UNITED STATES DEPARTMENT OF THE INTERIOR

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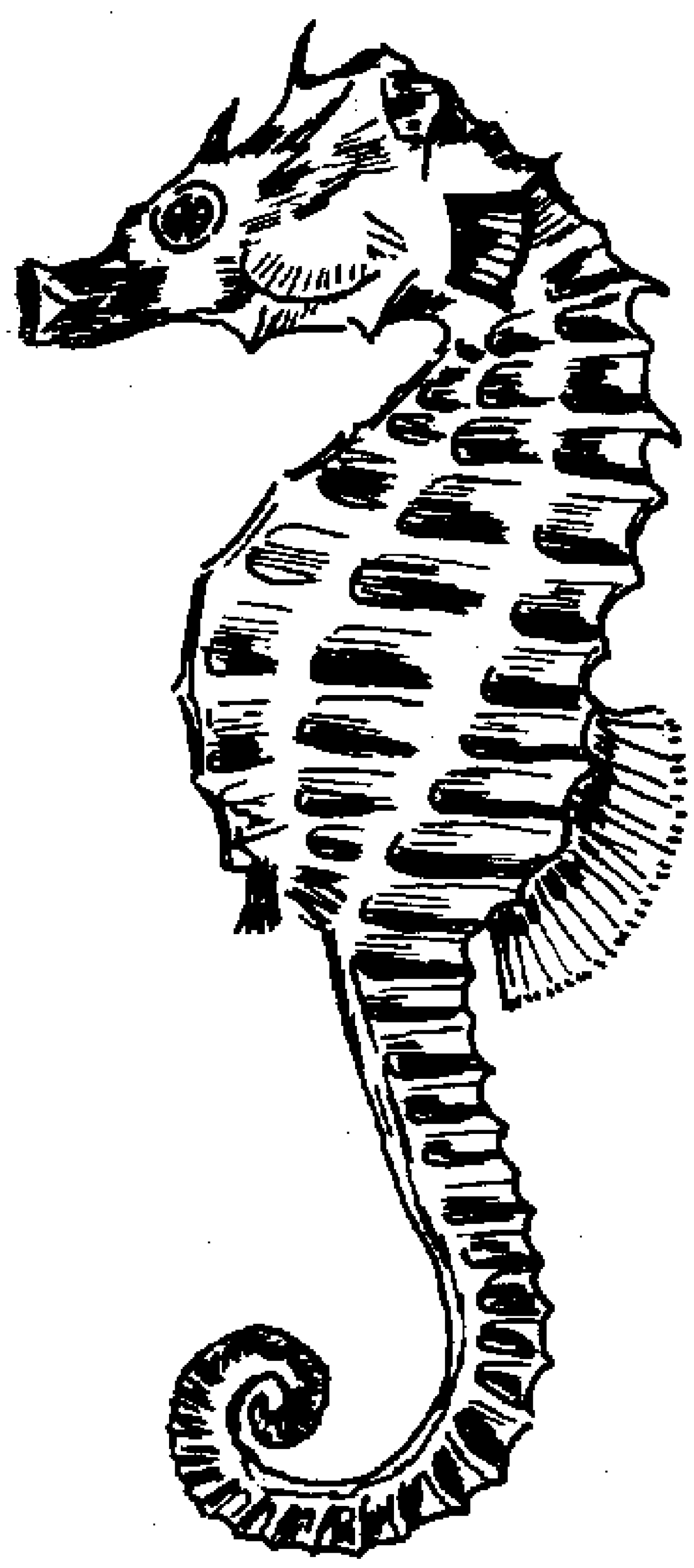
BUREAU OF COMMERCIAL FISHERIES, Donald L. McKernan, *Director*

BIOLOGICAL LABORATORY, GALVESTON, TEX.

FISHERY RESEARCH

for the year ending June 30, 1963

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



Contribution No. 183, Bureau of Commercial Fisheries
Biological Laboratory, Galveston, Tex.

Circular 183

Washington, D. C.
1964

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

Office of the Regional Director, Seton H. Thompson, is in the Don Ce-Sar Federal Center, P. O. Box 6245, St. Petersburg Beach, Fla.

