine area bait-shrimp catch over the same period consisted of 70 percent white and 30 percent brown shrimp. Production totals for Galveston Bay in 1963 indicate that while the harvest of bait shrimp decreased 6 percent from that of the previous year, the average catch per unit of effort increased 10 percent.

Kenneth N. Baxter, Project Leader
Charles E. Knight
Carlton H. Furr

The Tortugas Pink Shrimp Fishery

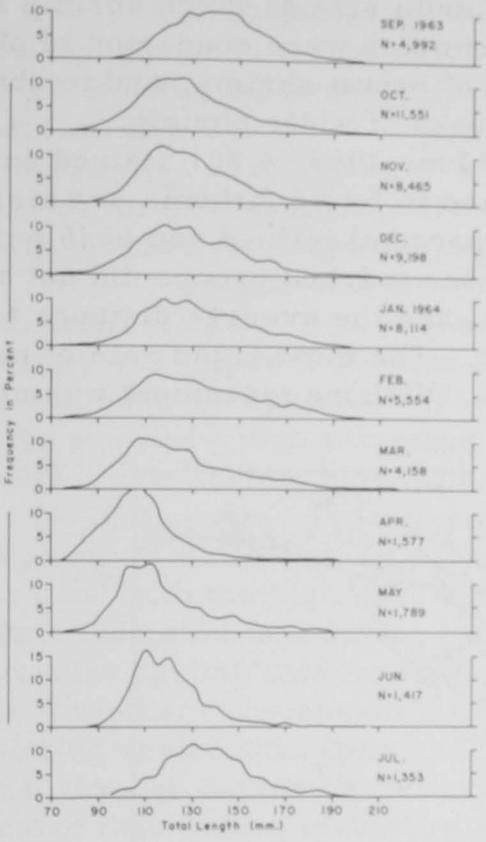
Systematic sampling of commercial catches was extended to the Tortugas (Fla.) pink shrimp fishery in 1963. The boundaries of this important fishery circumscribe an area extending from the vicinity of Cape Romano on the north to just beyond the keys on the south. The seaward limit is set at about the 45-fathom contour by the sparsity of shrimp and by areas of unfishable bottom overgrown with coral and loggerhead sponges. The bulk of fishing occurs in waters 10 to 20 fathoms deep north of a line from the Marquesas Keys to Rebecca light. In contrast to the seasonal distribution of harvests along the coasts of Texas and Louisiana, peak catches of shrimp from the Tortugas grounds are made in midwinter.



Dry Tortugas fishing grounds and the manner in which shrimp fishery statistics are systematically recorded.

Our study area, which includes the most heavily fished portion of the Tortugas grounds, lies between lat. 24°20' and 25° 10' N., and long. 81°40' and 83° 15' W. This region has been arbitrarily divided into 5-mile squares to facilitate the assessment of seasonal changes in catch and effort within specific geographic bounds. The accompanying figure shows a portion of the study area with accumulated information from vessel-captain interviews entered in each square to illustrate the manner in which data are recorded. In addition to information obtained through interviews, our personnel measure shrimp sampled from commercial landings, and periodically make trips aboard shrimp trawlers to observe fishing practices.

Length-frequency data so collected during the past year indicated that the size composition of landings from specific portions of the Tortugas grounds remained fairly stable throughout the winter. (See figure, next page.) This observation, along with catch-per-unit-of-effort data and information concerning the proportion of small shrimp which were discarded at sea, provides evidence of a protracted period of recruitment. The practice of culling and discarding small shrimp continued over the entire season but was confined to waters shallower than 15 fathoms. Estimates derived from interview information showed that



Size composition of pink shrimp landings from 10-18 fathoms on the Tortugas fishing grounds.

approximately 11 percent of the total catch by weight was not landed because the shrimp were too small. Measurements obtained during trips aboard commercial fishing vessels indicated that the size of shrimp selected to be kept or culled varied during the season, apparently in response to market conditions and the availability of shrimp of whatever happened to be acceptable sizes at the time.

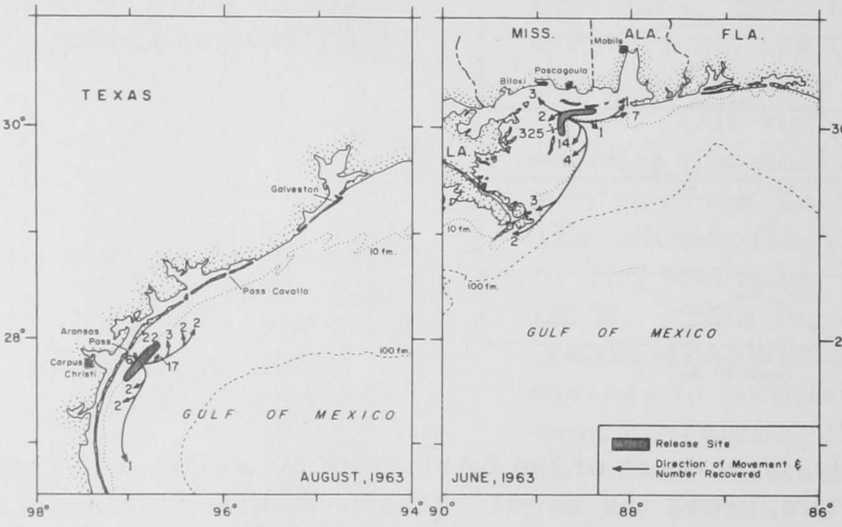
The Tortugas grounds, by virtue of their relatively limited extent and intensive fishery, provide a trial area in which the utility of our methods of collecting catch data can be assessed before they are applied to larger fishing grounds in other parts of the Gulf. Results of the detailed study of the Tortugas fishery during the past year have encouraged us to use similar methods in studies of the brown and white shrimp fisheries along the coasts of Texas and Louisiana.

Ray S. Wheeler, Project Leader
Robert C. Benton
James H. Hudson

<u>Mark-Recapture Experiments</u>

A number of mark-recapture experiments were conducted with white and brown shrimp in the northern Gulf of Mexico during the past 2 yr. These and similar studies in the future are designed to yield information on shrimp migrations, growth, and mortality, which can eventually be used to determine the optimum size at which shrimp should be harvested. During 1963, such experiments were conducted to obtain basic data on the movement and growth of brown shrimp, and to obtain measures of growth and mortality in stocks of white shrimp.

During the latter part of June 1963, 4,801 stained and 1,208 tagged brown shrimp were released in 5 to 8 fathoms of water off the Mississippi coast. Of these, 421 (9 percent) stained and 63 (5 percent) tagged shrimp were returned. Overall, the marked groups did not appear to move quickly from the release areas, and the average distance traveled was much less than 1 mile per day. The most rapid rate of movement observed was 2.7 miles per day. Offshore movement was not



Direction and distance of movement of marked brown shrimp released at two locations off the northern Gulf coast.

apparent, and only 9 percent of the marked shrimp were recovered beyond the 11-fathom depth contour. (See accompanying figure.) Less than 1 percent were taken beyond 16 fathoms. Some shoreward movement was apparent as four shrimp were recaptured in Mississippi Sound. More than 97 percent of the shrimp retrieved had moved less than 13 miles. The greatest movement was about 85 miles from Horn Island to Southwest Pass, the most westerly of the several mouths of the Mississippi River.

Length-at-recapture data revealed not only a difference between the growth rates of male and female brown shrimp but also that during the summer, males and females increase in size in 4 weeks from 4.5 in. (59-count, heads off) to about 5.2 and 5.3 in. (35-count), respectively.

In August, 3,016 brown shrimp ranging from 4 to 5 in. in total length were stained with green dye and released in depths of 10 to 12 fathoms off Aransas Pass, Tex. Of these, 58 were returned, 95 percent of which were recaptured inside the 15-fathom contour and within 30 miles of the release area. The longest movement recorded was 65 miles in a southerly direction. It appears that small brown shrimp in this area disperse parallel to the coastline and seaward.

In mid-August 1963, 3,115 white shrimp ranging in total length from 3.5 to 3.9 in. were marked with green stain and released in Trinity and Upper Galveston Bays. By mid-October, 512 (13 percent) had been recaptured. The distribution of recoveries disclosed that the marked group remained in the upper portions of the bay, although a few shrimp moved seaward, i.e., to the lower end of the bay. No offshore movement became evident during the study period. This group of white shrimp experienced rapid growth that was probably associated with the high water temperatures which prevailed. Resulting data indicated that during the period of study (late summer) the experimental shrimp increased in length to 5.3 in. in 4 weeks, and to 6.0 in. in 8 weeks. The amount of fishing effort expended on the marked population varied with time and declined slowly in magnitude from mid-August through September. Preliminary analysis of the recovery data indicated that fishing mortality ranged from 8 to 24 percent and that the natural mortality was 11 percent per 10-day period.

One of the problems encountered in estimating mortality rates from mark-recapture experiments results from the loss of marked animals which are recaptured but not returned. Errors of this type may seriously affect estimates of mortality, and studies were therefore conducted to determine the percentage of marked shrimp which are overlooked on fishing vessels and in processing plants. These studies indicated that about 17 percent of the marked shrimp caught were not noticed on the fishing boats, and that approximately 18 percent were overlooked in processing plants. Such observations imply that under conditions like those existing during this study, 83 percent of recaptured stained shrimp may be expected to be recovered on fishing boats and 14 percent in processing plants. Three percent will be overlooked.

At present, the most direct means for estimating the growth of shrimp is by mark-recapture experiments using biological stains as marks. Because the stains concentrate in the gills, a question has arisen as to whether or not its presence there affects oxygen uptake and, subsequently, metabolism and growth. To answer this question, a series of laboratory experiments was initiated in which the oxygen assimilated by whole animals as well as gill tissue from stained and unstained shrimp was measured. The results from these studies indicated no difference in oxygen uptake between stained and unstained shrimp. If the oxygen taken up by stained individuals had proved to be lower than that by unstained animals, it could be assumed that stains retard growth.

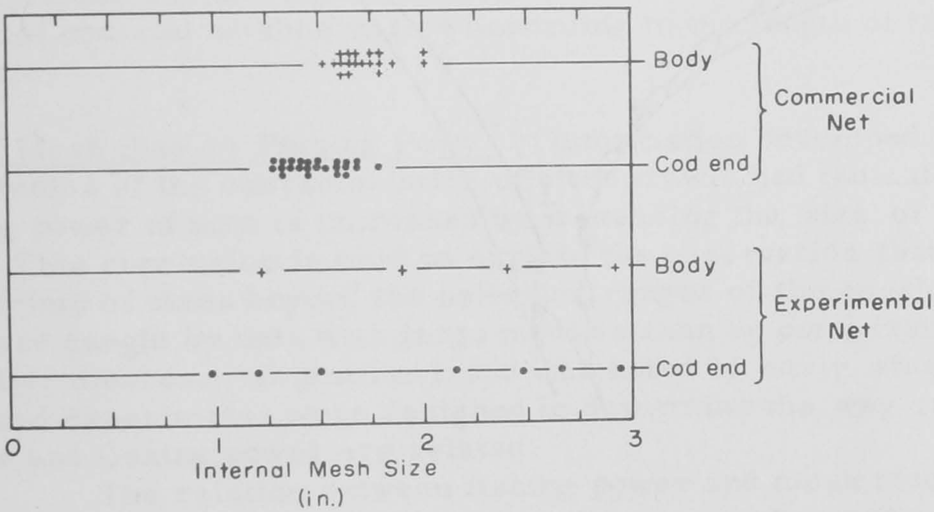
Edward F. Klima, Project Leader
Joseph A. Benigno

Marking shrimp by injecting biological dyes.

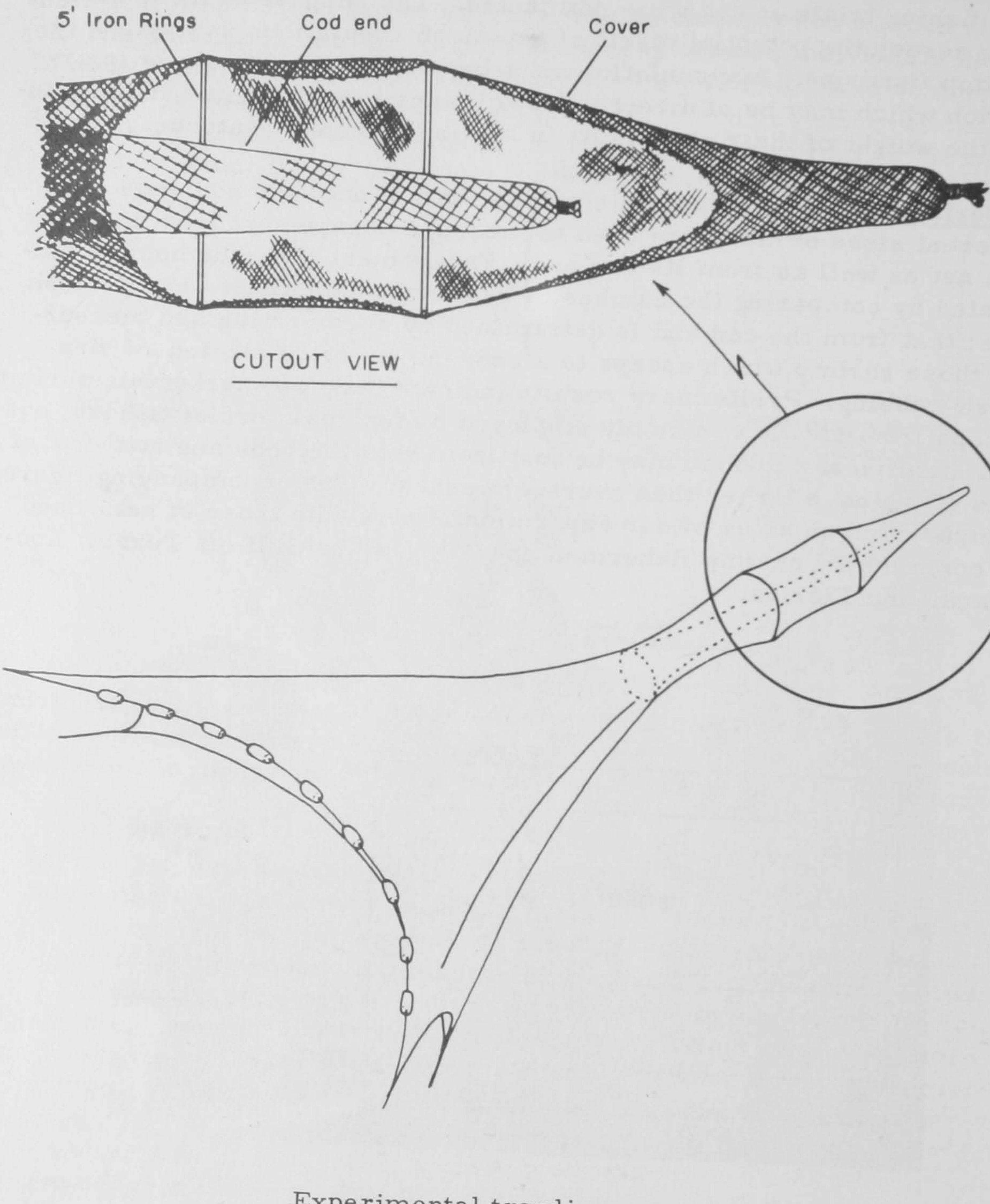
Mesh Selectivity Studies

Studies designed to demonstrate the selective action of shrimp trawls were initiated during the past year, and seven comparative fishing trials at sea were completed. The purpose of these studies is to assess the potential merit of net-mesh regulations as applied to shrimp fisheries. Accumulating as a byproduct of the work is information which may be of direct value to fishermen interested in increasing the weight of their catches or in making "cleaner" catches.

Experimental Nets Various combinations of nets and cod ends with different sizes of mesh are used to measure escapement from the body of a net as well as from its cod end. Escapement from the body is calculated by comparing the catches of two nets which differ only in mesh size; that from the cod end is determined by enumerating and measuring those shrimp which escape to a cod-end cover fabricated of fine-mesh webbing. Preliminary results indicate that few marketable shrimp escape from trawls commonly employed by the commercial fishery, but that significant numbers may be lost from both the body and cod end of nets which have larger than average meshes. The accompanying figure compares mesh sizes of our experimental nets with those of nets used by commercial shrimp fishermen operating in the Gulf off Texas, Louisiana, and Florida.

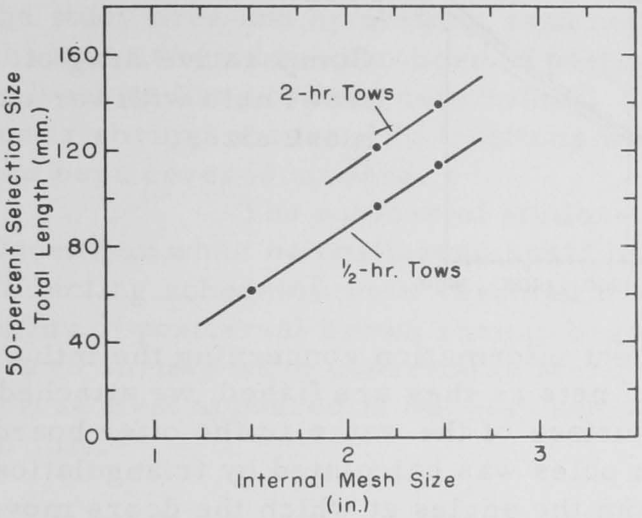


Size of meshes in the body and cod end of shrimp nets.



Experimental trawling gear.

Escapement of Shrimp Many factors influence the selectivity of trawls, including the type of material used for webbing, the duration of tow, the size and composition of shrimp and other organisms the trawl encounters, and environmental conditions which affect shrimp behavior. Within practical limits, we expect to investigate the effects of several of these items. For present purposes, however, we have grouped data in a manner which demonstrates the general nature of cod-end selection, and the difference in the selective action of cod-end meshes that results when a trawl is towed for periods of 30 min. and 2 hr. In the graph below, the 50-percent selection point is the shrimp length at which half the shrimp entering a cod end are retained and half escape. It is apparent from



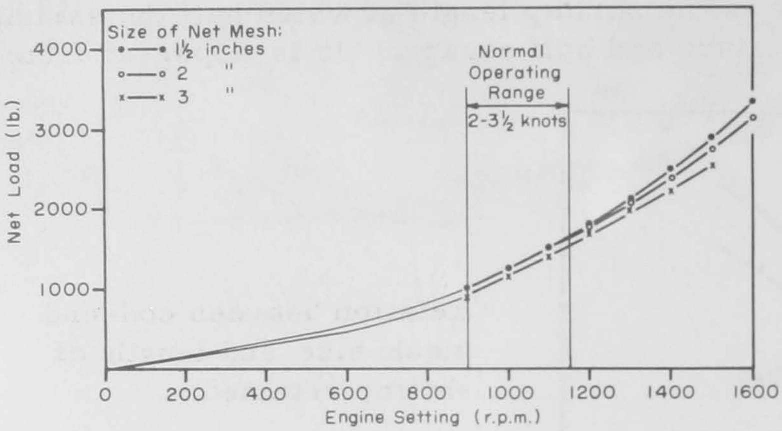
Relation between cod-end mesh size and length of shrimp retained.

these data that a straight-line relation exists between the length of shrimp retained by a cod end and its mesh size. It is also evident that the selective action of cod-end meshes varies according to the length of time trawls are fished.

Effects of Mesh Size on Fishing Power Information developed during several studies of the characteristics of otter trawls had indicated that the fishing power of nets is increased by increasing the size of their meshes. This conclusion is used to explain the observation that more fish or shrimp of sizes beyond the selection ranges of the meshes in question are caught by nets with large meshes than by comparable ones with smaller meshes. A similar trend was noted in early stages of our studies, and experiments were designed to determine the way in which mesh size and fishing power are related.

The relation between fishing power and mesh size is not entirely clear, but it is probable that use of large meshes reduces overall gear resistance, thereby increasing either the distance traversed by a net during a specific time interval (at a fixed power setting), or the width of its opening as it is towed.

Comparative measures of the towing resistance offered by 45-ft. flat trawls of different mesh size, but of similar construction, were obtained by attaching dynamometers to the towing warps. The results of these trials substantiate the supposition that the mesh size of nets affects the ease with which they are towed. Within the normal range of fishing speeds of our research vessel, no difference in the drag produced by $1\frac{1}{2}$- and 2-in.-mesh nets was apparent, but the 3-inch-mesh net produced measurably less towing resistance. (See figure.)



Comparative drag of trawl nets with various mesh sizes.

To obtain more direct information concerning the influence of mesh size on the spread of nets as they are fished, we attached a wooden pole, visible above the surface of the water, to the otter boards of each net. The distance between poles was calculated by triangulation. Correction factors determined from the angles at which the doors moved through the water at a given power setting enabled us to compute the distance between the bases of the doors. These results suggest that the

Mesh size in body of net	Average distance between doors	Measurements
Inches	Feet	Number
$1\frac{1}{2}$	31.0	5
2	31.1	14
$2\frac{1}{2}$	36.1	3
3	37.3	2

catch of large shrimp by nets with $2\frac{1}{2}$- and 3-in. meshes should be approximately 15 and 20 percent greater than the catch by $1\frac{1}{2}$- or 2-in. mesh nets. It must be realized, however, that trawls with large meshes throughout will permit some marketable shrimp to escape and therefore could profitably be used only in certain situations. Further studies are underway to determine the validity of these measurements.