Biological Research

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

Industrial Research

Exploratory Fishing and Gear Research Base, Pascagoula, Miss., auxiliary bases at Brunswick, Ga., and Panama City, Fla.
Marketing - Marketing Offices in Dallas, Tex.; Jacksonville, Fla.; and Pascagoula, Miss.
Technology - Technological Laboratory, Pascagoula, Miss.

Resource Development

Statistical Center and Market News Office, New Orleans, La.
Loans and Grants Office, St. Petersburg Beach, Fla.

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REPORT OF THE DIRECTOR

Milton J. Lindner

Research at the Bureau of Commercial Fisheries Biological Laboratory in Galveston concerns shrimp, estuaries, and industrial bottomfishes, and is conducted under four broad programs:

1. Shrimp Fishery (which includes four research contracts);
2. Estuarine;
3. Physiology and Behavior;
4. Industrial Fishery.

Each of these programs is subdivided into projects.

This report deals with progress in project research during fiscal year 1963. Since this is a progress report, the findings recorded are preliminary in nature.

Research Developments During the Year Pink shrimp (University of Miami contract) and one species of rock shrimp for the first time have been reared in the laboratory from the egg through the larval and postlarval stages.

Laboratory experiments showed that: (1) temperature is more influential than salinity in controlling growth of postlarval grooved shrimp; (2) within vertical salinity and temperature gradients, postlarval shrimp were able to avoid lethal salinities but not low lethal temperatures; (3) the molting frequency of postlarvae held at 76° F. was about twice that of those at 66° F.; and (4) after 28 days, postlarvae held at 90° F. were about 60 times heavier than those at 52° F.

Experiments with fluorescent stains yielded five additional substances which can serve as secondary marks for live shrimp. These results increase from 2 to 12 the number of marking projects that can be carried on simultaneously in the same general area.

Mark-recapture experiments demonstrated that brown shrimp from Galveston Bay are recaptured in the fishery at all points along the Texas coast.

White shrimp marked and released in late September grew in 2 weeks from 58 headless-count (120 mm. total length) to 41-count (135 mm.), and to 24-count (160 mm.) by the end of November.

Pink shrimp marked and released at Indian Key, Fla., were subsequently recaptured on both the Sanibel and Tortugas fishing grounds, which suggests the existence of an unexploited shrimp supply between Sanibel Island and Dry Tortugas where the bottom is not suited for trawling.

The large white shrimp (30 headless-count and under) that appear each spring in Galveston Bay apparently enter from the Gulf and work their way inland.

The Houston Ship Channel has the effect of a barrier, tending to separate Galveston Bay hydrologically into eastern and western portions.

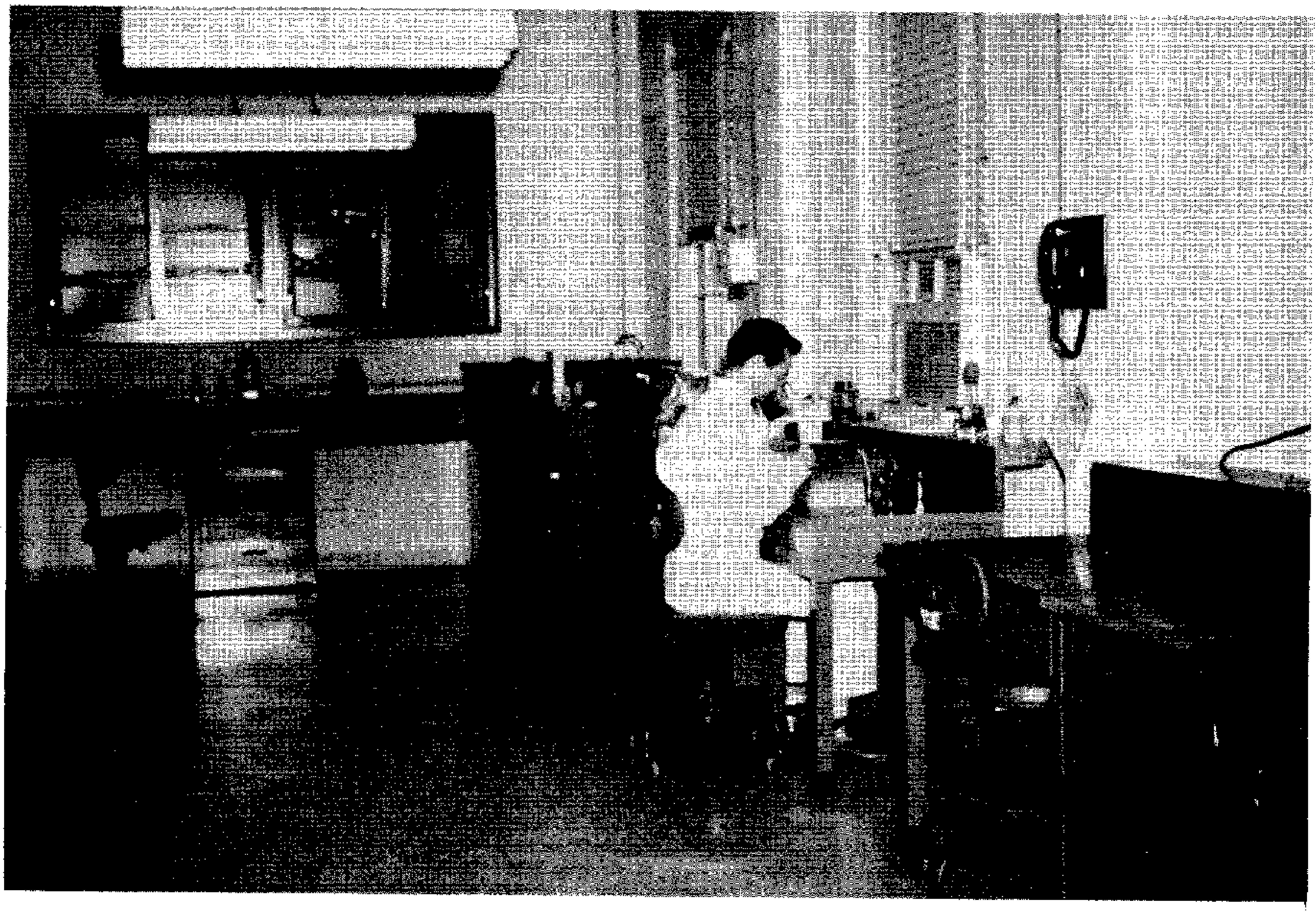
Improvement in Research Facilities The four constant-temperature rooms placed in operation during 1962 have already proved their value in terms of useful information obtained through controlled experiments with postlarval shrimp.

A 40-kw. power plant, which eliminates shutdowns during local power failures, was installed in the East Beach Lagoon Field Station. This installation was also provided with a 2,400-gal. recirculating system to permit the continuance of some experiments during periods when toxic plankton blooms occur in the lagoon. The system provides clear water when needed and facilitates temperature control during winter.

Because of susceptibility to damage by boring organisms, redwood holding tanks in the recirculating laboratory at Fort Crockett were replaced with fiberglass tanks. A constant-temperature bath and water purification unit were also installed as additional facilities for rearing larval shrimp and other purposes. One of the 28,000-gal. reservoir tanks was fitted with observation ports to permit its use in studying vertical, diurnal movements of various fishes.

Three additional masonry buildings were acquired at Fort Crockett, and two of these were made habitable. The largest of the buildings will provide laboratory and office space for the staffs of the Shrimp Fishery and Estuarine Programs, and will house the library. One of the smaller buildings will be converted for use as a storage and supply center.

Toward the close of the fiscal year, a contract was let for the design of a modern 95-ft. fishery-oceanographic research vessel. This vessel is expected to be in service the early part of calendar year 1965.



View showing typical accommodations in new laboratory facility.

STAFF

Milton J. Lindner, Laboratory Director[1/]

Joseph H. Kutkuhn, Assistant Laboratory Director

Biological Laboratory at Galveston, Tex.

Field Stations at Miami, Fla., and Pascagoula, Miss.