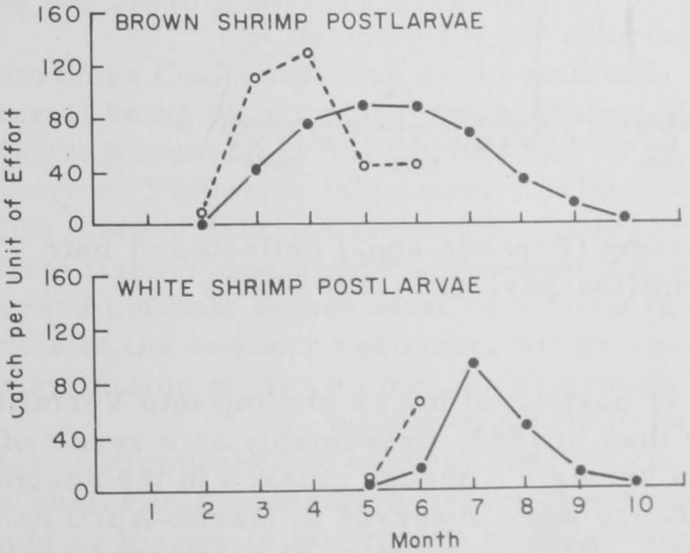
Richard J. Berry, Project Leader
John B. Hervey

Abundance of Postlarval Shrimp in Mississippi Sound and Adjacent Waters

J. Y. Christmas
Gulf Coast Research Laboratory
(Contract No. 14-17-0002-81-A)

The established program for sampling postlarvae of commercial species of shrimp was continued in 1964. Minor changes in the location of several stations were necessitated by dredging operations in the study area and by shifting sand near shore. Whether or not these changes affected the numbers of postlarvae present during sampling operations has not been determined, but there is some indication that fewer shrimp occurred in locations where grass beds or soft bottom had been covered by sand.

The number of stations occupied was reduced in mid-December when no postlarvae could be found in the area. Regular collecting schedules were resumed in early February when the spring influx of postlarval brown shrimp began. Peak numbers of postlarval brown shrimp were observed in March and April. White shrimp postlarvae first appeared in the May samples and reached peak abundance in July.



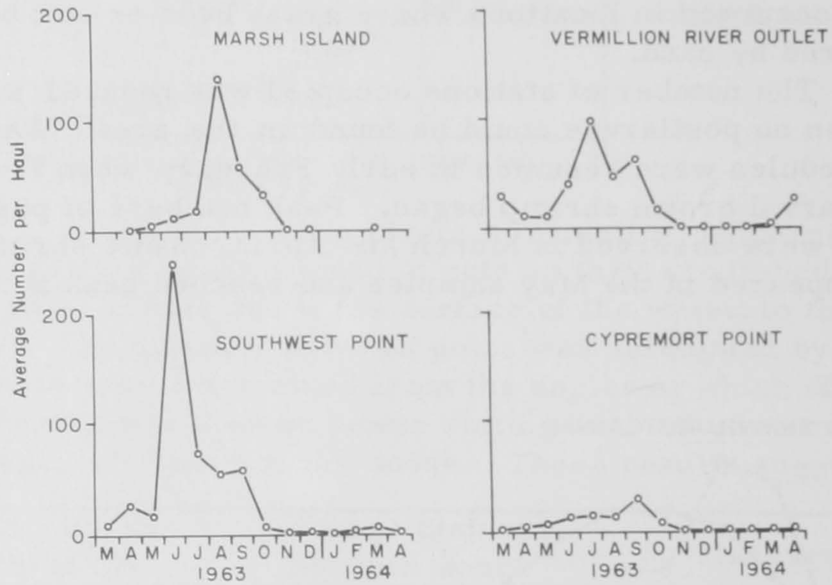
Postlarval catch per unit of sampling effort at seven stations in Mississippi Sound.

Results to date indicate that a reliable index of postlarval abundance in the Mississippi Sound area will require samples from several stations rather than from a single location.

Abundance of Postlarval Shrimp in the Vermilion Bay Area of Louisiana

Charles W. Caillouet, Jr.
University of Southwestern Louisiana
(Contract No. 14-17-0002-86)

Studies of the seasonal occurrence and abundance of postlarval shrimp in Vermilion Bay continued during the year, with samples being obtained at weekly and twice-weekly intervals by means of a 6-ft. beam trawl towed over prescribed distances. Indices of postlarval abundance at each station, calculated for each month over the period March 1963 to April 1964, are plotted in the accompanying figure.



Numbers of postlarval shrimp (Penaeus spp.) collected at four stations in Vermilion Bay, La., 1963-64.

The movement of postlarval brown shrimp into Vermilion Bay took place later this year than in 1963, presumably as a result of lower water temperatures this spring. Although masked in the accompanying figure, peaks of abundance were observed in March-April and again in August-September 1963. No accumulation of postlarvae could be detected outside Southwest Pass prior to their movement into the bay.

Postlarval white shrimp began to appear in samples taken in May. Throughout the period of their peak abundance, they were most numerous in the southern (seaward) portion of Vermilion Bay.

INDUSTRIAL FISHERY PROGRAM

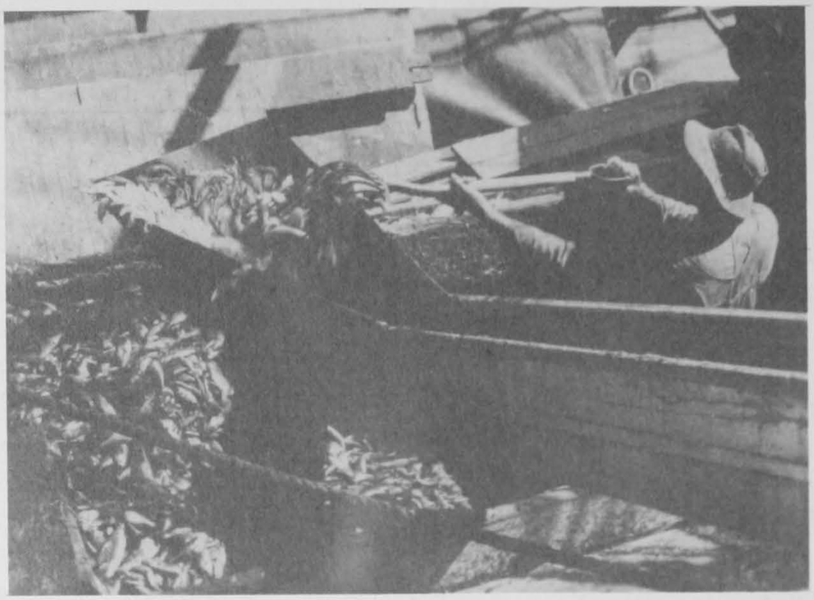
Joseph H. Kutkuhn, Program Leader

Although a preliminary review of associated statistics disclosed that the total effort expended by the industrial trawler fleet rose moderately, landings of miscellaneous bottomfishes for reduction to meal and animal food fell off slightly during the 12-month period covered by this report. This observation suggests that available bottomfish supplies in the north-central Gulf were somewhat less than those calculated for the comparable preceding period. The Atlantic croaker remained the dominant species but its contribution to the total harvest declined appreciably because of, it is believed, temporary unavailability in midseason of its strong 1961 year class. Accompanying the reduced catch of croaker was a corresponding increase in the relative contribution of the spot.

Emphasis continued on the acquisition of information needed to describe the life histories and study the dynamics of various finfishes supporting existent as well as potential industrial fisheries. Sampling of bottomfish stocks along the northern Gulf coast proceeded as before with most biological material being obtained from commercial landings which originate in the Mississippi Delta area. Supplementary material from unfished stocks lying west of this area was again collected systematically during sampling operations conducted by the Shrimp Biology Program.

A detailed survey of Atlantic croaker stocks along the northern Gulf coast was also continued, with additional croaker material being provided by the Alabama Marine Resources and Gulf Coast Research Laboratories, and by personnel at the Bureau of Commercial Fisheries laboratory in Galveston. Incomplete analyses of life history data and fishery statistics indicate that industrial (bottomfish) fishery operations and production in the Delta region are governed not only by seasonal variations in the overall relative magnitude of the croaker resource, but by seasonal differences in the depth distribution of its two major age groups (I and II) as well.

The matter of diurnal changes in the availability of certain bottomfishes to conventional trawls was examined further through a series of comparative fishing trials with midwater and bottom gear, and by means of laboratory studies with groups of fish held (and observed) in a large (28,000-gal.) tank. Gross examination of resulting data has revealed definite differences with time of day in the relative contributions of some species to sample (trawl) catches.



Unloading industrial bottomfish onto conveyor.

Sorting debris and undesirable forms (fish and shellfish with spines or hard body covering) from a landing of industrial bottomfish.

Life Histories of North-Central Gulf Bottomfishes

The industrial bottomfish fishery along the north-central Gulf coast is primarily supported by a single species, the Atlantic croaker, *Micropogon undulatus*, the catch of which leads that of all others both in quantity and value. The 1962 figures show a record production of 28,600 tons having a value when landed of approximately $955,000. Research activity at the Bureau's Biological Field Station in Pascagoula, Miss., has been largely restricted to this species. The immediate objectives of the work are to determine the age and size composition of the exploited stock, and to follow changes in relative abundance with respect to fluctuations in the commercial catch.

Geographical Distribution The croaker is known to be distributed over the area extending from Cape Cod in the Atlantic to Punta Frontera in the southern Gulf of Mexico, where it may be mixed with another species known to be present in the West Indies, and bathymetrically to a depth of less than 65 fathoms. It does not occur uniformly throughout this range, but tends to concentrate in depths of less than 10 fathoms in or near large estuaries along the middle Atlantic coast and the northern Gulf of Mexico. It is also found in greatest numbers during the warmer months of the year when the fish congregate on the bottom in schools of many thousands of individuals. An important commercial fishery for croaker was once prosecuted in the Chesapeake Bay area where it was one of the principal food fishes. Market sizes ranged from $\frac{1}{2}$ to $1\frac{1}{2}$ lb. For reasons unknown, its production declined abruptly beginning in 1948, prompting the need for improved knowledge of the basic features of the croaker's biology and ecology so that causes of such adverse fluctuations in its stocks might be better understood.

The largest commercial landings of croaker in recent years have been made along the northern Gulf of Mexico where they are processed for animal food. Biological research by the Bureau entails, among other things, representative sampling of bottom fish catches from each area of the north-central Gulf over which the trawler fleet operates. Material from inshore waters where the fleet does not ordinarily fish was collected by personnel of the Alabama Marine Resources Laboratory. The distribution of total-length measurements for October 1963 clearly shows that three size groups were present east of the Mississippi River Delta between the Chandeleur Islands, La., and Mobile Bay, Ala. The modal length of fish caught in Mobile Bay and Mississippi Sound was 12.0 cm., or almost 5 in., while that of fish captured

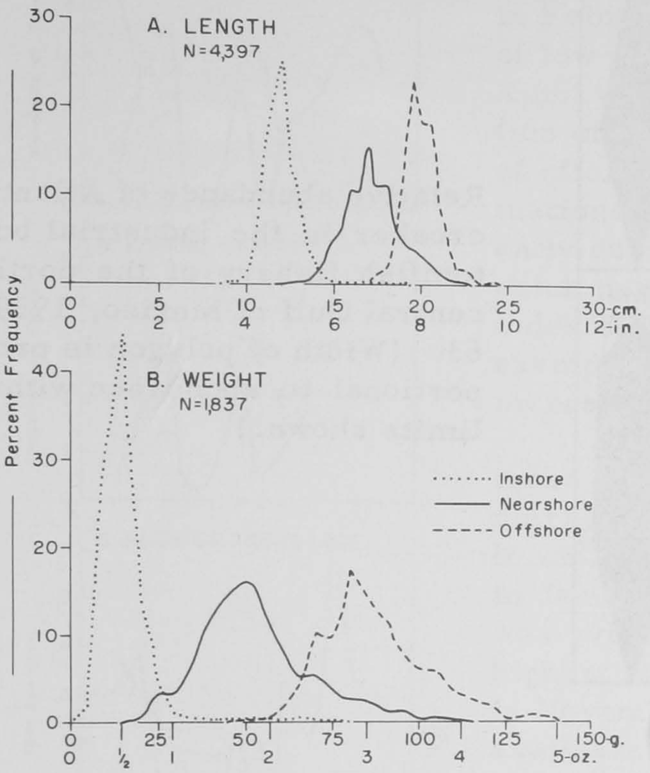
Industrial Bottomfish Landings From the North-Central Gulf of Mexico, 1959-63

[Tons]

Species	1959	1960	1961	1962	1963	Average	Percent
Croaker	20,108	19,185	22,077	28,628	24,814	22,962	56
Spot	5,409	4,565	4,547	4,741	3,772	4,607	11
Seatrout 1/	3,927	4,041	1,946	3,945	2,456	3,263	8
Cutlassfish	1,201	1,969	2,658	2,477	1,635	1,988	5
Sea catfish	1,201	797	1,000	1,213	965	1,035	2
Porgy	733	1,046	974	1,036	780	914	2
All others	7,303	8,627	5,227	6,200	5,153	6,502	16
Total	39,882	40,230	38,429	48,240	39,575	41,271	100

1/ Includes sand and silver seatrouts.

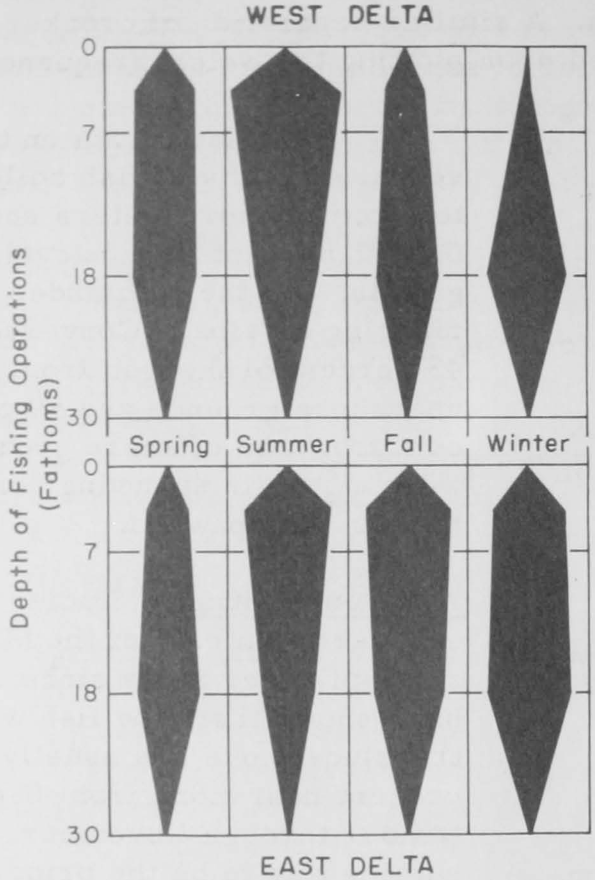
by commercial trawlers at 2 to 7 fathoms in the (nearshore) Gulf was 17.0 cm., or nearly 7 in. Specimens caught offshore in 15 to 40 fathoms during the same period by the charter research vessel GUS III averaged 19.5 cm., or nearly 8 in. A similar separation of croaker into three size groups was achieved upon plotting the weight frequency distributions of the same fish.



Frequency distributions of Atlantic croaker caught east of the Mississippi River Delta, October 1963.

Associated data on the sexual maturity of fish collected from inshore waters showed that 97 percent had undeveloped gonads, and the remainder were ripening or ripe. Conversely, 43 percent of the fish from the nearshore grounds and 59 percent from the offshore grounds were either in spawning condition or had spawned.

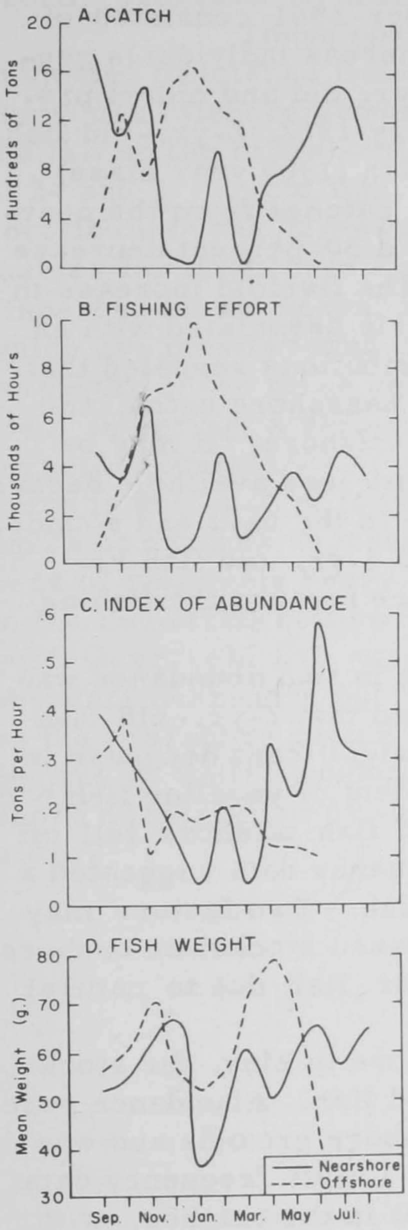
<u>Age Composition</u> Studies of croaker from east of the Mississippi River Delta since 1961 have shown that ripe fish with translucent ova are usually present nearshore from September through November. Assuming this to be the principal spawning period, it is hypothesized that the group represented by 12.0-cm. (5-in.) fish in the inshore waters during October 1963 was spawned in the fall of 1962, and may be identified as the 1962 year class. Somewhat larger fish, i. e., those averaging 17.0 cm. (7 in.) in length and believed to be a year older, constitute the 1961 year class which was spawning for the first time. The group consisting of 19.5-cm. (8-in.) fish which were taken farther offshore is identified as the 1960 year class. It should be noted that croaker in Chesapeake Bay apparently reach a length of 17.5 to 18.0 cm. (6.9 to 7.1 in.) and weigh about 60 g. (2.1 oz.) by the end of their first year, an observation which indicates a greater average growth rate for croaker in that area than for the same species in the northern Gulf. Commercial fishermen operating inshore in Alabama during October 1963 caught fish averaging 30.0 cm. (12 in.) and weighing 441 g. (about 1 lb.). It is estimated that these fish were 5 to 7 yr. old.



Relative abundance of Atlantic croaker in the industrial bottomfish fishery of the north-central Gulf of Mexico, 1959-63. (Width of polygon is proportional to abundance within limits shown.)

Seasonal Abundance by Fishing Area   Season-depth relation for croaker are indicated in the accompanying figure which shows seasonal abundance in terms of average catch per hour of trawling within the depth ranges fished by the commercial fleet over the period 1959-63. A conspicuous feature of conditions prevailing on grounds both west and east of the Delta was the twofold increase in abundance of croaker in nearshore areas from spring to summer. Marked declines in catches nearshore were evident in fall and winter west of the Delta, with an increase occurring offshore in winter. Similar changes of lesser magnitude also appeared east of the Delta. During the present study, the two areas differed significantly as to fluctuation in croaker abundance from winter to spring. Whereas availability nearshore increased markedly during spring west of the Delta, it declined at comparable depths east of the Delta.

Fluctuations in Yield and Abundance A plot of the monthly catches of of croaker caught in the east Delta area over the period September 1961 to August 1962 shows that on the nearshore grounds, the maximum yield occurred in September and was followed by a downward trend (interrupted by a temporary increase in November) with minimal catches in December, January, and March. After a short-term but significant increase in February, during what is usually a period of low yield, a rising catch trend began in April which lasted through July. Examination of associated effort and catch per unit of effort data revealed that seasonal fluctuations in nearshore catches were apparently due to corresponding variations in catch per unit of effort, here used as an index of abundance. Intensified effort, for example, was evidently responsible for the increased yield in November.



Statistics associated with the harvest of Atlantic croaker by the industrial bottomfish fishery east of the Mississippi Delta, 1961-62.

Offshore catches showed a rising trend beginning in October, followed by a marked decrease in November. The maximum catch for the 12-mo. period was made in January. Thereafter a downward trend was evident through June. Abundance was highest in October but decreased markedly in November, with fish being relatively unavailable through the following June. A comparison of yield, abundance, and fishing effort curves shows that the increased offshore catch during October was apparently the result of more fish on hand to be caught. Conversely, the maximal catches during December and January were evidently due to more intensive effort rather than to any increase in numbers. The downward trend in yield between February and June was allied with a decline in abundance as well as fishing effort.

In the case of nearshore catches, the observation that the mean weight of fish increased over the period September to December suggests that relatively large fish were present close to shore in December. It is assumed, however, that they were largely unavailable because of low abundance, such assumption being supported by the low yield at that time. The question then is: Where did the fish go that were present in such quantities in September?

Indirect evidence of an offshore movement was obtained by referring to length frequency data obtained previously. The majority of fish caught nearshore in September 1961 consisted of members of the 1959 year class (2 yr. old), whereas individuals representing the 1958 and earlier year classes (3 yr. old and older) predominated in catches made offshore. By January 1962, 2-yr.-old fish were mainly present offshore, while yearling fish (1960 year class) had made their appearance for the first time in catches from the nearshore grounds. Associated with this event was a 50-percent decrease in the mean weight of fish caught in January. The fivefold increase in fish abundance nearshore in February was clearly associated with an increase in fish weight. Length frequency distributions revealed that 2-yr.-old fish were once more dominant in the nearshore catch, and the assumption is that these had returned from offshore. It may be assumed that 1- and 2-yr.-old fish either became less available because of group dispersion, or they had moved inshore to the bays and sounds. Older age groups consisting primarily of 2- and 3-yr.-old fish remained fairly abundant offshore, however, where most of the fishing took place.

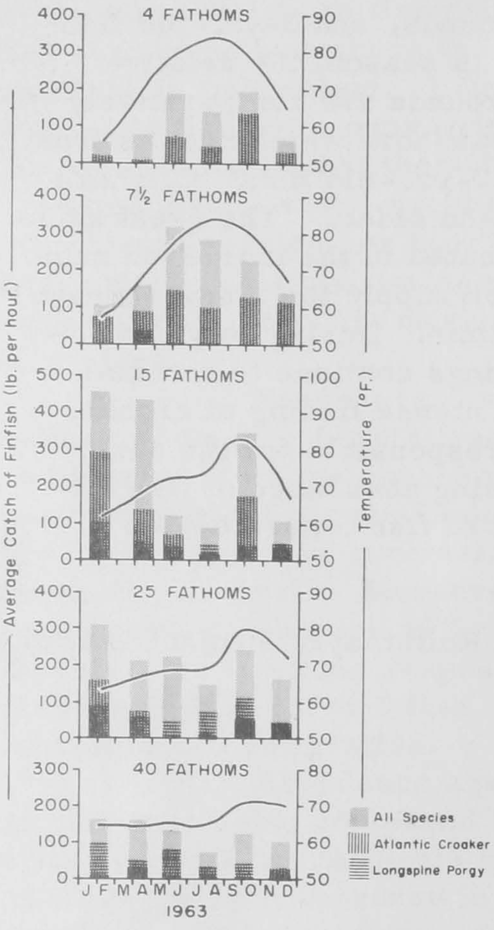
Nearshore, an eightfold increase in fish abundance was evident in April. Length frequency data revealed that 2-yr.-old fish had increased on the nearshore grounds, but a significant decrease in mean weight (20 percent) indicated that recruitment of yearling fish had also occurred. In contrast, the abundance of fish offshore fell off markedly in April. Moreover, the length frequency data suggested a considerable reduction of 3-yr.-old and older fish. Two factors may therefore be assumed responsible for the decreased stocks: an onshore movement of 2-yr.-old fish, and losses of older fish due to natural mortality and emigration.

Abundance again declined nearshore in May, the stock at that time being composed largely of 2-yr.-old fish. Abundance rose sharply to maximum levels in June on the nearshore grounds and was affiliated with an increase in mean fish weight. Length frequency data revealed that 1- and 2-yr.-old fish were present in the catches, with the older individuals being the more numerous. In June, abundance offshore declined to a minimum for the period. The greatest decrease in the amount of fish available nearshore occurred in July. Similarly, mean weight also declined. The corresponding catch of croaker nearshore increased 17 percent over that in June, and was associated with a twofold increase in effort. The abrupt increase in yield and effort may have reduced the abundance of the croaker stock nearshore in July. No samples of croaker were collected from the offshore grounds in July and August. Limited catch and effort data suggest, however, that fish became increasingly numerous on the offshore grounds during August.

These observations show that 2-yr.-old croaker are subjected to intense fishing effort throughout the year on both nearshore and offshore grounds east of the Delta. The population fished in the fall on the nearshore and offshore grounds is principally composed of 2- and 3-yr.-old fish, respectively. By winter, three age groups contribute to the harvest, namely, yearling fish which have left the estuaries for the nearshore grounds of the Gulf, 2-yr.-old fish that are dispersed on the nearshore and offshore grounds, and 3-yr.-old fish which are mostly found offshore. During this season, the relative strengths of the three age groups on both grounds are comparatively low. In spring, a rising trend is evident nearshore which results from increased abundance of yearling as well as 2-yr.-old fish. Offshore there is evidence of loss of fish 3-yr. old and older. The great abundance of croaker nearshore in June is attributed to the increased numbers of relatively heavy 2-yr.-old fish which supply the major tonnage to the industrial bottomfish fishery at that time. During July and August, 2-yr.-old fish supplemented by yearlings continue to remain abundant nearshore but at reduced levels. Intense fishing of croaker on the nearshore grounds in June could be responsible for the sharp decline in their abundance in July. Increasing abundance of fish offshore during summer suggests a movement of fish toward deeper water.

Charles M. Roithmayr, Project Leader

Bottomfish samples for our continuing study of species composition were collected monthly during calendar year 1963 at 41 stations on the continental shelf of the Gulf of Mexico between the mouths of the Mississippi and Rio Grande Rivers, and bimonthly at 10 stations between Mobile Bay, Ala., and the Mississippi Delta. (See chart on page 7 .) At each station, a subsample weighing about $7\frac{1}{2}$ lb. was drawn from the sample catch of fish after its total weight was determined. Samples were collected by a 45-ft. (flat), 2-in.-mesh trawl fitted with rollers and towed on the bottom for 1 hr. The percentage contribution by weight of certain common species which exhibit good potential from a commercial standpoint was used as an index of their relative abundance at various seasons and locations. Trends in size composition and abundance relative to water depth and coastal region have been discussed in earlier reports.



Bottomfish catch per hour (shaded bar) and corresponding bottom temperature (line) averaged over 2-mo. intervals for samples collected and observations made at five depths off Louisiana in 1963.

During Fiscal Year 1964, two cruises were made to study diurnal variation in the species composition of sample catches made at a given location. The trawl, the same kind as used in the study described above, was fished at a given location both on and just above the bottom for about 30-min. periods during various times of day. Twenty-five-pound subsamples provided information on the composition and relative quantity of bottomfishes at each station.

To determine more precisely the probable nature of diurnal activities resulting in variations observed among catches of different bottomfishes, we made provisions to hold and observe fairly large groups of fish at the laboratory. A 28,000-gal., 18-ft.-high, open-top tank of recirculating sea water was fitted with viewing ports at several levels, through which the experimental fish were repeatedly observed for periods of 5 to 10 min. Floodlights were installed in the tank to facilitate observations at night.

Abundance vs. Temperature Average catches per unit of effort for all species combined as well as for the croaker, *Micropogon undulatus*, and the longspine porgy, *Stenotomus caprinus*, alone, are compared with the average bottom temperature over six periods of approximately 2 mo. each during 1963. (See figure.) Catches were made on the bottom at five depths (4, 7½, 15, 25, and 40 fathoms). The catches per hour of sampling effort off Louisiana, which averaged 1½ to 3 times larger than those off Texas, are discussed below. Samples were taken at different times and from fewer locations off Texas, making it undesirable to combine the data from Texas with those from Louisiana.

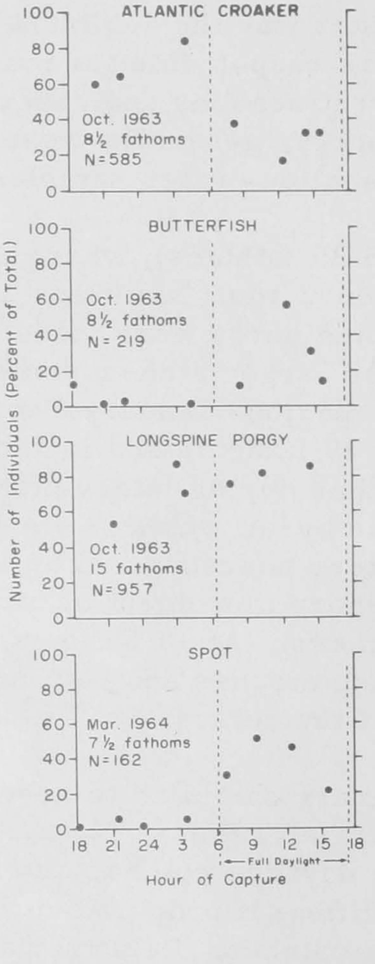
A relation between temperature at the bottom and bottomfish catch per unit of effort became apparent upon analysis of sample material from the shallower depths (4 and 7½ fathoms) off Louisiana -- except for July-August when an unexplained drop in average catches occurred. The Atlantic croaker was the dominant species in most of these catches and was therefore responsible for much of the variation in catch size observed at different seasons and under different temperature conditions. The longspine porgy, generally most abundant in deeper water, was usually scarce in shallow-water samples except during March-April.

At intermediate depths (15-25 fathoms), where the highest average bottom temperatures occurred 2 mo. later than at shallower depths, sizeable catches of longspine porgy were made in all seasons. The Atlantic croaker dominated large catches made off Ship Shoal and Southwest Pass during the periods January-February, March-April, and September-October at 15 fathoms and in January-February at 25 fathoms. The large catches during late winter and early spring were probably made possible by an offshore movement of croakers from the colder, shallow waters nearshore. The increased catch in early fall coincides with the offshore movement of croakers reported for this season by previous workers. At 40 fathoms, where the longspine porgy predominated, both fish catches and bottom temperatures were fairly uniform throughout the year.

Catch vs. Hour of Collection. Preliminary sampling to assess variability in trawl catches was conducted off Galveston at 7½ fathoms in June 1962. This study indicated that the daytime catches of each of four species of fish contributed a much different proportion to the total catches than did the respective nighttime catches. Relative catches (by number) of Atlantic croaker and star drum, *Stellifer lanceolatus*, were greatest at night, whereas those of sand seatrout and silver seatrout, *Cynoscion arenarius* and *C. nothus* (combined), and cutlassfish, *Trichiurus lepturus*, were greatest during daylight. Catches of another important bottomfish, the southern kingfish, *Menticirrhus americanus*, exhibited no discernable diurnal variation.

Further studies of diurnal variation in the capture of these and other species were undertaken in Fiscal Year 1964. In addition, some of the causes of such variation were studied experimentally at the laboratory.

Atlantic croakers constituted 60 percent or more of bottom trawl catches at night and less than 40 percent in daylight during a study conducted at $8\frac{1}{2}$ fathoms in early October 1963. (See figure.) In catches during the daylight, croakers were generally replaced by the butterfish, Poronotus burti, which constituted less



Catch of four species of fish at various times of day, expressed as percent by number of total catch per trawl haul.

than 2 percent of the fish caught at night, instead of by seatrout as in the previous (June 1962) study. Few seatrout were caught at any time during the study of October 1963. When the trawl was fished with its leadline about 6 ft. above the bottom during daylight, croakers constituted about the same proportion (20-28 percent) of the total catch as when the trawl was fished on the bottom, whereas at night they made up less than 4 percent of the catch when the trawl was fished above the bottom. Thus, the diurnal variation in croaker catches made 6 ft. off the bottom was inverse to that of catches made on the bottom, suggesting that much of the variation in bottom trawl catches was caused by the movement of sizable segments of the croaker population slightly off the bottom during daylight.

The longspine porgy, caught in a series of samples trawled from 15 fathoms, constituted more than 50 percent by number of both day and night catches. This species exhibited no noticeable diurnal variation in susceptibility to capture.

Significant diurnal variation in catches of spot, *Leiostomus xanthurus*, was noted in a series of samples collected at $7\frac{1}{2}$ fathoms during March 1964. The spot made up 20-50 percent of the fish in each sample collected during daylight, and less than 5 percent in those collected at night.

Forty Atlantic croakers placed in the previously described tank of sea water were observed, throughout each of a series of 5-min. observations in September and October 1963, to be generally more active during daylight. In daylight, they swam 6 or more feet above the tank bottom one-fourth to one-half of the time, whereas at night they never rose higher than 6 ft. above the bottom. During a similar series of observations in January and February 1964, the experimental croakers were less active and never moved higher than 6 ft. off the bottom even in daylight.

Donald Moore, Project Leader

ESTUARINE PROGRAM

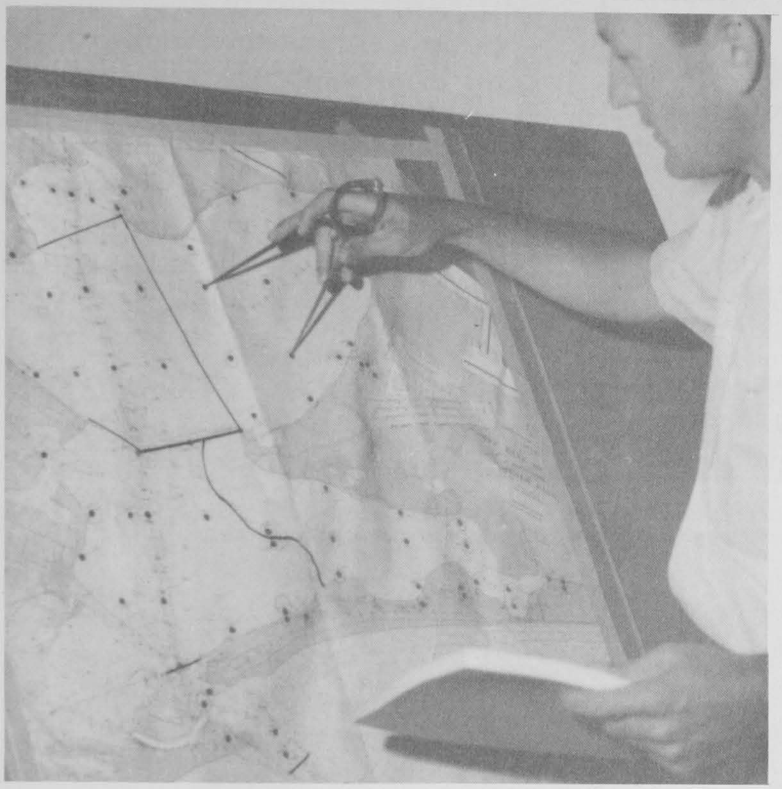
Charles R. Chapman, Program Leader

Understanding the role of the estuarine environment in their maintenance is prerequisite to the intelligent management of fish and shellfish resources that support important commercial fisheries in the Gulf area. Such understanding becomes doubly significant when one recognizes that the estuaries themselves are rapidly being exploited in a manner that is frequently detrimental to the living resources they harbor. Thus, modification and frequent destruction of estuaries by an ever-increasing number of engineering projects prompted the implementation of a research program several years ago to study these complex, but highly productive ecosystems.

Research in the Galveston estuary has progressed to the point where we can now predict with reasonable accuracy the seasonal patterns of distribution as well as the size composition and abundance of numerous fish and shellfish species of commercial importance. Many species tend to concentrate over relatively small areas of the estuary shortly after arriving from the Gulf. As they grow, however, they disperse from these restricted locations and occupy ever-larger portions before eventually returning to the Gulf. Significantly, it is now possible to identify those parts of the estuary which constitute the most important nursery areas during the various stages of a species' estuarine development.

The physical, chemical, and biological characteristics of these nursery areas are also being assessed to determine why such areas are unique and why certain species demonstrate a preference for one location over another. Ultimately, our research should permit us to classify the entire estuary and rate each of its ecological subdivisions in terms of its relative contribution to the maintenance of commercial and recreational fishery resources. As important but probably more difficult will be the predetermination of the degree to which one type of area would be modified and transformed into another by various kinds of construction projects and the diversion of fresh water.

Assessing the anticipated effects of water development projects continued to require considerable effort. In this activity, knowledge of the role of stream discharge in relation to the capacity of an estuary to sustain commercial and recreational fishery resources at high levels of productivity has become increasingly important. It has been estimated, for example, that Texas estuaries will lose, on the average, half of their historical supply of tributary fresh water by the year 2010, with expectations that more than 80 percent would be diverted during subsequent dry years. Unless modified, the single largest water development project yet proposed, the Texas Basins Project, would be responsible for about one-third of this loss. Simultaneously, the discharge of pesticides, herbicides, domestic sewage, and industrial wastes into Gulf coast estuaries is expected to increase.

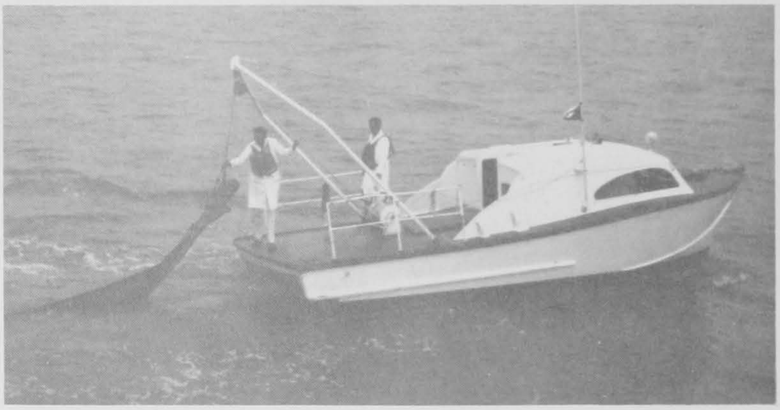


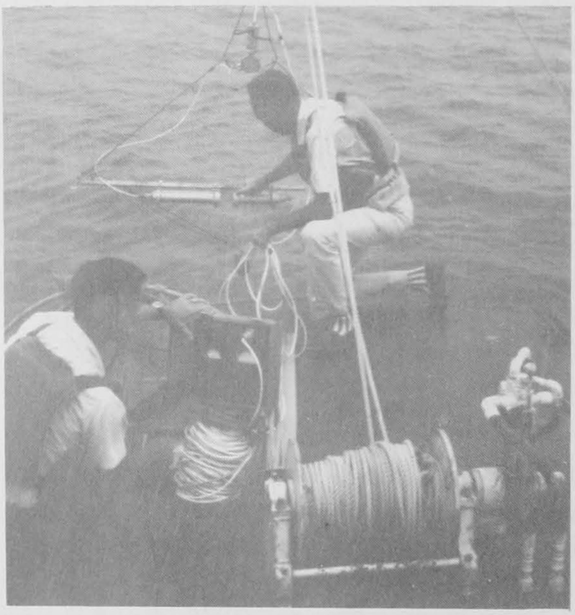
Biologist plans collecting trip in the Galveston estuary. Material obtained will be returned to the laboratory for study.

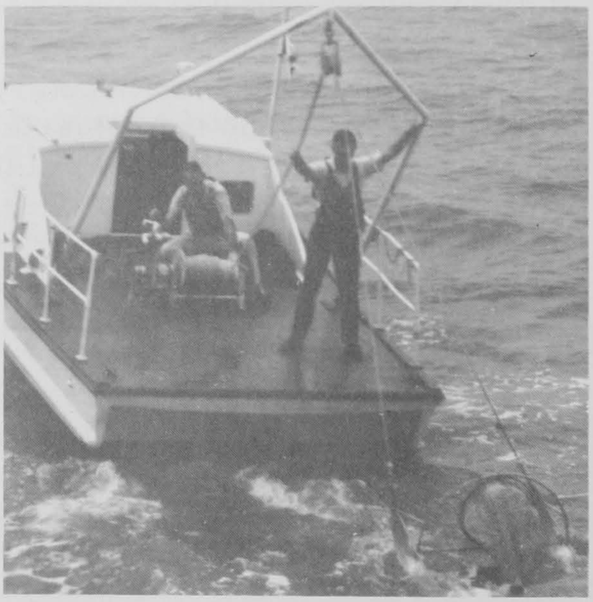
In evaluating the anticipated effects of reduced tributary discharge, preliminary estimates were developed which indicate the relative contribution to the State's overall commercial seafood harvest of fishery resources inhabiting each Texas estuary. It is evident therefrom that estuaries in the eastern part of the State, which receive relatively large amounts of tributary water, contribute much more to the total harvest than do the estuaries and coastal lagoons of the semiarid southwest. Efforts to establish the role of stream discharge in estuarine productivity have not progressed far enough, however, to permit specification, with certainty, of the minimum annual discharge required by each estuary. It must be emphasized that considerable study will be required to resolve the many problems posed by plans to divert fresh water from the estuaries.

Our research facilities during the year received a big boost when the new tunnel-stern vessel REDFISH was delivered. We continued to enjoy excellent cooperation with the Texas Water Pollution Control Board and the U. S. Army Corps of Engineers in the exchange of hydrological data from the Galveston estuary.

The 28-ft., tunnel-stern REDFISH, capable of operating in only $1\frac{1}{2}$ ft. of water and having a cruising speed of 25 m.p.h., is ideally suited for estuarine research.







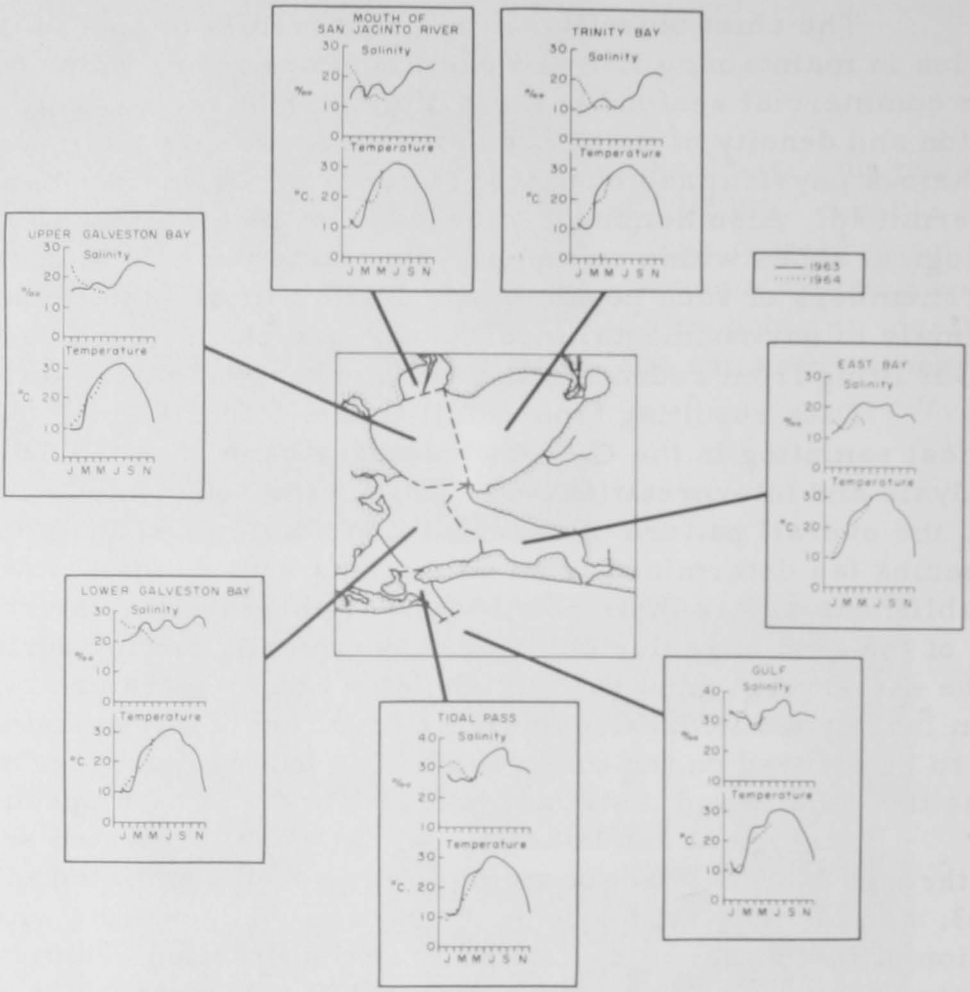
The chief objective of this research is to assess the role of estuaries in maintaining fish and shellfish populations which contribute to the commercial seafood harvest of the northwestern Gulf. The distribution and density of these populations, as well as their relationship to various physical and chemical features of the environment, need to be determined. Also helpful is knowledge of the extent to which various ecological zones within an estuary constitute the habitat of the young and adult members of such populations. Furthermore, the response of these animals to environmental modification and change, including changes resulting from reduced tributary discharge, must be evaluated.