<u>Shrimp Fishery Program</u>

J. Bruce Kimsey	Program Leader	Galveston
Thomas J. Costello	Head, Field Station	Miami
Donald M. Allen	Biologist	Miami
William C. Renfro	Biologist	Galveston
Richard J. Berry	Biologist	Galveston
Robert F. Temple	Biologist	Galveston
Edward F. Klima	Biologist	Galveston
David L. Harrington	Biologist	Galveston
Harry L. Cook	Biologist	Galveston
Harold A. Brusher	Biologist	Galveston
Kenneth N. Baxter	Biologist	Galveston
Ray S. Wheeler	Biologist	Galveston
Charles E. Knight	Biologist	Houma
Clarence C. Fischer	Biologist	Galveston
Thomas W. Turnipseed	Biologist	Morgan City
James M. Lyon	Biologist	Aransas Pass
Joseph A. Benigno	Biologist	Pascagoula
John B. Hervey	Biologist	Galveston
Charles R. Frith	Biologist	Brownsville
Robert C. Benton	Biologist	St. Petersburg Beach
James H. Hudson	Biologist	Key West
Kenneth W. Osborn	Biologist	Galveston
Aubrey A. LaFrance	Aid	Galveston
Carl E. Wood	Aid	Galveston
Dennis A. Emiliani	Aid (resigned 4/63)	Galveston
Larry M. Wiesepape	Aid	Galveston

1/ George A. Rounsefell retired as Laboratory Director in April 1963.

Shrimp Fishery Program (continued)

Imogene A. Sanderson	Technician	Galveston
M. Alice Murphy	Technician	Galveston
David S. Greene	Summer Aid (resigned 8/62)	Galveston
John G. Migliavacca	Summer Aid (resigned 9/62)	Galveston
Christopher D. Noe	Summer Aid (resigned 9/62)	Galveston
Robert C. Haas	Summer Aid	Galveston
Frank N. Moseley	Summer Aid	Galveston
Frederick D. Miller IV	Summer Aid	Galveston
James B. Reynolds	Summer Aid	Galveston
John A. McDonald	Summer Aid	Galveston
John H. Tweedy	Aid (Intermittent)	Miami
Richard L. Aaron	Aid (Intermittent)	Miami
Jack C. Mallory	Aid (Intermittent) (resigned 10/62)	Miami
Joseph J. Ewald	Aid (Intermittent) (resigned 10/62)	Miami
Donald R. Nelson	Aid (Intermittent) (resigned 11/62)	Miami
Andrew E. Jones	Aid (Intermittent) (resigned 7/62)	Miami
Jack L. Gaines	Aid (Intermittent) (resigned 12/62)	Miami
Stanley I. Becker	Aid (Intermittent) (resigned 3/63)	Miami
Johnny L. Ledford	Aid (Intermittent) (resigned 3/63)	Miami
Henry M. Smith	Aid (Intermittent) (resigned 3/63)	Miami
Douglas R. Gunter	Aid (Intermittent) (resigned 3/63)	Miami

Estuarine Program

Charles R. Chapman	Program Leader	Galveston
Anthony Inglis	Biologist (transferred 1/63)	Galveston

Estuarine Program (continued)

Richard A. Diener	Biologist	Galveston
Charles H. Koski	Biologist (transferred 8/62)	Galveston
Cornelius R. Mock	Biologist (transferred to Galveston 1/62)	Miami
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 B. Adams	Statistical Clerk	Galveston
Domingo R. Martinez	Summer Aid (resigned 9/62)	Galveston
Terry C. Allison	Summer Aid (resigned 9/62)	Galveston
Thomas W. Ates	Summer Aid	Galveston
Edward I. Bault	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
James G. Ragan	Biologist (resigned 8/62)	Galveston
Jerry T. Goff	Aid (resigned 8/62)	Pascagoula
Ronald J. Arceneaux	Summer Aid (resigned 8/62)	Galveston

Physiology and Behavior

David V. Aldrich	Program Leader	Galveston
Zoula P. Zein-Eldin	Biochemist	Galveston
Don S. Godwin	Biologist	Galveston
Roger M. Friedberg	Aid	Galveston
Robert E. Trist	Summer Aid	Galveston