Data resulting from a full year's intensive biological and hydrological sampling in the Galveston estuary have been tabulated but their analysis and interpretation will continue for some time. Briefly, however, the overall pattern of seasonal distribution and abundance of major species (as determined from collections with a small trawl) has been established, as has their relationship to the physical environment in terms of the kind of ecological zone they typically occupy during their stay in the estuary. Annual salinity regimes and temperature cycles have been largely defined. Considerable attention has been and will continue to be focused on the importance of tributary discharge as it influences the density and distribution of fish and shellfish species.

Biological and hydrological data were collected semimonthly through March 1964 according to the scheme initiated in January 1963, and monthly thereafter. A phase of study dealing with the distribution of bottom fauna as related to various bottom sediment types was initiated during the year, and a segment of this work which pertains to the Clear Lake area is presented as a special contribution elsewhere in this report. The scope of the project was expanded in March 1964 to incorporate a preliminary ecological survey of peripheral marshes as nursery areas. To monitor the concentration and dispersion of pollutants and nutrients throughout the estuary, we obtained monthly, beginning in March, indices of dissolved oxygen, total nitrogen, and total phosphate. Such measurements will supplement the extensive estuary-wide hydrological coverage provided by the Texas Water Pollution Control Board, which includes determinations of pH, conductivity, chloride, total phosphorus, total nitrogen, potassium, biological oxygen demand, dissolved oxygen, temperature, and salinity. Plans to initiate a study of primary productivity in July were completed.

Hydrology Following the normal seasonal pattern, monthly mean temperatures were highest in August 1963 and lowest in January 1964. In the month of February, waters were warmer in 1964 than in 1963.

March temperatures for both years, however, were almost identical, whereas in April 1964, the temperature averaged about 5° C. (41.0° F.) lower than during the same period in 1963. (See graphs.)



Temperature and salinity in subareas of the Galveston estuary from January 1963 through May 1964.

Bottom temperatures in the Galveston estuary ranged from 35.5° C. (95.9° F.) in August 1963 to 2.0° C. (35.6° F.) in December. Both values were recorded in East Bay. The nearby Gulf was warmer than the estuary in winter and cooler in summer, ranging from 8.1° C. (46.6° F.) in January 1963 to 31.0° C. (87.8° F.) in September.

In the shallow areas of the estuary, differences between surface and bottom temperature rarely exceeded 1° C. (1.8° F.) whereas in the deep channels, differences as great as 5° C. (9.0° F.) were noted. The temperature was usually lower near the bottom of the deeper channels than near the surface except during winter storms ("northers") which caused rapid cooling of surface waters.

Salinity gradients from the tidal pass and the Gulf to East Bay and the mouths of the San Jacinto and Trinity Rivers in the upper estuary were evident during each season of the year. Considerable most pronounced in bay areas nearest the sources of fresh water. Salinity was notably higher throughout the estuary during the winter of 1964 than during the previous winter. In the spring, however, it was about the same both years.

It is apparent that discharge from the major rivers entering the estuary was the primary factor controlling bay salinity. Local precipitation usually had only temporary effects. Rainfall associated with Hurricane Cindy in September 1963 did, however, reduce the salinity of East and Lower Galveston Bays, as precipitation in excess of 16 inches was recorded in the upper East Bay watershed.

Dissolved oxygen at the bottom (daytime) varied between a low of 5.6 p.p.m. (parts per million) in the Gulf and a high of 13.7 p.p.m. near the mouth of the San Jacinto River (March-May 1963). It was most variable in the Intracoastal Waterway and near the mouth of the San Jacinto River, probably because of marsh drainage and contamination by sewage and industrial wastes, respectively, in these areas. Elsewhere in the estuary, dissolved oxygen generally varied between 8.0 and 9.0 p.p.m.

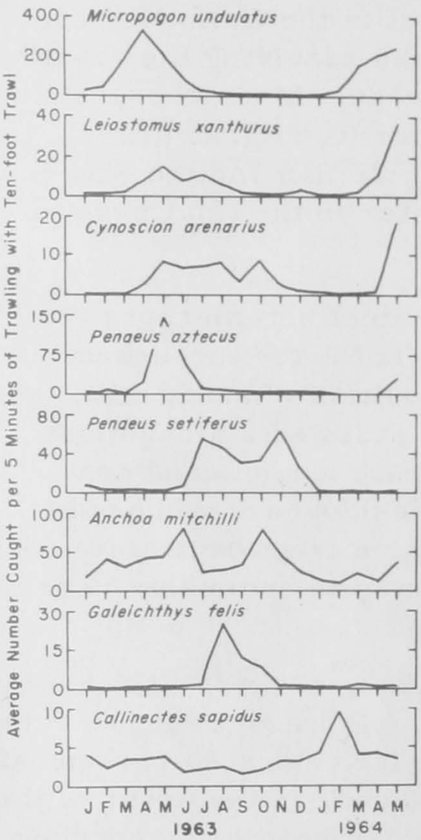
Total nitrogen and phosphate levels, determined simultaneously with dissolved oxygen, were highest in Upper Galveston Bay near the mouth of the San Jacinto River and lowest in the Gulf. Highest readings were consistently recorded in those areas receiving the greatest amounts of industrial waste and domestic sewage. Mean phosphate values ranged from 0.8 microgram atoms per liter (0.8 µg. at. /liter) in the Gulf to 12.9 µg. at. /liter near the mouth of the San Jacinto River. Mean nitrogen values ranged from 16.3 µg. at. /liter in the tidal pass to 119.9 µg. at. /liter in Upper Galveston Bay.

<u>Sedimentation</u> For purposes of developing a map of bottom types characterizing the entire bay system, sediments collected throughout the estuary are being analyzed for percent composition of sand, silt, and clay. Preliminary findings indicate that the sediments along most shorelines and throughout Lower Galveston Bay have a high sand content (ranging upwards of 50 percent near the jetties), whereas those of Upper Galveston, Trinity, and East Bays (exclusive of shoreline areas) are highest in clay content. Clay also predominates in sediments near the mouths of the San Jacinto and Trinity Rivers.

<u>Composition of Trawl Catches</u> Since January 1963, 109 fish, 13 shrimp, and 29 crab species have been collected with a small trawl throughout the estuary. Eight estuary-dependent species comprised about 80 percent of the total number of animals collected. They included, in the order of their abundance, the Atlantic croaker, *Micropogon undulatus*; the bay anchovy, *Anchoa mitchilli*; the brown shrimp, *Penaeus aztecus*; the white shrimp, *P. setiferus*; the spot, *Leiostomus xanthurus*; the sand sea trout, *Cynoscion arenarius*; the blue crab, *Callinectes sapidus*; and the sea catfish, *Galeichthys felis*.

Seasonal Abundance and Distribution Of the aforementioned eight species, only the bay anchovy, a forage species, is not of direct commercial importance. Five of the species, the croaker, spot, sand seatrout, brown shrimp, and white shrimp, have similar life histories and have been described as semicatadramous. The adults of this group spawn in the Gulf of Mexico between early fall and the next spring, except for the white shrimp which spawns over a somewhat later period. The resulting larvae, postlarvae, or very small juvenile forms eventually enter the estuary, during early winter in the case of the croakers but in the spring and summer in the case of the others. As the bay warms in the spring and early summer, they grow very rapidly. The croaker, spot, and brown shrimp usually depart for the Gulf during early or midsummer, whereas the sand seatrout and white shrimp emigrate with cooler temperatures in the fall.

The adult sea catfish enters the estuary only during the warmer months when (being oviparous) it releases its young during the period of maximum summer temperature, which usually occurs in August.

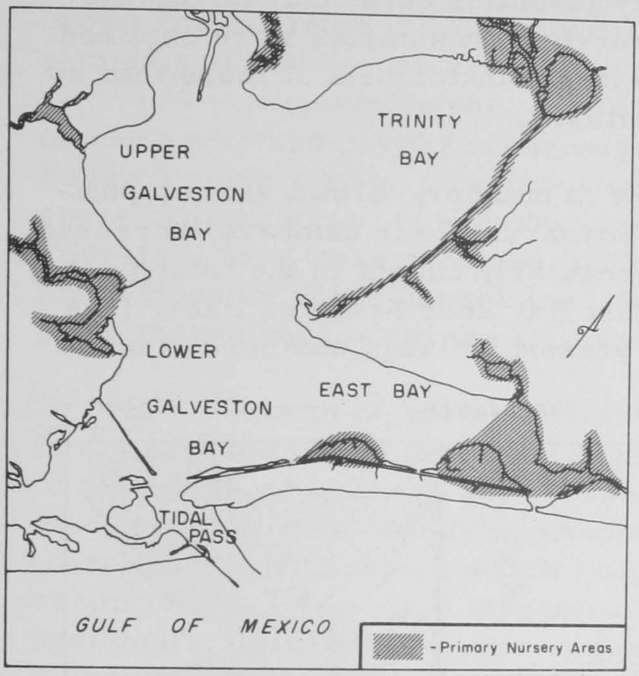


Seasonal abundance of the major fish, shrimp, and crab species in Galveston estuary as determined by sampling with a 10-ft. trawl.

The blue crab, on the other hand, is found throughout the estuary all year. Mating takes place in the estuary; but the females, with eggs attached, migrate to its lower, more saline portions, or more frequently, to the near-shore Gulf. After hatching, young crabs move into all areas of the estuary. Spawning activity extends from spring to early fall, reaching a peak during early summer.

The bay anchovy is also present the year round throughout the estuary. It spawns in Gulf coast bays from spring to fall and is one of the most numerous of estuarine forms. It is similar to the blue crab in that it can complete its life cycle entirely within the estuary.

Life histories of the five semicatadramous species and the blue crab have at least one feature very much in common. Their young, after invading the estuary from the Gulf (or transitional areas of the bay), initially migrate to and tend to concentrate in the peripheral bayous, marshes, tertiary bays, or along protected shorelines of the upper bays. In the Galveston estuary, the upper portion and adjacent bayous and marshes of East Bay, the lower Trinity River delta and Double Bayou areas of Trinity Bay, the Dickinson Bayou complex of lower Galveston Bay, and the Clear Lake area of upper Galveston Bay exemplify such habitat. (See figure.) Since these areas are characterized by lower salt content than that of the Gulf or adjacent open bay waters, the young of these forms are subjected to ever-decreasing levels of salinity as they move through the estuary.



Important nursery areas of the brown shrimp in the Galveston estuary in 1964.

Laboratory research by the Experimental Biology Program indicates that survival and growth of brown shrimp postlarvae are better in low-salinity water when its temperature is relatively high. In reviewing the results of our sampling activity during the first 6 months of 1964, we were not surprised to learn, therefore, that the greatest concentration (and presumably the best growth) of postlarval brown shrimp occurred in Galveston Bay's peripheral areas where the salinity was somewhat lower (5‰-6‰) and the temperature measurably higher (2°-4° C.; 35.6°-39.2° F.) than in adjacent open waters. Furthermore, even though these areas are separated by considerable distances (see figure), they possess several features in common. Their waters are mostly less than 2 ft. deep and are generally protected from severe wind-wave action. Connecting or nearby marshes typify each area, and during the period of maximum postlarval buildup and early growth in the spring of 1964, their salinity averaged less than 17‰. It is believed that such shoreline-marsh zones in the Galveston estuary constitute primary nursery areas, not only for the brown shrimp, but possibly for the white shrimp, croaker, spot, sand seatrout, and blue crab as well.

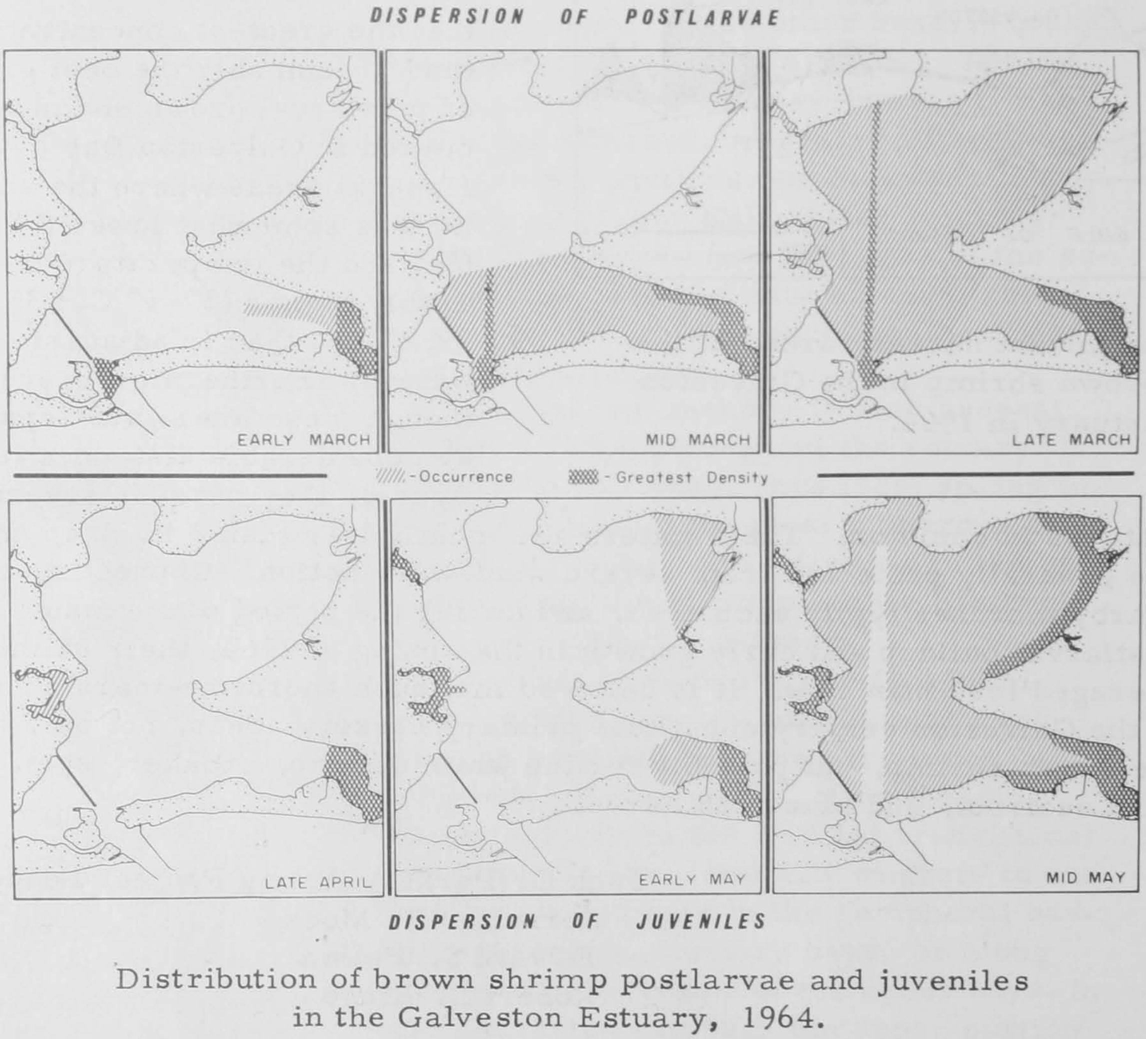
Jack C. Parker, Acting Project Leader
Cornelius R. Mock
Edward J. Pullen
Robert D. Ringo

Dispersion and Growth of Young Brown Shrimp

The investigation of larval and early juvenile stages of commercially important fish and shellfish was initiated in March 1963 as part of the overall estuarine research program. Specifically, this phase of study is directed toward increasing our knowledge of the distribution and abundance of these early stages and assessing their relation with the physical and chemical properties of the environment.

The findings reported herein were based upon samples of brown shrimp postlarvae and early juveniles collected during the spring of 1964. Both surface and near-bottom samples were obtained every 6 to 11 days with $\frac{1}{2}$-meter (19-in.) plankton nets at more than 40 locations throughout the Galveston estuary.

Entry and Dispersion Although few in number, brown shrimp postlarvae were first collected in late February. Their numbers increased during early March when they were regularly caught in the tidal pass (Galveston Entrance) and in upper East Bay near Rollover Pass. (See figure.) By mid-March, they were present in large numbers in both

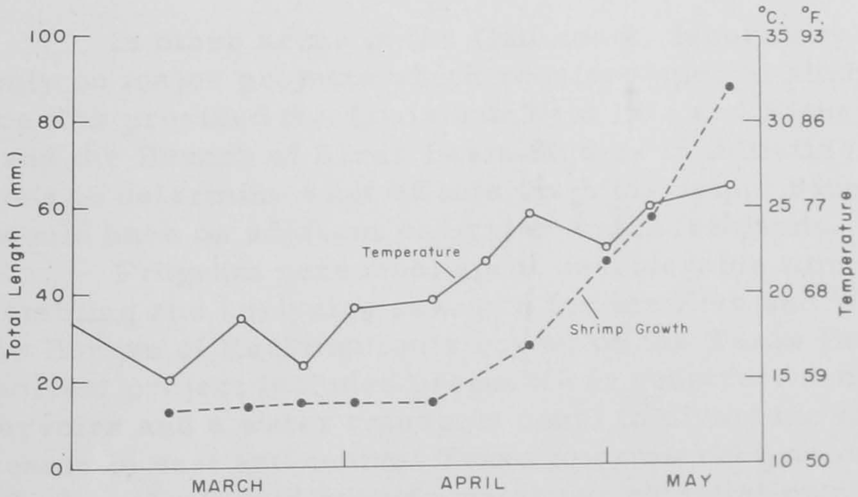


Distribution of brown shrimp postlarvae and juveniles in the Galveston Estuary, 1964.

areas and gave evidence of having scattered throughout East and Lower Galveston Bays. Within about 2 weeks from the time of their first appearance in large numbers, these small brown shrimp had spread throughout the study area. During this period of dispersion, large numbers were caught in the Houston Ship Channel. Though postlarvae were also caught in adjacent open-bay waters, this channel and associated current systems evidently provide the postlarvae a more direct and rapid means of penetrating the upper estuary. Influx of postlarval brown shrimp from the Gulf continued through mid-May, at which time sampling effort was reduced.

Juvenile shrimp were first collected in late April in the marsh areas and bayous at the edge of upper East and Lower Galveston Bays. By early May, juveniles were abundant throughout the estuary in areas characterized by marshes, tertiary bays, and bayous. During mid-May, they were captured (with trawls) everywhere except in the lower Houston Ship Channel and tidal pass, indicating that their anticipated movement toward the Gulf was insignificant at this time.

Growth Growth of brown shrimp as determined from serial changes in the average length of those caught by sampling was obscured because of the continual influx of postlarvae from the Gulf. As a consequence, rate of growth was simply approximated by calculating the collection-to-collection increments which resulted from measuring the largest shrimp in each sample. Inspection of these measurements indicated systematic differences in the length of brown shrimp as water temperatures associated with the advancing season increased.



Growth of young brown shrimp in relation to water temperatures in East Bay, 1964.

This phenomenon was demonstrated in the peripheral areas of upper East Bay where brown shrimp postlarvae were abundant in early March. Maximum daily water temperatures, however, remained well below 20° C. (68.0° F.) over the next month. Very little growth was evident during this period, the average daily increase in length being less than 0.1 mm. (.004 in.) per day. Shortly thereafter, the maximum daily water temperature exceeded 20° C. (68.0° F.) and the rate of growth started to accelerate, averaging 1.7 mm. (.07 in.) per day until water temperatures reached 25° C. (77.0° F.). Maximum growth of 3.3 mm. (.13 in.) per day was then attained. Similar patterns of growth were evident throughout other similar areas of the estuary during this period.

The Laboratory's Experimental Biology Program has demonstrated that, under controlled laboratory conditions, (1) brown shrimp postlarvae grow very little when the average water temperature is held below 18° C. (64.4° F.), and (2) their maximum rate of growth in relation to highest survival is achieved when the water temperature remains between 25° and 27° C. (77.0° - 80.6° F.). The experimental findings and field observations seem to be in good agreement when allowance is made for differences between the maximum daily temperatures recorded in the field and the average temperatures tested in the laboratory.

Robert D. Ringo, Fishery Biologist

Effects of Engineering Projects

The ultimate goal of this project is to amass sufficient knowledge with which to predict the effects of various types of engineering projects upon the estuarine environment, and to recommend project modifications that would ensure the least damage to and in some instances enhance the value of estuarine fishery resources.

Even though our present knowledge about the effects of estuarine changes upon fishery resources is somewhat deficient, it is nevertheless necessary that we advise on current and future engineering projects. In Texas, personnel at this installation are working directly with representatives of the Bureau of Sport Fisheries and Wildlife, the Texas Parks and Wildlife Department, and other Federal and state agencies. Under this system of coordination, program personnel during Fiscal Year 1964 reviewed plans and proposals for more than 360 construction projects, 130 of which were adjudged to have potential effects upon estuarine fishery resources. Sections pertaining to estuarine fishery resources in 40 Bureau of Sport Fisheries and Wildlife draft reports were also reviewed.

The greatest number of engineering projects appraised in Fiscal Year 1964 for their potential effect upon the fisheries of Texas are to be located near large population centers, with one-third scheduled for construction in or near the Galveston estuary. After discounting those involving mineral development, almost half of all bulkheading-fill and dredging-channelization projects were slated for this estuary. As the population density increases elsewhere along the coast, an increase in engineering projects can be expected in other areas as well. More than 90 percent of all projects appraised were privately sponsored.

In other areas of the Gulf coast, laboratory personnel worked only on major projects which required special study. Thus, assistance was provided the Louisiana Wild Life and Fisheries Commission and the Branch of River Basin Studies in initiating interim investigations to determine what effects the Mississippi River-Gulf Outlet Project would have on adjacent estuaries and marshlands.

Program personnel spent considerable time during the year assembling and analyzing raw data for the Fish and Wildlife section of the Bureau of Reclamation's report on the Texas Basins Project. This important project includes proposals to construct numerous upland reservoirs and a water transport canal to divert the flow of principal streams in east and central Texas to semiarid portions of southern Texas. Such a plan would provide water for potential municipal, industrial, and irrigational demands, but would greatly reduce tributary discharge into most Texas estuaries and, unless modified, could adversely affect their fishery resources. During drought years, this

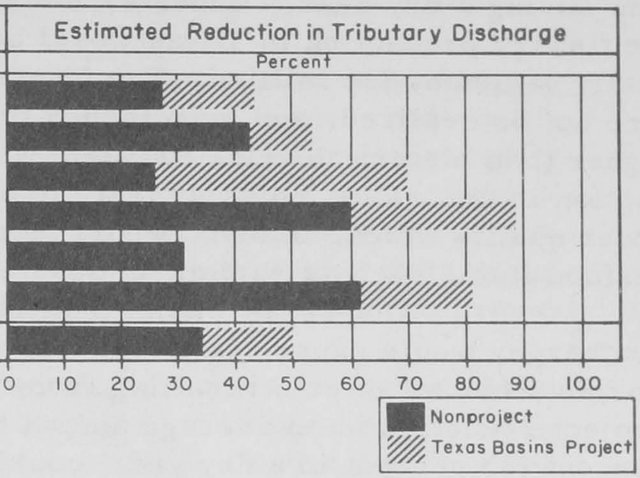
Number, Type, and Location of Engineering Projects Appraised in Fiscal Year 1964.

Texas estuaries	Projects			Type of project			
	Total	Private	Federal	Mineral development	Dredging and channelization	Bulkheading and fill	Other
Sabine Lake	10	10	0	8	1	1	0
Galveston	46	43	3	14	18	12	2
Matagorda	18	17	1	14	1	2	1
San Antonio	14	13	1	9	2	3	0
Aransas-Copano	13	13	0	6	5	2	0
Corpus Christi	17	17	0	8	6	2	1
Laguna Madre	14	13	1	5	4	5	0
Rivers and streams	3	1	2	0	0	0	3
Total	135	127	8	64	37	27	7

reduction could become critical, especially in view of other water demands which are expected in the future, since it is also apparent that nonproject reservoirs will divert twice as much water as the project itself. The proposed Texas Basins Project would, from the standpoint of lowering the quality of habitat for fishery resources, compound an already critical problem.

Estuary	Historic Annual Average (Thousand acre-feet)
SABINE LAKE	14,363
GALVESTON	9,071
MATAGORDA [1]	689
SAN ANTONIO	1,550
ARANSAS	226
CORPUS CHRISTI	602
TOTAL	26,501

[1] Excludes Colorado River



Expected changes by the Year 2010 in the amount of fresh water discharged into Texas estuaries. (Figures do not include waters diverted, used, and then returned.)

In order to evaluate the effects of the Texas Basins Project upon estuarine fishery resources, it was necessary to predict the production by commercial fisheries under with-project and without-project conditions over the next 100 years.

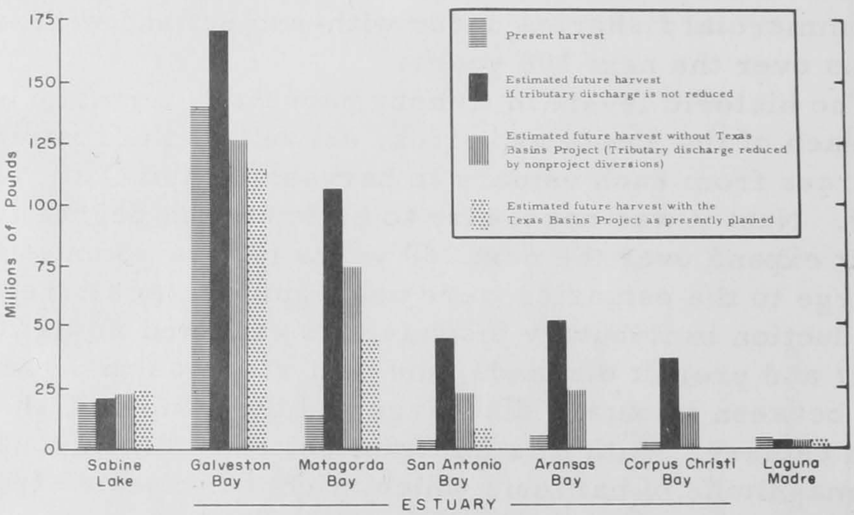
The historic levels of fishery harvest in terms of amount and value from each of the Texas estuaries, as well as the contribution of fishery resources from each estuary to harvests in the Gulf, were first determined. Next it was necessary to estimate the degree to which the fishery might expand over the next 100 years (future potential) if tributary discharge to the estuaries were not significantly altered. Since a large reduction in tributary discharge is expected in the future due to nonproject and project demands, the next step was to determine the relationship between tributary discharge and the historic fishery harvest for each estuary. With this information, it was then possible to estimate the magnitude of harvests which might be expected from each estuary under various levels of tributary discharge.

Our analysis indicated that commercial fisheries in Texas coastal waters are capable of expanding from a historic average annual yield of 187 million pounds valued at $26 million, to a maximum potential estimated at 435 million pounds with a value in excess of $40 million.

The increase in both poundage and value would be attributed to increasing harvest rates, higher economic return, population growth, technological advances, and improved fishery management practices.

Nonproject demands for fresh water for municipal, agricultural, and industrial uses will, however, reduce the present average annual tributary discharge (26,501,000 acre-feet) to Texas estuaries by about 35 percent by the year 2010. This reduction could exceed 60 percent during a dry year. Under such conditions, it was estimated that the fishery production in Texas would be about 285 million pounds annually valued at $26 million. The future potential harvest would therefore not be realized, and even though the forecast poundage would be higher than historic levels, its value would be comparable. This reduction in unit value indicates that the estuarine habitat would be of lower quality which, in turn, would tend to reduce the yield of choice seafood items such as shrimp and oysters.

The Texas Basins Project, by further reducing tributary discharge, would cause additional losses to coastal fishery resources. The detrimental effects resulting from the combined project and nonproject reduction in an average annual tributary discharge of about 50 percent (85 percent in a dry year) could be intensified through the introduction of highly toxic pesticides and herbicides into the estuaries from adjacent irrigation units. Harvests and harvest values under these conditions were estimated at 192 million pounds and $19 million, respectively. Populations of preferred species such as shrimp, oysters, crabs, and several fishes would possibly be subjected to wholesale depletion in several estuaries by such a drastic change.



Projected changes in average annual commercial fishery harvest from Texas estuaries over the next 100 years.

Project and nonproject effects would also be detrimental to various recreational fisheries since many sport fishes are estuary-dependent.

In view of the large-scale losses which could be experienced by resources supporting sport and commercial fisheries along the Texas Gulf coast, it is imperative that satisfactory measures be found to offset the undesirable effects of man-induced changes in the estuarine environment, and to encourage perpetuation of these fisheries at high levels of production.

On the basis of preliminary analysis of harvest and discharge records, it was estimated that an average of approximately 1,870,000 acre-feet of tributary discharge would be required annually (in addition to that remaining after project diversion) to prevent anticipated fishery losses due to the Texas Basins Project. It was furthermore estimated that an additional 3,650,000 acre-feet of tributary discharge (before project diversion) would be required annually to prevent nonproject losses of a similar nature.

In order to secure these volumes of water for estuarine fishery resources, it will first be necessary to develop a comprehensive water-supply plan. The Texas Basins Project could possibly be modified to incorporate the development and execution of such a plan and thus become a truly multiple-purpose project. A great amount of research and engineering study, however, will be required to implement such a plan and to solve the problem of pesticide introduction. Study must be undertaken in each of the Texas estuaries to obtain refined data with which to (1) permit complete documentation of fishery values, (2) determine more exacting estimates of minimum discharge requirements, (3) determine the most opportune time for release of water, (4) determine if return flows could partially replace direct tributary discharge (or the treatment required to do so), and (5) establish criteria to assist in developing plans to prevent losses in Aransas and Corpus Christi estuaries from pesticide contamination. We intend to recommend to the construction agency that such research be undertaken at the earliest opportunity.

Richard A. Diener, Project Leader

EXPERIMENTAL BIOLOGY PROGRAM

David V. Aldrich, Program Leader

During the year, this program developed important new information about the effects of controlled environmental conditions on commercially important shrimps. A month-long growth and survival experiment in which young white shrimp were held at known levels of temperature and salinity yielded the first measurements of this species' response to variations in such environmental factors. When compared with findings from similar experiments with brown shrimp, these results suggest what may be significant differences between the ecological requirements of the two species. For example, white shrimp exhibited better survival than did brown shrimp at 90° F. but poorer survival at 52° F. Such information provides a physiological basis for explaining seasonal dissimilarities in the occurrence and abundance of these species in Gulf estuaries.

Continued Laboratory experiments with brown shrimp postlarvae have extended our knowledge of shrimp growth under fixed as well as changing temperature levels. Results so far indicate that the influence of temperature on growth is particularly marked between 15° and 25° C., tending to confirm previous observations of biologists in the field.

Two types of studies have provided much-needed information on the physiological response of shrimp to rough treatment when they are used as test animals, afield or in the laboratory. Study findings indicate no chronic effect of handling on the subsequent growth of postlarval and juvenile brown shrimp.

A new approach to shrimp ecology involves the study of a parasite life cycle. The discovery of a previously undescribed stage in the life history of a shrimp parasite has provided a new lead concerning natural predation on shrimp. A tapeworm commonly parasitizing brown and white shrimp in Galveston Bay has also been found in the common sting ray of that area. Since the worm reaches adulthood in the ray, this fish is implicated as a natural shrimp predator, for such tapeworm infections can only be acquired through ingestion of infected intermediate hosts. The host of this parasite's first intermediate stage, undoubtedly an important organism in the natural diet of shrimp, awaits detection.

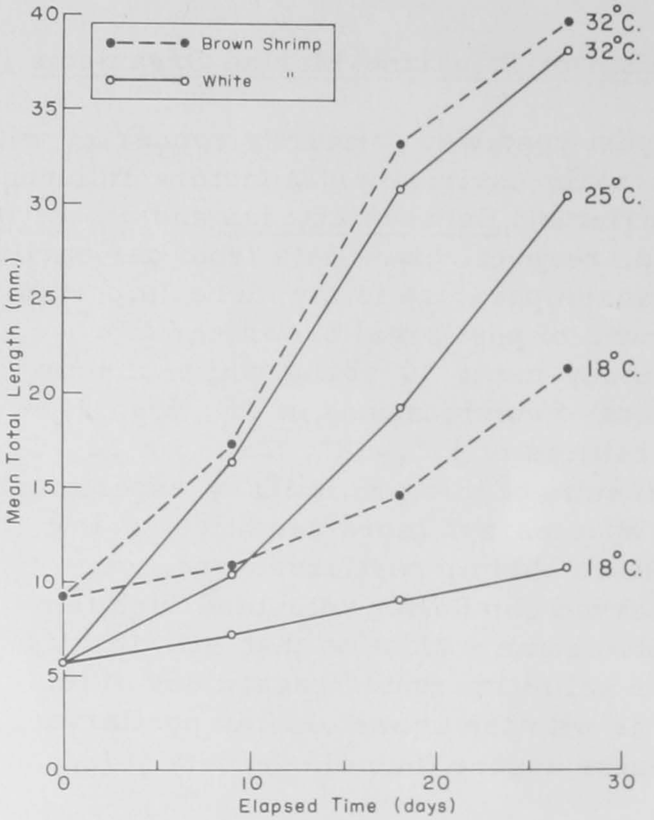
Growth, Tolerances, and Metabolism of Estuarine-Marine Organisms

Work during the past year was primarily concerned with determining the extent to which certain environmental factors influence the growth of two commercial shrimps, Penaeus aztecus and P. setiferus, the brown and white shrimp, respectively. Data from our earlier work indicated, for example, that temperature is far more important than salinity in regulating the growth of postlarval brown shrimp.

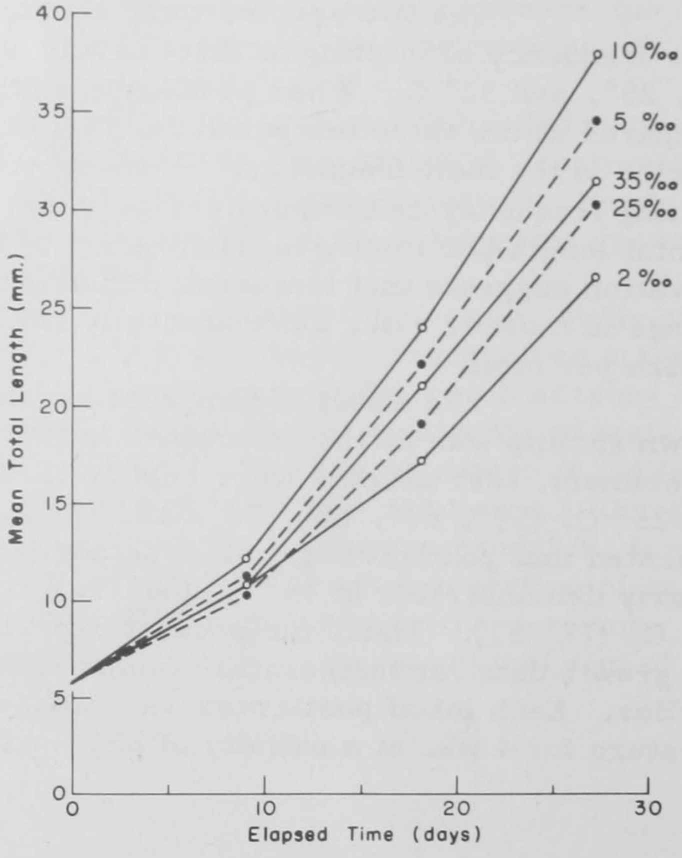
In a more recent study using 40 young white shrimp per aquarium, we tested the effects of combinations of 2‰, 5‰, 10‰, 25‰, or 35‰ salinity with temperatures of 11°, 18°, 25°, or 32° C. (52°, 63°, 77°, and 90° F.). Results of this preliminary experiment suggested that postlarvae of this species are more sensitive to low temperature (11° C.) than are brown shrimp postlarvae and, conversely, that white shrimp postlarvae can better withstand high temperature (32° C.). There was also some indication that growth was less rapid at 2‰ than at the other salinities tested regardless of temperature, but that temperature, as with the brown shrimp postlarvae, affected growth patterns to a greater degree than did salinity. (See figures, next page.)

The two species were also compared with respect to their frequency of molting at three levels of temperature, namely, 18°, 25°, and 32° C. When postlarvae of the same total length were compared at the same temperature, there was no difference between species in the molt frequency. Both species showed a decreasing molting frequency as temperature decreased, although the increase in total length per molt was independent of the temperature. This observation suggests that temperature influences growth rate through a change in molting rate, but that it may have no effect on the increase in size per molt.

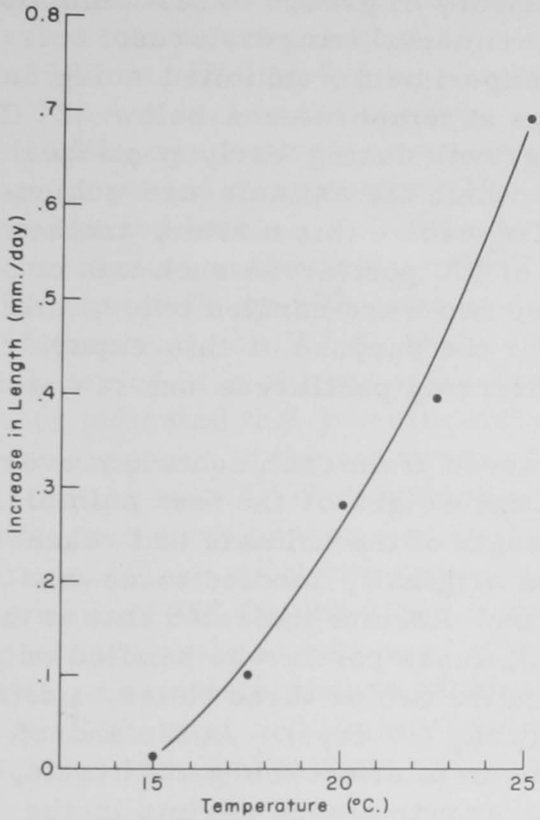
The effect of temperature on the growth of postlarval brown shrimp was further examined in two experiments. In the first experiment, test animals were held at 15.0°, 17.5°, 20.0°, 22.5°, and 25° C. (59°, 63°, 68°, 73°, and 77° F.). Past experiments had indicated that postlarval growth was negligible at 11° C. (52° F.), clearly demonstrable at 18° C. (64° F.), and comparatively rapid at 25° C. (77° F.). Thus, the present experiment was designed to supply growth data for temperatures intermediate between those tested earlier. Each lot of postlarvae was exposed to an experimental temperature for 4 wk. at a salinity of 25‰, a level of salinity previously



Effect of temperature on growth in length of postlarval white and brown shrimp at a salinity of 25‰.



Effect of salinity on growth in length of postlarval white shrimp at a temperature of 25° C. (77° F.)



Growth rate of postlarval brown shrimp in the temperature range 15° to 25° C. (59° to 77° F.).

determined to be well tolerated by this species and used throughout all the growth series described here. Growth rate increased rapidly with temperature throughout the range tested, with 15° C. apparently supporting only limited growth. (See figure.) The second experiment, designed to test temperatures in the range of 25° to 35° C., is now in progress.

The effect of changing temperature upon growth of young brown shrimp was also measured in a 30-day study. In a manner similar to that described in previous reports, 20 aquaria containing water of the same salinity were divided into groups of five, one each being maintained at temperatures of 11°, 18°, 25°, and 32° C. Temperatures were subsequently changed at 5-day intervals.

Experimental units that were changed only 7° C. usually reached the new temperature within 8 hr. A change of 14°, however, usually required 24 hr. No shifts were made from 32° to 11° C. or vice versa because of the undue stresses to which the experimental animals would probably be subjected. Like the others, this experiment demonstrated the strong influence of temperature upon growth, although the rate of growth of animals introduced to a new temperature did not differ from that of animals maintained at the same temperature. Final size was therefore dependent only upon the length of time at which the animals had been held in a fixed or changing temperature regime. Decreased survival of animals at 11° C., as compared with that in a similar previous experiment, suggested that this temperature may be close to the absolute limiting value for 30-day survival of brown shrimp postlarvae. However, postlarvae from the same collection used in the first experiment reported here showed lower survival at 17.5° and 15° C. than in earlier work at the same levels. There is thus a possibility that the previous temperature history of groups of test animals can influence their tolerance of low experimental temperatures.

Animals in all previous experiments exhibited a lag in growth rate during the first 5 to 10 days at temperatures below 32° C. Such a lag could either reflect normal growth during early postlarval stages or be a result of the handling to which the animals are subjected when setting up the experiments. To resolve this matter, another growth experiment involving four units of 100 postlarvae each was conducted. One unit was handled only once, two were handled twice, and the fourth was handled three times. For the purpose of this experiment, one "handling" consisted of transferring postlarvae out of water from one aquarium to another.

Ten postlarvae were removed from each aquarium every 5 days to determine the average length and weight of the test animals. At the end of 20 days, when the mean length of the animals had reached 25 mm. (1.0 in.), one of the two groups originally handled twice was again handled as in the original procedure. Results indicated that at the end of the first sampling period (5 days), those postlarvae handled only once were slightly larger than those handled two or three times, a difference which disappeared at the next sampling (10 days). At the end of 20 days, however, rehandling did not seem to affect the growth rate, as there was no detectable difference in growth among shrimp in the four tanks 10 days later (30 days after the experiment began). Growth of small postlarvae may therefore be depressed immediately following handling, although such handling has little apparent effect on postlarvae in the length range of 20 to 30 mm. (0.8 to 1.2 in.). It must be noted, however, that small differences in mean rate of growth are more difficult to detect in the late stages of a growth experiment since, as noted in our other reports, the variation in size of animals becomes increasingly marked. It would appear that handling has far more effect upon the growth of postlarvae than of juveniles and that whatever suppression does occur is overcome rapidly, so that within a period of less than 2 wk. animals grow at identical rates regardless of the amount of handling.