Chemistry and Sea-Water Laboratories

Kenneth T. Marvin	Supervisory Chemist	Galveston
Raphael R. Proctor	Chemist	Galveston
Larence M. Lansford	Technician	Galveston
Elroy L. Young	Aid (resigned 8/62)	Galveston
Larry L. Elam	Aid	Galveston
James Wallet	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	Statistical Draftsman	Galveston
Nellie P. Benson	Clerk-Stenographer (part-time)	Miami

Administration and Maintenance

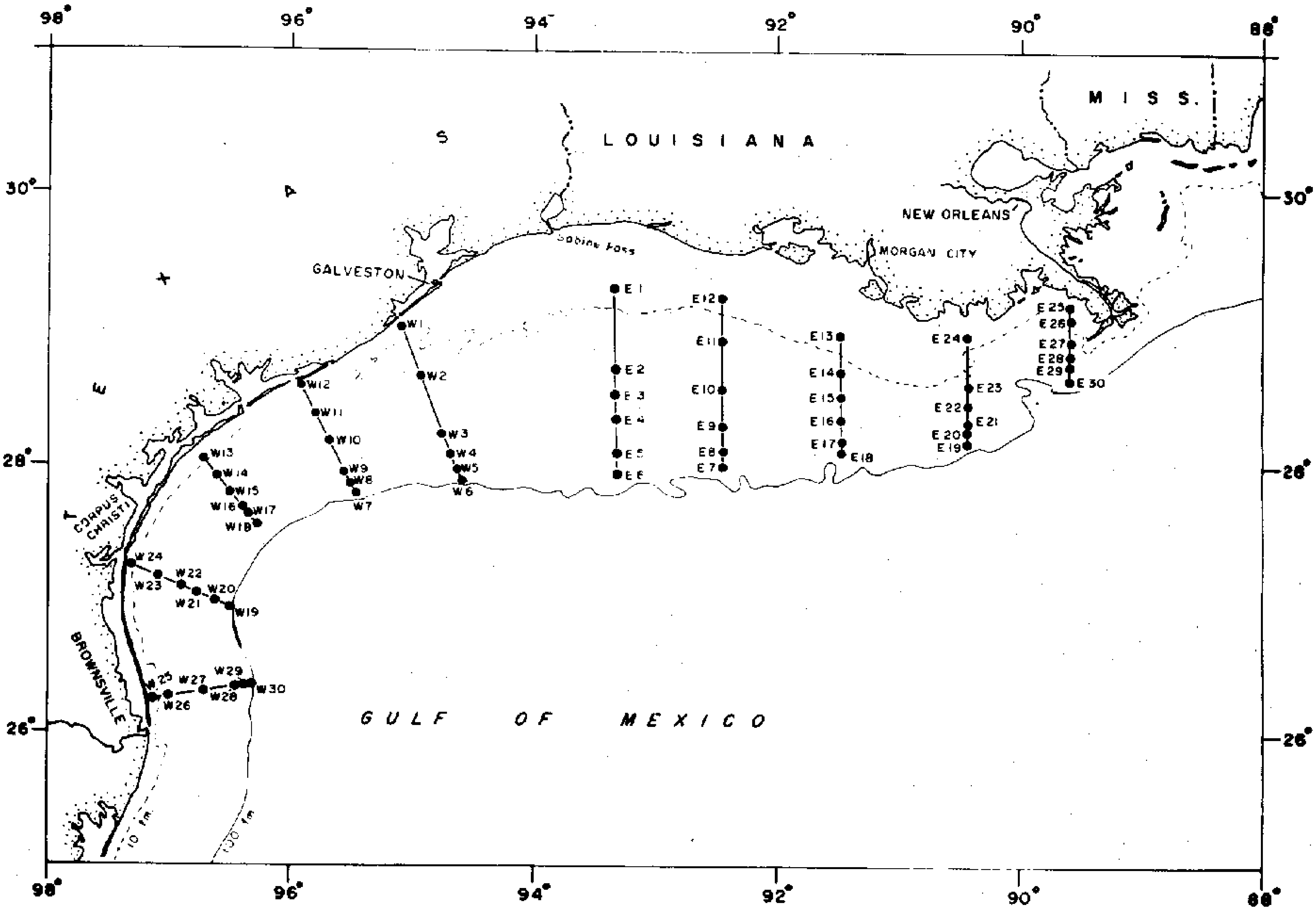
Lawrence E. Wise	Administrative Officer (resigned 8/62)	Galveston
Raymond H. Niblock	Administrative Assistant	Galveston
Laura M. Hermann	Museum Technician (Natural Science)	Galveston
Corinna L. Denbo	Purchasing Agent	Galveston
Glo S. Baxter	Clerk-Stenographer	Galveston
Peter M. Villarreal	Maintenance Foreman	Galveston
Tidas C. Alcorn	Maintenanceman	Galveston
Robert L. McMahon	Maintenanceman	Galveston

SHRIMP FISHERY PROGRAM

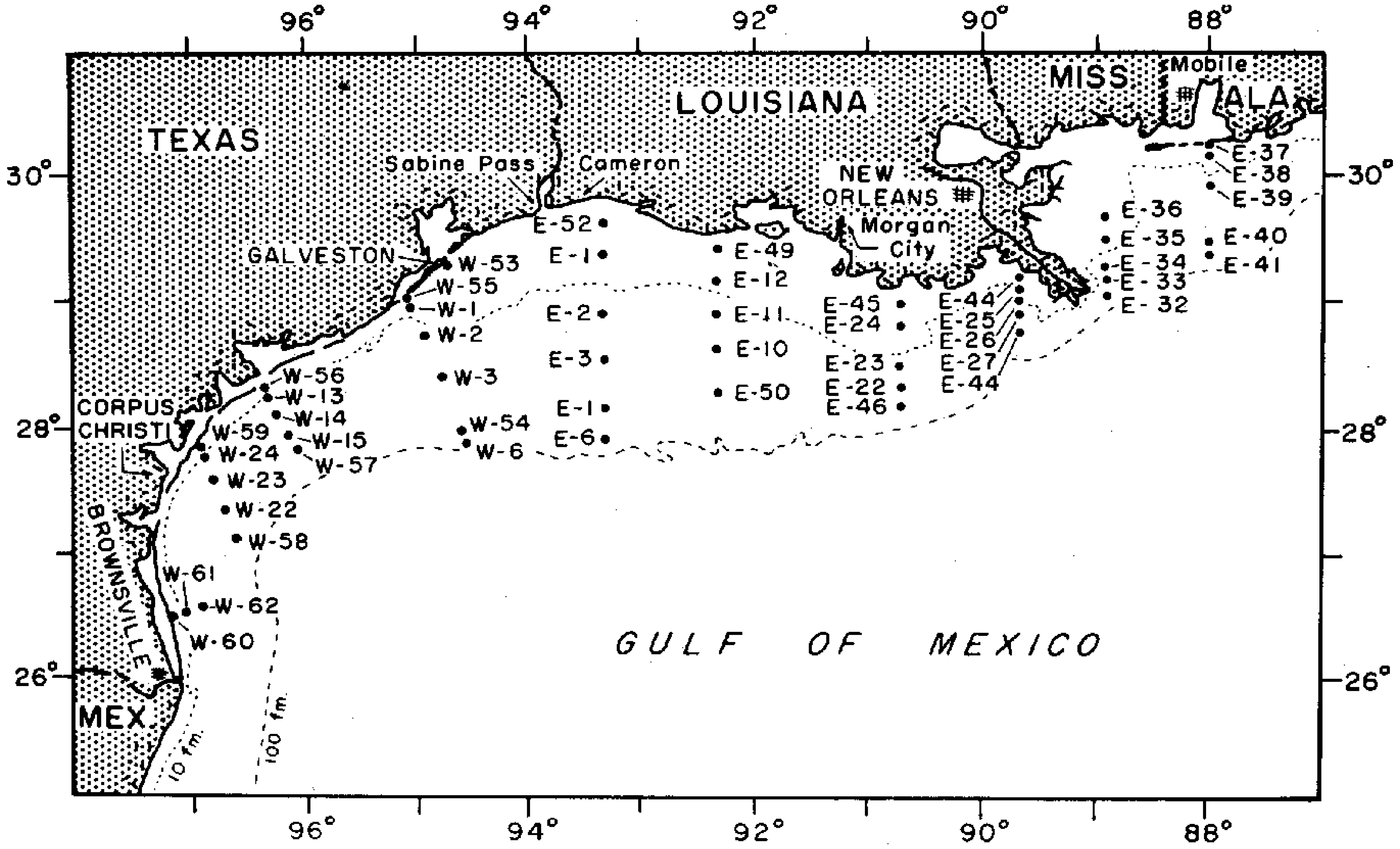
J. Bruce Kimsey, Program Leader

Our program of shrimp research is balanced between the biological and dynamics aspects of commercial shrimp populations in the Gulf of Mexico, with our eventual goal being the establishment of management criteria for the shrimp resource as a whole.