In still another type of experiment, salinity and temperature tolerances of juvenile and subadult brown shrimp were studied in an attempt to secure tolerance data comparable with those previously obtained for postlarvae. In each of two studies, temperature-salinity combinations were tested using groups of 10 shrimp individually separated to prevent cannibalism. The animals' length ranged from 53 to 108 mm. (2.1 to 4.3 in.) in the first study and from 75 to 121 mm. (3.0 to 4.8 in.) in the second. Initial temperature and salinity, 25° C. and 25‰, respectively, were the same for all groups. Over an acclimation period of approximately 24 hr., both factors were brought to the desired levels. Salinity was adjusted by adding either distilled or concentrated sea water. Animals were held 24 hr. at a salinity of 5‰, 25‰ (control), or 50‰, and at each of three temperatures, namely, 5°, 25° (control), or 35° C. (41°, 77°, or 95° F.). At the conclusion of this period, the shrimp were examined and mortalities recorded. Results indicated that juvenile and subadult brown shrimp could not tolerate exposure to the extremes of temperature, 5° and 35° C., in the salinities tested. They further suggested that at 25° C., the limits of tolerance were approached at the limits of the experimental salinity range. Since postlarvae have been shown to tolerate 25° C. and 5‰ as well as 35° C. and 25‰, it appears that salinity and temperature tolerance changes with age. Continued work of this type will provide a more complete picture of the tolerance limits of subadult and adult brown shrimp, and permit useful analysis of this animal's physioecology throughout most of its life cycle.

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

Previous work had shown plerocerci (larvae) of the tapeworm Prochristianella penaei (Order Trypanorhyncha) to be common parasites of brown and white shrimp in the Galveston area. Although no infected individuals were found among the first brown shrimp juveniles entering samples from Clear Lake in May of 1960 and 1961, incidence of the worm was widespread a month later in the same area. This finding was considered evidence implicating Clear Lake, a secondary bay in the Galveston Bay system, as a site of infection. The present year's activities have brought to light an additional piece of data pointing to the estuary as the area in which shrimp acquire this tapeworm. A positive relation was found between parasite incidence and size of the brown or white shrimp host during the estuarine phase of the shrimps' life cycle. Since these patterns suggested brackish bays as the environment in which the infection of shrimp takes place, it was assumed (1) that the first intermediate host of P. penaei also inhabits such areas, and (2) that the range of the elasmobranch final host -- final host of this order of cestodes are characteristically sharks or rays -- includes such low-salinity areas to permit infection of the first intermediate host, thus completing the parasite's life cycle. The latter point postulates a broad range of salinity tolerance for the final host. Our discovery of adult P. penaei in Dasyatis sabina, a ray noted for the extent of its salinity tolerance, lends support to these assumptions.

Finding the adult stage of this tapeworm in the sting ray automatically implicated the latter as a natural shrimp predator, since such cestode infections are acquired only through ingestion of infected intermediate hosts. The lack of useful information concerning the relative importance of shrimp as food for this ray suggested additional studies. As a result, a number of laboratory experiments were conducted to observe the feeding activities of adult D. sabina to help determine how susceptible shrimp might be to predation by rays. Observations in 80-gal. tanks at normal room illumination indicated that the ray's eyes are of little use in detecting food (whether it be live shrimp, or ground shrimp or fish). Food items passing within an inch of a hungry ray's eyes remained undetected unless physical contact was made with the fish. D. sabina must apparently depend on tactile, auditory, or olfactory senses, or some combination of these, in finding and capturing shrimp. On the other hand, the live subadult and adult brown shrimp placed in the tanks with the rays clearly indicated the use of their eyes in attempting to escape attacks. Despite the seeming visual disadvantage, the ray occasionally trapped, pinned, and ate a shrimp in a corner of the experimental tank, using the disk to hold itself and its prey firmly to the tank wall or bottom. Under conditions of normal room illumination, individual adult rays were capable of capturing and consuming two to three live shrimp in 2 hr. In darkness, the same rays disposed of three to six shrimp in the same time period. These observations suggest that D. sabina is an efficient natural predator of shrimp, particularly at night. The ray's method of capture also indicates that this fish is probably morphologically well adapted to the capture of shrimp which have burrowed into the bottom.

The life cycle of the parasite P. penaei should also have applied value in providing much-needed information on the food habits of shrimp. Before conducting a search for the parasite's first intermediate stage, we observed the feeding behavior of shrimp in the laboratory to gain a better idea of this animal's predatory capabilities. Bits of food (fish meat) introduced into an aquarium containing white or brown shrimp caused them to increase greatly their activity, but their movements were poorly directed. Although illumination was provided the shrimp showed no signs of using their eyes in locating food. Their movements appeared to be random regardless of whether the food was located near or far from the eyes. This finding is consistent with the generally held view that the compound eyes of many arthropods are primarily functional in detecting rapid movements (like those of the ray mentioned above) and of less use in locating or identifying stationary or slowly moving objects. Further observations indicated that the walking legs, equipped with microscopic sensory organs, are quite sensitive to contact with food, carrying it immediately to the mouth. Other appendages, including those on the abdomen and tail, and even antennae, failed to orient the animal to food. These observations suggest that brown and white shrimp are not well equipped to capture agile organisms and thus may feed largely on sessile or slow-moving forms.

Since the pattern of shrimp infection discussed above suggested that these animals acquire the parasite in Clear Lake, we have started sampling that area for benthic invertebrates which might carry the first intermediate stage of P. penaei.

Bottom samples taken with a modified plankton trawl have yielded large numbers of annelids, mollusks, mysidaceans, and larval fishes. Microcrustaceans have been quite rare. Considering the observed feeding behavior of shrimp, we feel the annelids and fragile mollusks to be those elements of the bottom fauna most likely to be eaten by shrimp. To date, we have not discovered the first intermediate host of P. penaei, but the search is being continued.

Experimental work is also being carried out to determine whether short-term shrimp mortality is associated with P. penaei infection. Lack of pathogenicity is a necessary characteristic of parasites which have utility as "biological tags." In future work we hope to explore further the potentialities of P. penaei as a natural tag for commercially important shrimp.

David V. Aldrich, Project Leader

OPERATION AND MAINTENANCE OF SALT-WATER LABORATORIES

Kenneth T. Marvin, Supervisory Chemist

Fort Crockett Recirculating System   Except for a few unscheduled shutdowns due to city power failures, this installation was practically trouble-free during the past year. The factor largely responsible for the unit's improved operation was the closer regulation of water flow. By adjusting the rate of flow to about 70 percent or less of maximum, we found that the filter beds require a minimum of attention. Filter-bed maintenance now consists of backflushing the entire bed about every third week and thoroughly cleaning the top 4 in. but twice a year. At the higher recirculating rates employed previously, the filter beds often clogged with little warning, a situation which on occasion necessitated shutdown of the entire system.

The facilities of this unit have been operating at about full capacity, and it is seldom that there is a tank not being used in some type of experiment. Additional equipment, such as a constant-temperature water bath for small aquaria and temperature regulators for small volumes of water contained in individual tanks, has helped considerably in meeting increased demands for facilities with which to conduct specialized studies.

In addition to daily temperature and salinity checks, the recirculating water supply is analyzed twice a week for levels of nitrate, nitrite, and ammonia nitrogen, and phosphate-phosphorus.

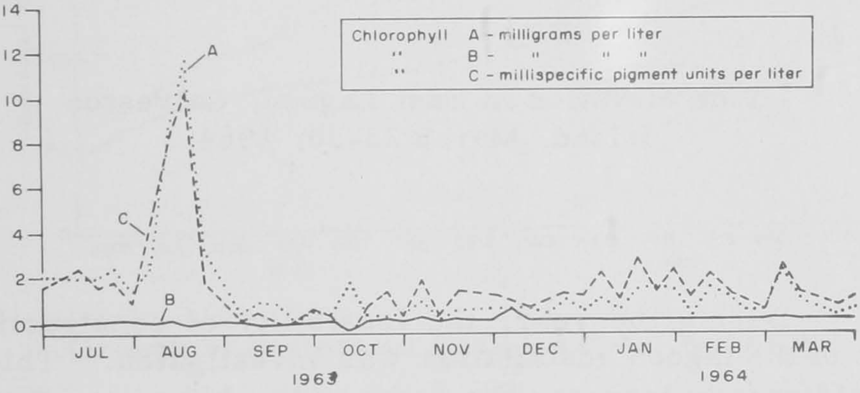
East Lagoon Circulating System   Operationally, this experimental facility also had a good year. The only difficulties occurred when, on two occasions, very low tides temporarily impaired water circulation in the system. We hope to prevent the recurrence of such malfunctions by lowering the two water-pump inlets several feet.

Twice during the year the system's plastic feed lines became choked with growths of oysters and other organisms to an extent that flow was reduced to an objectionably low rate. In each instance the lines were easily and completely cleared of all obstructing material with dilute hydrochloric acid.

In previous years, poisonous plankton blooms have been pumped into the system, killing all organisms held captive therein. To prevent recurrences of such contamination, frequent biological examinations of the water are now being made. At the first indication of a noxious bloom, the water pumps are turned off, and the unit is operated temporarily as a recirculating system. The necessary storage tank, filter, water pump, etc., for this conversion were installed a little more than a year ago and allow us to recirculate water through portions of the laboratory at a maximum rate of 1,000 gal. per hour. We usually operate on a recirculating basis during the winter because only by such means do we have adequate control of water temperature.

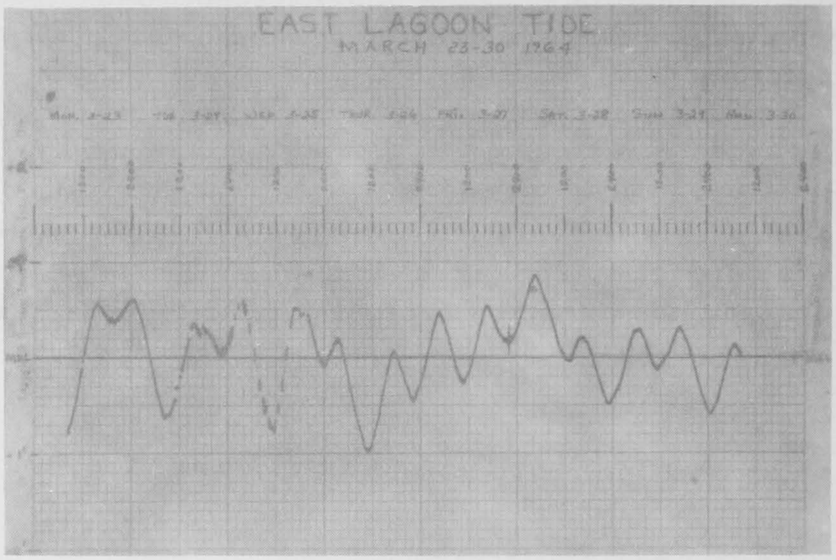
The water flowing through the system is analyzed twice weekly for the same constituents that are checked in the water of the Fort Crockett recirculating system, and also for chlorophyll and carbohydrate content. The increase in chlorophyll during August 1963 (see accompanying graph) was caused by a bloom of Gonyaulax monilata, a minute dinoflagellate. Such blooms seem to occur seasonally in East Lagoon waters and are being described in a report which is nearing completion.

In addition, we are recording on a continuous basis: water salinity, pH, water and air temperature, wind force and direction, barometric pressure, humidity, precipitation, solar radiation, and water level. This information is being used, not only by our biologists who are conducting ecological studies in the Galveston area, but also by several outside agencies such as the U. S. Weather Bureau.



Weekly chlorophyll content of water in the circulating system at East Lagoon, 1963-64.

Our tide gage, for example, was apparently one of the few in this region sensitive enough to record a signal from the Alaskan earthquake of March 27, 1964. Shown in the accompanying figure, this recording was of great interest to local geologists as well as to Coast and Geodetic Survey officials in Washington.



Tide elevation in East Lagoon, Galveston Island, March 23-30, 1964.

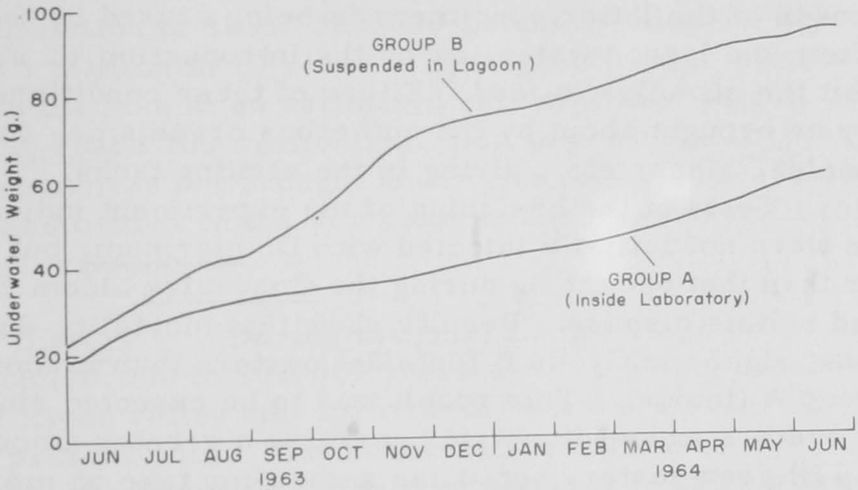
During the year, the feasibility of constructing ponds on the site of the lagoon installation was investigated. This type of facility would greatly increase the scope of the Laboratory's research program, particularly in the area of artificial culture of shrimp and other estuarine organisms. The U. S. Army Corps of Engineers has checked the physical structure of the soil at the proposed pondsite and has assured us that, from an engineering point of view, the idea is sound.

Biological Indicators in East Lagoon, Galveston Island

Raphael R. Proctor, Jr., Chemist

A study was started in 1963 to determine if the water in East Lagoon, the site of the Bureau of Commercial Fisheries circulating salt-water laboratory, is suitable for oyster culture. The indices being used are the growth and mortality rates of two groups of oysters, one (Group A) maintained in the laboratory, the other (Group B) suspended several feet below the surface of the lagoon. Each group initially contained 25 oysters having an average underwater weight of about 20 g. (0.7 oz.) The growth rates are based on weights determined biweekly using an established underwater weighing technique.

During June and July 1963, Group B oysters gained an average of 8.1 g. (0.29 oz.) per month. In contrast, Group A oysters gained 6.0 g. (0.21 oz.) per month in June but then experienced a drop to about 3.6 g. (0.13 oz.) per month by mid-July, and to about 2.4 g. (0.08 oz.) per month by mid-August. (See accompanying figure.)



Growth of oysters in East Lagoon, Galveston

A dense growth of <u>Gonyaulax monilata</u> developed in the lagoon in August and lasted for about 2 wk. To present the test oysters from being adversely affected by this bloom, both groups were placed in a closed system of recirculating water inside the laboratory. While there, the growth rate in Group B decreased markedly and both groups suffered mortality (10 in Group A and 2 in Group B). It is believed that death was caused by <u>G. monilata</u> which were trapped in the closed system, although the toxicity of this organism to oysters has not yet been established.

Upon being returned to their original locations after the bloom subsided, the 23 oysters remaining in Group B resumed rapid growth, gaining 8.3 g. (0.29 oz.) in September and 23.7 g. (0.83 oz.) in October. The rate decreased, however, to about 3 g. (0.11 oz.) per month during the cool months of November, December, and January, and then gradually increased again during the spring of 1964. Four oysters of this group died in May 1964 and one in June. An examination of the dead oysters indicated that death was caused by the disease organism, Dermocystidium marinum.

The 15 oysters remaining in Group A maintained a growth rate of about 2.5 g. (0.09 oz.) per month from July 1963 through February 1964, at which time a gradual increase began. A maximum growth rate of 5.7 g. (0.20 oz.) per month was attained in May. No mortality occurred in Group A during this period.

Results to date disclose that the overall rate of oyster growth in the lagoon proper has been considerably higher than that of individuals kept in the laboratory itself. It is not known whether the reduced growth of the latter specimens is being caused by the loss of nutrients from the lagoon water, or by the introduction of substances which inhibit the stimulus to feed. Either of these conditions could conceivably be brought about by the numerous organisms, such as oysters, barnacles, algae, etc., living in the settling tanks.

Tests at the beginning of the experiment indicated that the oysters were not initially infected with D. marinum, but all mortality other than that occurring during the Gonyaulax bloom has since been caused by this disease. Results show that mortality due to D. marinum was higher in Group B (outside) oysters than in those comprising Group A (inside). This result was to be expected since it is known that oysters exposed to water carrying a greater amount of food (Group B) grow faster, but at the same time take on more D. marinum and die sooner than those which receive less food and grow slowly. Since it is also known that oysters are most likely to acquire D. marinum during warm weather and at times when they are feeding heavily, it is probable that the Group B oysters became infected during the months of August through October 1963, although no mortalities occurred until May 1964. This delayed mortality is in agreement with the established pattern of D. marinum infections, which shows that oysters infected during warm months but able to survive until the advent of cool weather, will continue to survive at a reduced growth rate throughout the winter, then begin to die as warm weather approaches.

Distribution of Bottom Sediments in Clear Lake, Texas

Cornelius R. Mock, Fishery Biologist (General)

As part of an ecological study of the entire Galveston estuary, this investigation was undertaken to determine the distribution of bottom sediments and related benthic fauna in Clear Lake. Such a study was prompted by the realization that estuaries, which play an important role in the maintenance of coastal fishery resources, are rapidly being destroyed or altered by man's activities.

During 1963, more than 6 million lb. of fish and shellfish were harvested commercially in Galveston Bay. Furthermore, it is estimated that fish and shellfish which utilize this estuary as a nursery area annually contribute, on the average, more than 135 million lb. to fishery landings from nearby Gulf waters. Clear Lake being an important component of the Galveston Bay system, supports (during juvenile stages of population development) large numbers of various species which eventually enter these landings.

The value of Clear Lake as a nursery area for estuary-dependent resources is in jeopardy. Its watershed is presently inhabited by a population of about 250,000 people, which is expected to increase to 1 million in 10 years. Sewage effluent, now being discharged into the lake at an estimated rate of 2 million gal. per day will probably reach 100 million gal. per day within 15 years. If the pollution problem is not brought under control, this productive estuary could be transformed into a series of settling basins unfit for desirable aquatic organisms.

Geological History — During the interglacial stage of the Late Pleistocene epoch (70,000 to 100,000 years ago), a rising sea level flooded the Trinity River valley and formed an estuary similar in configuration to the present one. The youngest formation of the Pleistocene coastal plain, the Beaumont, was then deposited. During the Late Wisconsin glacial stage (40,000 years ago), sea levels declined, sediment deposition was interrupted, and weathering of the Beaumont formation produced an unconformity. The sea level again rose during the Recent or Late Wisconsin postglacial stage (25,000 years ago) and finally stabilized about 3,000 years ago. The present stand of sea level is permitting a Gulfward deposition of alluvial and deltaic sediments which are gradually filling the estuary.

Description of Area — Clear Lake is a small, protected, brackish-water estuary located just west of Upper Galveston Bay in Harris and Galveston Counties, Tex. (See figure on p. 91.) It is about 2.5 miles long, less than 1 mile wide, and has an area of about 1,000 acres.

Average depth is 3-4 ft., excluding a channel dredged to a depth of 6 ft. that extends its entire length and joins a natural channel which connects the lake with Upper Galveston Bay. Two smaller bodies of water, Mud and Taylor Lakes, are located immediately to the north and are joined to Clear Lake by narrow, restricted channels. Although some fresh water enters Clear Lake from Mud Lake and Taylor Lake drainages, the major source is Clear Creek, which discharges into its western end.

Generally speaking, the salinity of Clear Lake, although somewhat lower, fluctuates with that of Upper Galveston Bay except during short periods immediately after heavy (local) rainfall. Considerable variation in salinity is evident both annually and seasonally. An average annual value of 4.7‰ was recorded in 1961, and 17.8‰ in 1963. During 1963, salinity was lowest in the winter (averaging 10.8‰), increased during spring and summer, and reached a high in the fall when it averaged 22.5‰. A temporary low of 0.7‰ was recorded in early February 1964. Winds thoroughly mix the shallow waters of the lake as little difference in salinity was ever noted between surface and bottom. Only small differences occurred at any particular time, with the lower values usually being recorded nearest the points of fresh-water discharge.

As in other years, water temperature during 1963 varied considerably with the seasons. A low of 2.9° C. (37° F.) was recorded in late January and a high of 34.0° C. (93° F.) in July. Although the temperature distribution in Clear Lake was superficially similar to that in Galveston Bay proper, the waters of Clear Lake usually responded more rapidly to changes in air temperature. In general, Clear Lake evidently warms faster in the spring, reaches a higher value in the summer, cools somewhat slower in the fall, and is colder in late winter. Except in the dredged channel, little variation was noted between surface and bottom temperatures.

Methods Sediment samples were obtained at 45 locations with a modified Ekman dredge. They were analyzed for proportions of sand, silt, clay, shell debris, and organic matter. Sand was separated by means of standard sieves, whereas silts and clays were identified with soil hydrometers using procedures employed by the U. S. Army Corps of Engineers. Sediment classification was based upon textural nomenclature developed by the American Petroleum Institute's Project 51. Organic content was determined by burning a dried sample at 1,200° F.

At six locations that had been previously designated as sampling stations by investigators engaged in other studies, bottom fauna were collected seasonally with a 3-ft. "scraping" try-net constructed of 3-mm. nylon mesh (stretched measure).