In January 1963, offshore population sampling was expanded to include the area just east of the Mississippi River Delta. The present sampling pattern, first adopted in January 1962, was further modified by the addition of stations at 4 fathoms, and the elimination of some deep-water stations and one transect. The total number of stations was reduced from 60 to 51. (See accompanying figures.) Sampling procedures remained the same. At each station, a 45-ft. shrimp trawl was towed for 1 hr., a 20-min. plankton tow was made with a Gulf-V plankton sampler, drift bottles were released, and salinity and temperature measurements were made at various depths. In addition to the regular



Offshore station pattern for operations of the Shrimp Fishery Program, 1962.



Revised station pattern adopted in January 1963.

monthly research cruises of 15 to 20 days each, several shorter trips were made to undertake special plankton work, to conduct net-selectivity studies, and to collect gravid shrimp from which eggs for studies concerned with rearing and finding ways to identify shrimp larvae are obtained.

A project designed to obtain biological and additional statistical data from commercial shrimp landings was started in early 1962, with biologists being stationed at Morgan City, La., and Port Aransas, Tex. This project was expanded during the past year, and catch samplers are now located at Brownsville, Tex., Houma, La., Pascagoula, Miss., and Tampa and Key West, Fla., as well.

These personnel also contributed to the expansion of our continuing survey of postlarval shrimp abundance. In addition to more intensive sampling in Galveston Entrance, weekly samples are now obtained at Port Isabel, Port Aransas, and Sabine Pass (Tex.), Caminada Pass (La.), Bay St. Louis (Miss.), and Mullet Key in Tampa Bay, Fla.

Work on developing methods for distinguishing between larval stages of penaeid shrimps was resumed in April 1963 following a lapse of about a year. After a successful spawn of *Sicyonia brevirostris* eggs, resulting larvae were reared for the first time as far as the postlarval stage.

Eighty-five-foot trawler GUS III chartered for research operations in the northern Gulf of Mexico.

Studies continued on the distribution of commercial species of shrimp in the northern Gulf of Mexico and in south Florida waters. Information on seasonal changes in the spawning condition of penaeid shrimps in the northwestern Gulf of Mexico was obtained concurrently with observations on the distribution and abundance of larvae. The models of distribution being developed from these data demonstrate apparent variation in timing and magnitude of events, but consistency in terms of cyclic (annual) pattern.

Seven mark-recapture experiments were undertaken during the year. All but one were designed to obtain information on migrations, growth, and mortality in exploited shrimp stocks. An experiment initiated at Indian Key, Fla., yielded additional information on the geographic distribution of the Tortugas pink shrimp population. Experiments to increase the number of agents for marking shrimp continued. Five fluorescent pigments proved suitable as secondary marks when used in conjunction with one of the two satisfactory biological (primary) stains, thereby increasing the number of possible marks or combinations thereof from 2 to 12. The results of a series of experiments with pink shrimp indicate that "machine" inks can also be used to provide an accessory mark.

Five research contracts were in force during the year.

Summary of Shrimp Mark-Recapture Experiments, 1962-63.

Date	Area of release	Species	Number marked	Mark
1962:				
July	Grand Isle, La.	Brown	2,370	Fast green
July	Galveston, Tex.	Brown	2,973	Trypan blue
September	Indian Key, Fla.	Pink	19,860	Trypan blue
September	Cameron, La.	White	1,905	Fast green
September	Sabine Pass, Tex.	White	2,291	Trypan blue
1963:				
March	Dry Tortugas, Fla.	Pink	2,496	Fast green
June	Off Mississippi	Brown	2,526	Fast green
June	Off Mississippi	Brown	2,275	Trypan blue
June	Off Mississippi	Brown	1,208	Petersen tag

Summary of Contract Research, 1962-63.