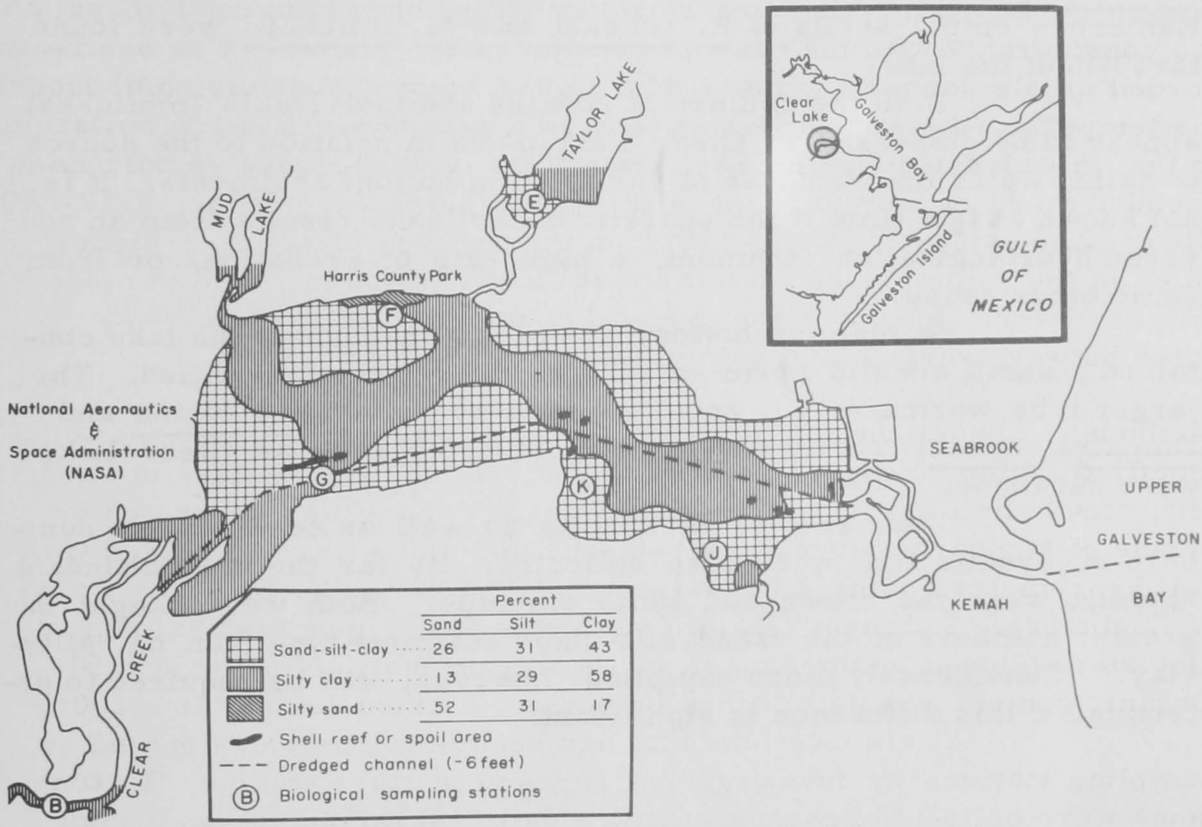
Bottom Sediments Sediments throughout Clear Lake are fairly uniform and vary mostly in the amount of sand present. (See accompanying figure.) Those near and adjacent to the shoreline may be classified as "sand-silt-clay," whereas sediments in the central portion of the lake and in Mud and Taylor Lakes are predominantly "silty-clays."

The higher sand content along the margins probably results from weathering of the Beaumont formation. Shoreline erosion washes this material into the lake where the heavier sediments (sand) drop out first, and the silts and clays tend to migrate toward the central basin.

A small patch of "silty-sand" occurs along the north shore between Mud Lake and Taylor Lake channels. This accumulation probably resulted from construction of an artificial sand beach at the Harris County Park.

Analysis also revealed that organic content in the surface sediments is fairly uniform at about 2.0 percent throughout the lake except in the dredged channels where it is considerably lower.

Bottom Fauna Invertebrate bottom fauna exclusive of shrimp were sparsely represented, with collections producing too few animals to permit comparison of seasonal trends in abundance. Moreover, it



Distribution of sediments in Clear Lake and adjacent areas based on sand-silt-clay content.

was found upon completion of a sediment distribution map that sampling stations other than those in natural and dredged channels had been fortuitously located in the same sediment type (sand-silt-clay). These stations were originally established (1958) solely to facilitate representative sampling of fish and shrimp, and since they had already yielded considerable biological data that could be used for comparative purposes, were also employed for sampling the bottom fauna during the present investigation. Despite this happenstance, however, it is expected that differences in the faunal composition of the two major but closely related sediment types are not great. Preliminary confirmation of this similarity was obtained from limited sampling.

Only five species of mollusks were represented among the bottom organisms collected from this variable-salinity environment. These forms included the pelecypods, Rangia cuneata, R. fleuxosa, Macoma mitchelli, and Mulinia lateralis, as well as the gastropod, Nassarius acutus.

R. cuneata was the most numerous mollusk, being found everywhere except in the extreme upper lake and in the dredged channel. Each of the five species, however, was present in the lower lake nearest the source of higher salinity water. Only one species, M. lateralis, was recovered from the upper, less saline portion. Numerous empty shells of R. cuneata and M. mitchelli were found throughout the lake.

Both the number of species and individuals (mollusks) appear to be dispersed in Clear Lake more in relation to the source of saline water than because of variation in bottom sediments. It is not known at this time if the sparsity of mollusks results from an adverse hydrological environment, a high rate of predation, or from some other cause.

Samples of bottom fauna from throughout the lake contained a small annelid worm which has not yet been identified. The larger tube worms (e.g., annelids such as Polydontes lupina and Diopatra cuprea) usually observed in estuaries such as Clear Lake were not found.

Four species of shrimp as well as considerable numbers of juvenile fish were also collected. By far the most abundant shrimps were the brown and white shrimps. Both were caught in greater numbers on the "sand-silt-clay" sediment type than on "silty-clay." Considerably more sampling, however, will be required to determine if this difference is significant.

Research on the Molecular Basis of Brain Function in Fish

Donald A. Rappoport, Director, Division of Molecular Biology
University of Texas Medical Branch, Galveston

A project has been initiated at The University of Texas Medical Branch, Department of Pediatrics, which deals with the molecular basis of brain function, primarily the accrual and recall of information in the olfactory system of fish. Since this project specified the sea catfish (Galeichthys felis) as the experimental organism, it was necessary to locate a source of and storage facilities for live specimens. Personnel at the Bureau of Commercial Fisheries Biological Laboratory in Galveston have been instrumental in acquiring and storing live catfish whenever these services did not interfere with normal laboratory functions. Such assistance has allowed the Division of Molecular Biology in the Department of Pediatrics to carry out experiments on the changes in ribonucleic acids in the olfactory bulbs and frontal lobes of the catfish brain after stimulation. In this early stage of these investigations, a specific enzyme (nucleotide phosphorylase) has already been identified in the nuclei of the catfish brain and is conceptualized as an enzyme whose activity is intimately associated with afferent impulses entering the brain. (This work, concerned with the exploration of basic mechanisms of information processing in the brain, is supported by United States Public Health Service Grant No. MH 10053-01.)

Description of Salt-Water Laboratories

Kenneth T. Marvin and Raphael R. Proctor, Jr.

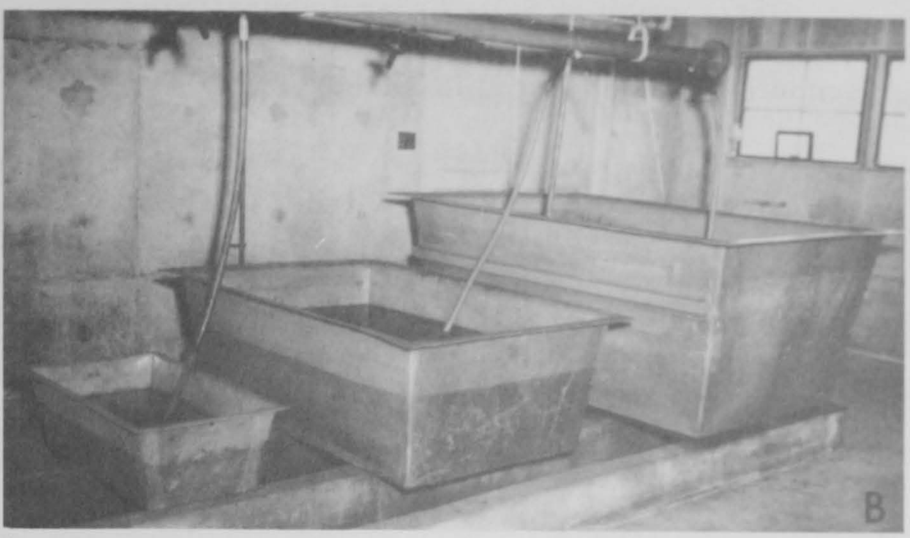
During 1961 and 1962, two large salt-water systems were added to the research facilities of the Bureau of Commercial Fisheries Biological Laboratory in Galveston, Tex. Dearth of information on the construction of salt-water research laboratories handicapped Bureau personnel during the planning stages of both systems. But with the help of the U. S. Army Corps of Engineers and much educated guessing, the two units were built and have functioned reasonably well since becoming operative. One of these, a recirculating system located on the laboratory grounds at Fort Crockett, is capable of holding large numbers of marine organisms for experimental and other purposes. The other, a constant-flow system located on East Lagoon 5 miles east of the laboratory, permits the study of estuarine organisms under seminatural conditions.

Recirculating Salt-Water Laboratory The recirculating salt-water laboratory (fig. A) has a capacity of about 70,000 gal. It consists of


A

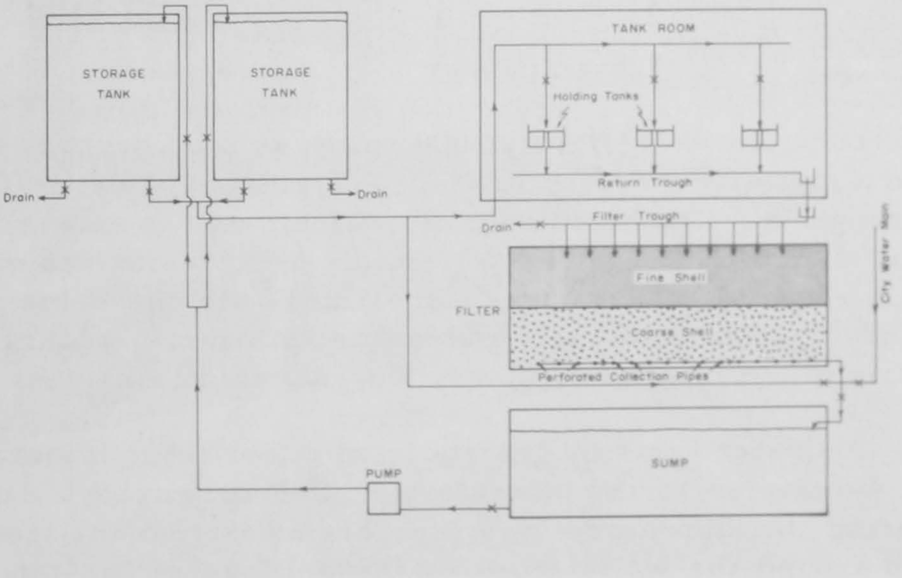
three tank rooms covering about 1,000 sq. ft., a food preparation room, office, and a foyer for public exhibits. Polyvinylchloride (PVC) piping is used throughout. The holding tanks, which range in size from 50 to 650 gal. (B) are made of fiberglass reinforced polyester resin; the two 28,000-gal. redwood storage tanks are lined with the same material. The only direct contact the salt water has with metal occurs during a 5-mile trip to the laboratory in a 4,000-gal. stainless steel tank truck.

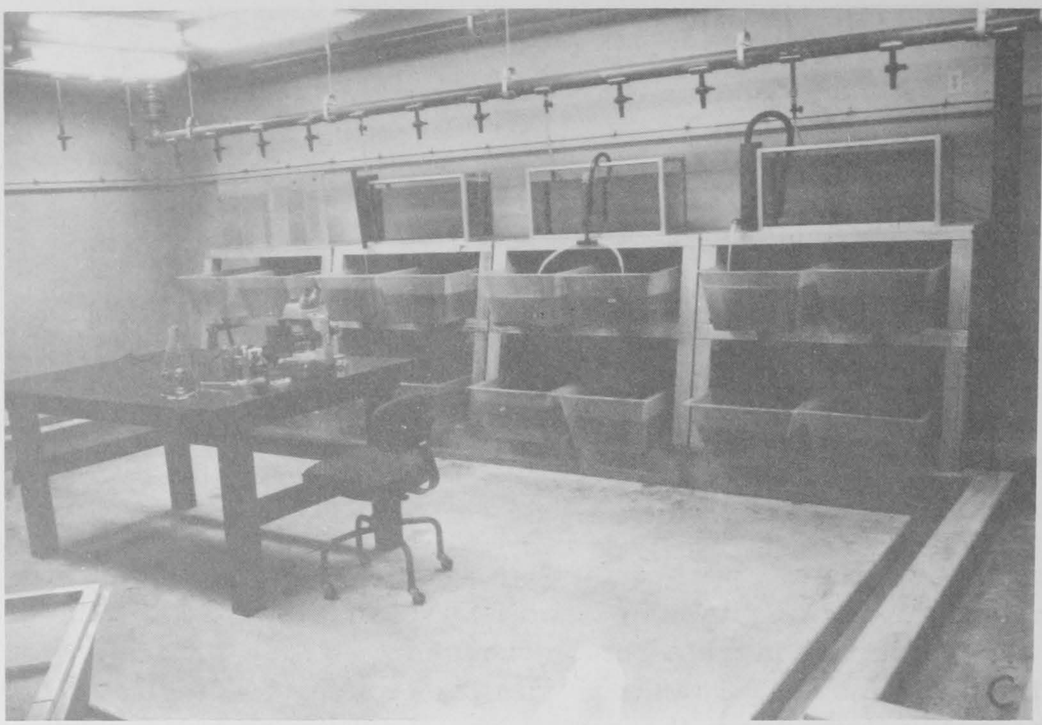
Water flows by gravity from either or both storage tanks through a 4-in. pipe to the laboratory. (See accompanying diagram.) After entering the laboratory, the pipe branches to 3-in. feeder lines that extend around the walls close to the ceilings of the tank rooms.



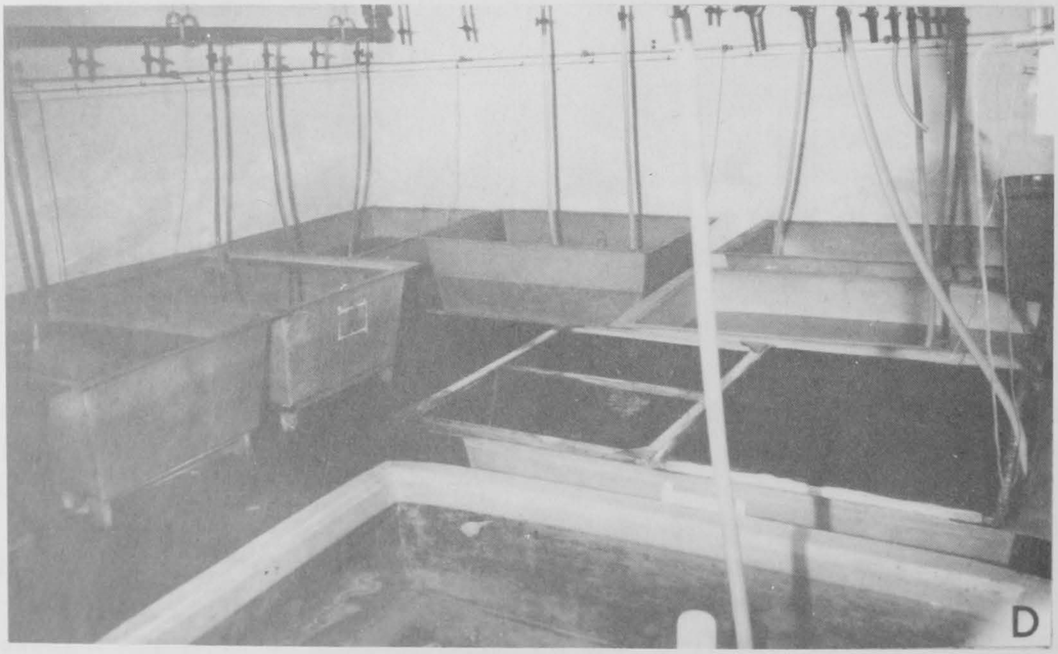
From the feeder lines it passes through $\frac{1}{2}$-in. or $\frac{1}{4}$-in. petcocks to the experimental or holding tanks (C and D). Standpipes within the tanks conduct the water to concrete return troughs. Water may also be siphoned from the individual tanks to similar troughs leading to the drain (E). The water flows from the return troughs through a 4-in. pipe that branches into two concrete filter troughs. PVC valves at the end of each branch direct water to either or both of these troughs. By opening 4-in. valves located at the end of each filter trough, the water can be discharged to the drain. By closing the valves, the water overflows the entire $12\frac{1}{2}$-ft. lengths of the troughs into the two sections of the filter bed (F).

The filter bed is divided into two independently operated sections so that it can be cleaned one section at a time without interrupting service in the tank rooms. The filter overlays a network of





perforated 2-in. pipe which collects the filtered water and carries it to a 4-in. line. This line discharges the water into a 9,000-gal. concrete sump located beneath the filter beds. It also connects to the city water-main and the two storage tanks. These connections permit backflushing of the filter beds with tap water and then the removal of residual tap water with system water. Two $7\frac{1}{2}$-hp. pumps, one of which is a standby, are located outside the sump and 15 ft. below ground level. These force the water back into the outside storage tanks, thus completing the cycle.



Both laboratory and filter rooms are insulated, and the laboratory is air-conditioned to minimize temperature change.

When the system was first placed into operation, the maximum flow rate was about 3,000 gal. an hour, less than half the design rate of 8,000 gal. an hour. This volume could not be increased because the inlet and outlet ends of the pipe connecting the tank-room return trough with the filter trough were not totally submerged. Thus, siphoning of the water between the two trough systems was not possible because the 15 or so inches of potential head pressure could not be utilized. This condition was rectified by extending the inlet end of the connecting pipe (with an L fitting) into a 6-in. well at the end of the return trough, and submerging the branching outlet ends into the water in the filter troughs.

Maintenance of an adequate flow rate also required some modification of the filtering system. The filter bed is similar in design to those of municipal water-treatment plants and covers an area of 100 sq. ft. It originally contained 18 in. of washed sand on top of 12 in. of gravel. Cleaning was attempted by first backflushing with tap water to float off entrapped dirt and to regrade sand that had become mixed with the gravel layer, and then backflushing with "tank" water to remove residual tap water from the filter bed. The maximum volume of tap water available, however, was only 6 gal. per min. per sq. ft. of bed area, or about half that required for efficient cleaning and regrading. Consequently, it was necessary to occasionally replace the top half inch or so of the sand layer which contained virtually all the dirt.

Filtering efficiency was also reduced by the presence of air in the interstices of the aggregate material. The air entered when the water level fell below that of the filter surface. Also, the low pressure within the filter bed resulted in the release of some of the dissolved air content of the water in the filter bed, which contributed to "air binding."

The difficulties experienced when backflushing and with entrapped air were somewhat alleviated by replacing the sand and gravel in the filter bed with crushed and uncrushed oyster shell, respectively. The grading problem was overcome by separating the shell layers from each other with fiberglass screening.

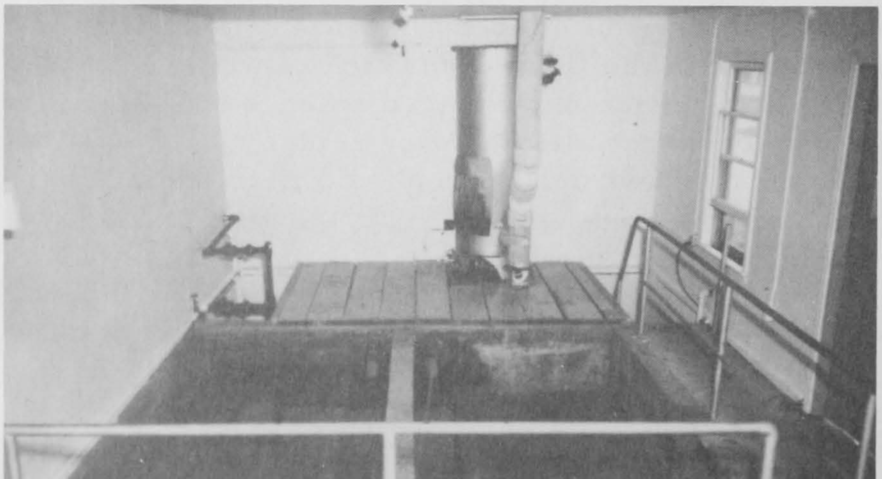
During the first 1½ yr. of operation, boring organisms, which had been inadvertently introduced into the system, destroyed practically all the redwood tanks. The large water storage tanks were saved by lining them with fiberglass reinforced resin, and the smaller ones were replaced with tanks made entirely of the fiberglass-resin material.

A 2-hp. air compressor supplies air to the three tank rooms. One-half-in. plastic lines parallel the salt-water feeder lines and are fitted with outlets to supply air to holding and experimental tanks.

A salt-water line in one of the tank rooms is connected to a 120-gal., 150,000-B.t.u. gas heater. This line supplies water to experimental units requiring precise temperature control.

Shock hazard in the tank rooms has been reduced by supplying all wall plugs with electrical current from an isolation transformer. This device eliminates the possibility of circuit completion through the damp tank-room floors.

Twice a week the system's water is sampled for the following chemicals: nitrate, nitrite, and ammonia nitrogen, and phosphate phosphorus. In addition, it is checked five times a week for salinity and temperature.

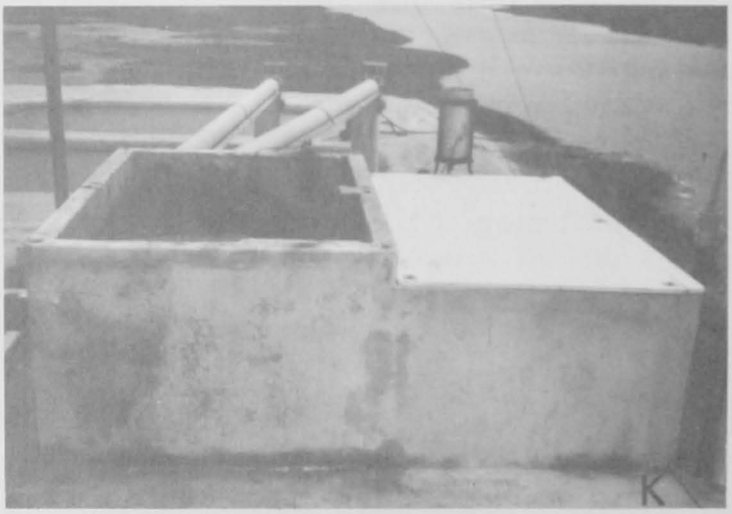


For several years now, the system has been operating satisfactorily. An electrical disturbance known as "single phasing" resulted in the flooding of the filter bed and subsequent loss of water on several occasions, but this source of trouble has been virtually eliminated by the installation of a phase "safeguard" device.

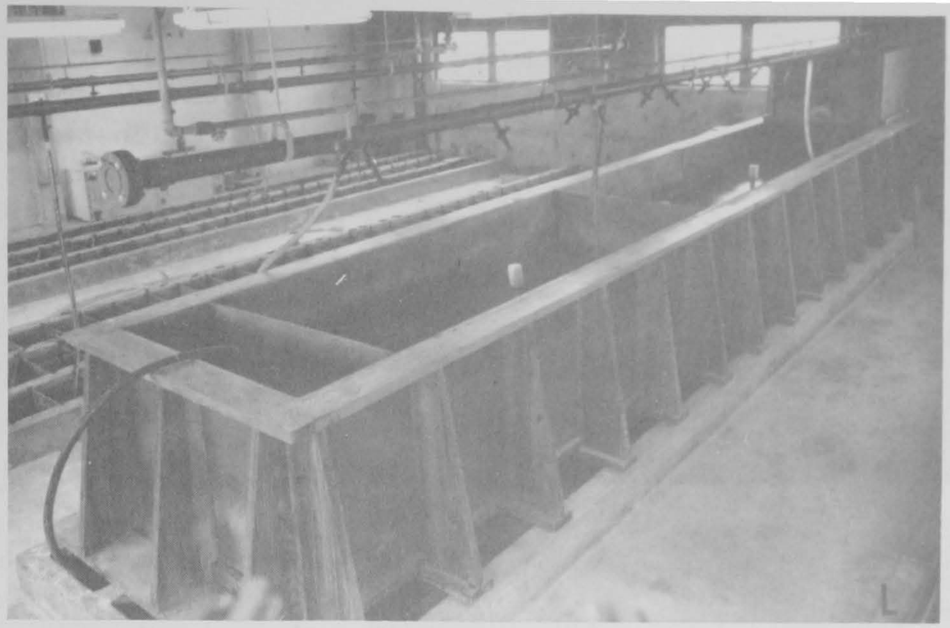
<u>Continuous-Flow Salt-Water System</u> The continuous-flow laboratory (G) occupies a 42- by 92-ft. concrete slab, supported $18\frac{1}{2}$ ft. above East

Lagoon by concrete piling. It consists of a 40- by 50-ft. tank room, a food preparation room, a pump room, and a combination office and instrument room. Auxiliary power is provided by an engine-generator set (50 kw.) located in a small room near the main entry. A stairway (H) leads down to a small pier at the south end of the laboratory. The

roof is constructed of prestressed concrete beams and supports, among other things, the receiving, settling, and distribution tanks (J). These have a combined capacity of about 22,000 gal.

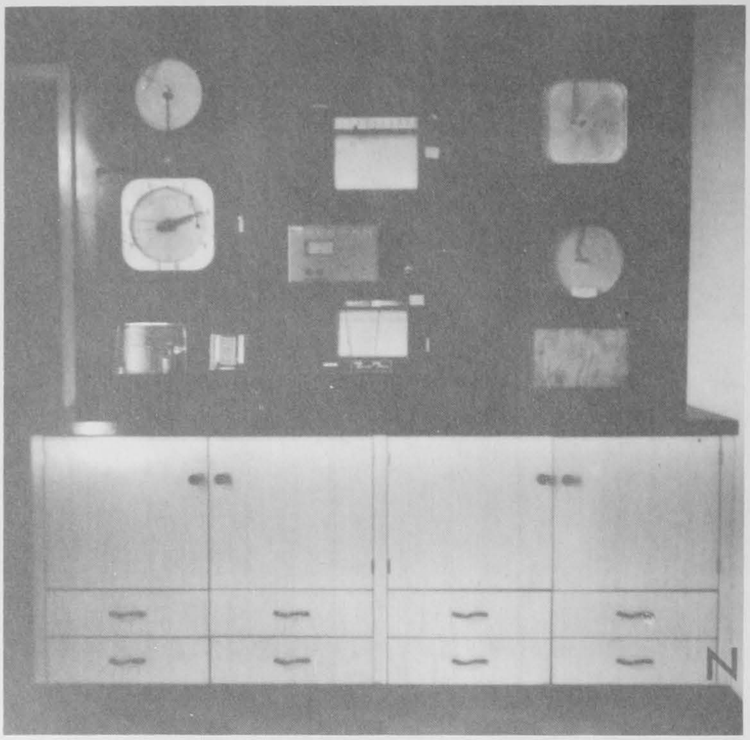


The heart of the system consists of two 10-hp. pumps that can operate singly or in tandem. Each delivers water at 30,000 gal. an hour from the lagoon beneath the pump room to the receiving tank which is located on top of the settling tank (K). A spillway from the receiving tank allows water to overflow through a 1/8-in.-gage, stainless steel filter into the 10- by 40- by 5-ft. concrete settling tank.



Two 12- by 18-in. ports in a common wall allow water to pass from the settling tank into the distribution tank which is 3 ft. wide, 5 ft. high, and extends along the west edge of the roof directly over the tank room. The water level in the two connecting tanks is controlled by a float switch. Two 4-in. standpipes prevent overflow if, for any reason, the float switch fails to operate. Five 3-in. feeder lines run from the bottom of the distribution tank to the tank room (L), and one to a valve on the outside of the building which is used to dispense water into the laboratory's tank truck (M).

Each of the five tank-room feeder lines is suspended over a set of four concrete troughs that support experimental and holding tanks. These sets are 6 ft. wide, 30 ft. long and discharge into a sluiceway which extends along the wall the full length of the tank room. The tanks receive water from plastic tubing connected to petcocks in



in the feeder lines. Water is discharged from the tanks through standpipes into the troughs and thence to a sluiceway which, in turn, discharges it back to the lagoon at a location approximately 100 ft. removed from the inlet end of the water pumps.

Air from a 5-hp. compressor circulates throughout the tank room in iron pipes suspended several inches over the salt-water feed lines. The pipes contain a sufficient number of petcocks to supply all holding and experimental tanks.

Propane fuel used to heat the laboratory and, when needed, to run the emergency generator, is piped from a 1,000-gal. storage tank located several hundred feet from the laboratory.

Several weeks after the laboratory was placed in operation severe leakage developed in the roof tanks. This problem was corrected by lining all concrete tanks with fiberglass-reinforced polyester resin. The restricting effect of fouling organisms in the salt-water feeder lines is minimized by periodically flushing the lines with dilute hydrochloric acid.

Recording equipment in the laboratory's instrument room (N) maintains continuous records of water temperature and conductivity (salinity), water elevation, pH, air temperature, barometric pressure, humidity, precipitation, solar radiation, and wind direction and speed. In addition, samples are taken twice a week from the receiving tank for the following chemical analyses: nitrate, nitrite, and ammonia nitrogen; phosphate phosphorus; chlorophyll; and carbohydrates.

Usually, about the end of July or the beginning of August, severe blooms of the dinoflagellate, Gonyaulax monilata, occur in the lagoon. Such blooms can be very disruptive to laboratory experiments. So to minimize the effect of this organism, biological examinations of the water are made starting in mid-June. At the first indication of an impending bloom, a portion of the tank room is maintained independently on a recirculating basis. This subsystem consists of a 16-sq. ft., crushed-shell filter, and a 2,400-gal. combination holding and storage tank (M). Experiments that might be adversely affected by G. monilata are then, if feasible, temporarily incorporated into the recirculating subsystem.

Library

Stella Breedlove, Librarian

Additions to the library during Fiscal Year 1964 totaled 507 volumes of books and journals, 2,263 reprints and miscellaneous items, and microcard editions of 182 out-of-print publications. With these acquisitions, the library collection has increased to more than three times its size in 1959. The new library quarters have provided more adequate accommodations for the expanding collection, and use of cataloged material has been facilitated.

Statistical Summary of Library Collection

	On hand 1963	Additions 1964	On hand 1964
Books	2,110	271	2,381
Journals (Bound)	464	55	519
Journals (Unbound)	1,214	181	1,395
Reprints	2,626	322	2,948
Institutional	7,653	1,691	9,344
Other	1,025	250	1,275
Total items	15,092	2,770	17,862

There has been a corresponding increase in requests for library services. In addition to those services regularly provided the Laboratory staff, the library also satisfied a number of inquiries from outside sources regarding reference and bibliographical information, and forwarded to numerous citizens and organizations official publications on various subjects in the field of fishery science.

Forty-seven volumes were borrowed from other institutions for use by the Laboratory staff, while loans to other libraries and institutions totaled 101 volumes.

During the year, use of the Library of Congress Classification System was resumed. Documentation processes included the assignment of subject headings to a major portion of the reprint file. Received and processed were official publications from over 40 laboratories and Government offices. A weekly list of library acquisitions continued to be distributed to the staff and to other laboratories.

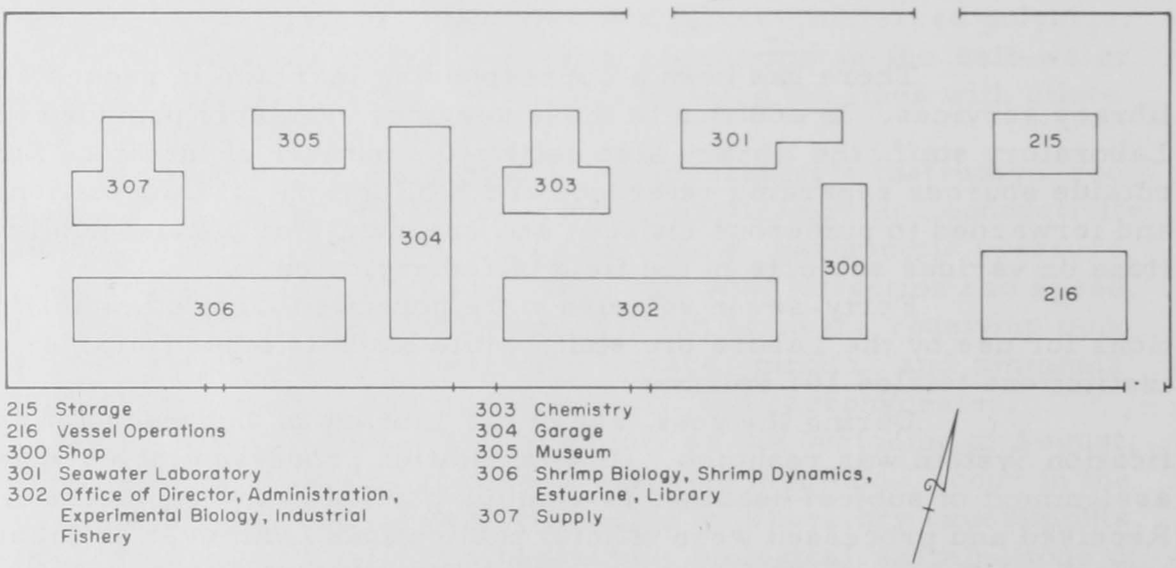
The librarian assisted in the organization of libraries at Texas A & M University's Marine Laboratory in Galveston, and at Bureau installations in St. Petersburg Beach, Fla. and Brunswick, Ga.

Laboratory Facilities

Raymond H. Niblock, Administrative Officer

The research program of the Bureau of Commercial Fisheries Biological Laboratory at Galveston, Tex. enjoyed a healthy expansion over the past 18 months. To accommodate accelerated research activities, a number of well-qualified professional and support personnel joined the staff, programs and supporting services were reorganized to ensure full utilization of manpower, and new facilities were added.

In the fall of 1962, formal transfer from the General Services Administration of real estate consisting of 1.32 acres of adjacent land and three permanent-type buildings was consummated. The buildings involved had not been occupied for a number of years so it was necessary to completely renovate their interiors to make them habitable. This work included installation of plumbing for scientific equipment and additional restrooms, and of new electrical and gas service with sufficient capacity to provide the needs of year-round air conditioning as well as other special apparatus.



Ground plan of the Bureau of Commercial Fisheries Biological Laboratory at Fort Crockett, Galveston, Tex.

Building 307, a single-story, T-shaped, masonry building was the first structure to be converted and now houses our central supply operation which provides a systematic means for better control and utilization of supplies, equipment, and materials.

Taking inventory of scientific glassware.

The interior of Building 306, a two-story masonry structure, was completely refurbished by first sandblasting and redecorating the walls, then installing accoustical ceilings, asphalt floor tiles, new lighting fixtures, and metal partitions. Laboratories and specimen-processing rooms were equipped with modern cabinetry, fume-vent hoods, and special wiring for scientific equipment. Loading platforms and large access doors were provided to facilitate handling biological samples arriving at the wet laboratories. Year-round air conditioning was accomplished by installing (window) cooling units and large-capacity space heaters. This building now houses three major research programs and the library, each of which had out-grown its previously assigned space.

Building 305, a single-story masonry building, was recently remodeled and is being outfitted as the Laboratory's museum. Also to be stored here for ready retrieval or reference will be the numerous biological collections and environmental data acquired during routine investigational activities. Plans are being formulated to install a large, walk-in, deep-freeze unit (equipped with auxiliary power) which will provide a central facility for holding biological samples until they can be processed.

The Experimental Biology Program, housed in Building 302, now enjoys the use of four large constant-temperature rooms equipped with electronic controls that operate individual refrigerating and heating units necessary for maintaining desired temperatures. The rooms were designed to accommodate simultaneously 112 20-gal. aquaria. Aeration is provided through a plastic manifold system connected to a dual air compressor specifically designed for this purpose.

Because of the vulnerability of this location to hurricanes, telephone cables and 50 percent of the electrical service have been relocated underground. The remainder of the electrical service is scheduled for underground installation in the near future. Similarly, all laboratory units are now supplied with distilled water and sea water through an underground plastic pipe system.

MEETINGS ATTENDED*

American Institute of Biological Sciences, Amherst, Mass., August (2)

American Fisheries Society, Minneapolis, Minn., September (2)

American Fisheries Society (Southern Division), Hot Springs, Ark., October (3)

Gulf States Marine Fisheries Commission, Biloxi, Miss., October (4)

California Cooperative Oceanic Fisheries Investigation, Lake Arrowhead, Calif., November (1)

American Society of Parasitologists, Chicago, Ill., November (1)

Gulf and Caribbean Fisheries Institute, Miami, Fla., November (5)

Committee for the Scientific Exploration of the Atlantic Shelf (SEAS), Washington, D. C., December (1)

Texas Shrimp Association, Galveston, Tex., January (2)

Louisiana Shrimp Association Meeting, New Orleans, La., January (2)

Estuarine Symposium, Jekyll Island, Ga., April (2)

Gulf States Marine Fisheries Commission, New Orleans, La., April (4)

Infrared Survey Technique Workshop, Washington, D. C., April (1)

Louisiana Wild Life and Fisheries Commission, Grand Isle, La., April (1)

Seminar on Advanced Water Resource Topics, University of Texas, Austin, Tex., April (1)

Shrimp Association of the Americas, Mexico City, Mex., May (1)

*Attendance shown in parentheses.

Special Assignment

J. Bruce Kimsey, Leader, Shrimp Biology Program, participated (as a member of a five-man team of experts) in a 3-mo. project designed to provide Bureau of Commercial Fisheries technical services to USAID/Brazil to appraise and determine the feasibility of developing the fresh-water fish resources of northeastern Brazil, and to review the program and operation of the Tamandare Ocean Fisheries Training Center.

WORK CONFERENCES*

A policy conference on Texas Basins Project, Austin, Tex., September (3)

Conference with Branch of River Basin Studies and Louisiana Wild Life and Fisheries Commission personnel to assist in initiating contract research for hydrological studies in the Mississippi River-Gulf Outlet Project area, New Orleans, La., and vicinity, September (2)

Meeting with Bureau of Reclamation and Branch of River Basin Studies personnel regarding the Texas Basins Project, Austin, Tex., October (1)

Conference with Texas Water Pollution Control Board relative to the Galveston Bay Pollution Survey, Seabrook and La Marque, Tex., October (1)

Meeting with Economics Laboratory personnel concerning techniques of forecasting Gulf coast shrimp supplies, Washington, D. C., October (2)

Meeting with naval architect relative to construction of the Laboratory's new research vessel, New Orleans, La., December and January (1)

Meetings with personnel of the Bureau's Radiobiological and Biological Laboratories (Beaufort), Duke University Marine Laboratory, and North Carolina University Institute of Fisheries Research to examine facilities and exchange ideas, December (2)

Conference with personnel of the Texas Parks and Wildlife Department concerning problems of oyster growers along the Texas coast, January (1)

Informal meeting with shrimp fishermen and industry members to describe shrimp research activities in the west-Florida area, Key West, Fla., February (5)

Conference with personnel of the Texas Parks and Wildlife Department on Audubon Society leases and private oyster leases in Texas estuaries, Harlingen, Tex., February (1)

Meeting of the Technical Advisory Committee of the Texas Water Pollution Control Board relative to the Galveston Bay Pollution Survey, Austin, Tex., February (1)

Conference with personnel of the Texas Parks and Wildlife Department and Branch of River Basin Studies concerning the Texas Basins Project, Galveston, Tex., March (2)

*Attendance shown in parentheses.

PUBLICATIONS

Allen, Donald M.

1963. Shrimp farming. U.S. Fish Wildl. Serv., Fish. Leafl. 551, 8 p.

Costello, T. J.

1964. Field techniques for staining-recapture experiments with commercial shrimp. U. S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 484, ii+13 p.

Dragovich, Alexander, John H. Finucane, John A. Kelly, Jr., and Billie Z. May.

1963. Counts of red-tide organisms, Gymnodinium breve, and associated oceanographic data from Florida west coast, 1960-61. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 455, ii+40 p.

Klima, Edward F.

1964. Mark-recapture experiments with brown and white shrimp in the northern Gulf of Mexico. Proc. Gulf Carib. Fish. Instit., 16th Annu. Sess.: 52-64.

Marvin, Kenneth T.

1964. Construction of fiberglass water tanks. Progr. Fish-Cult. 26(2): 91-92.

Marvin, Kenneth T., and Raphael R. Proctor, Jr.

1964. Preliminary results of the systematic screening of 4,306 compounds as "red-tide" toxicants. U.S. Fish Wildl. Serv., Data Rep. 2, 84 p. (3 microfiches).

Rounsefell, George A.

1963. Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas. U.S. Fish Wildl. Serv., Circ. 154, i+29 p.

1964. Preconstruction study of the fisheries of the estuarine areas traversed by the Mississippi River-Gulf Outlet Project. U.S. Fish Wildl. Serv., Fish. Bull. 63: 373-393.

*Storr, John F.

1964. Ecology of the Gulf of Mexico commercial sponges and its relation to the fishery. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 466, iii+73 p.

U. S. Fish and Wildlife Service.

1964. Biological Laboratory, Galveston, Texas., Fishery Research for the year ending June 30, 1963. U.S. Fish Wildl. Serv., Circ. 183, iv+106 p.

MANUSCRIPTS IN PRESS

Cook, Harry L.

A generic key to the protozoean, mysis, and postlarval stages of the littoral Penaeidae of the northwestern Gulf of Mexico. U.S. Fish Wildl. Serv., Fish. Bull. (27 MS. p., 7 figs.).

Diener, Richard A.

The occurrence of tadpoles of the green treefrog, Hyla cinerea cinerea (Schneider), in Trinity Bay, Texas. Brit. J. Herpet. (4 MS. p.).

Murphy, Maud Alice.

A microcounting chamber. Progr. Fish-Cult. (4 MS. p., 1 fig.).

Roithmayr, Charles M.

Review of the Gulf of Mexico industrial bottomfish fishery, 1959-62. Com. Fish. Rev. (12 MS.p., 9 figs.).

Temple, Robert F., and Clarence C. Fischer.

Vertical distribution of the planktonic stages of penaeid shrimp. Publ. Instit. Mar. Sci. (18 MS.p., 5 figs.).

MANUSCRIPTS SUBMITTED

Marvin, Kenneth T., and Raphael R. Proctor, Jr.

Stabilizing the ammonia-nitrogen content of estuarine and coastal waters by freezing. Limnol. Oceanogr. (8 MS. p., 1 fig.).

*Contract Research

MS. #1477

GPO 894-250