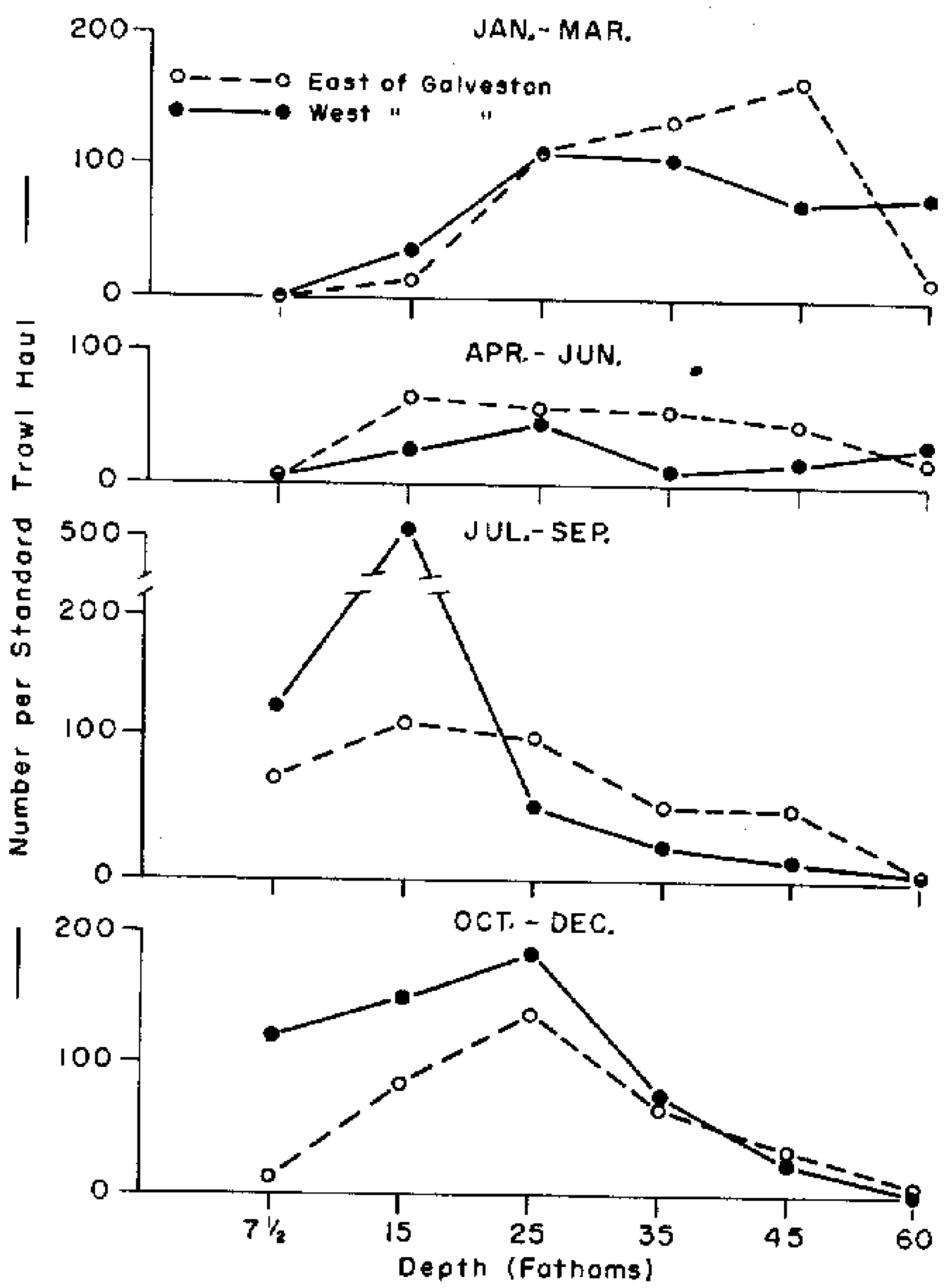
Contracting institution	Project title	Expiration date
Institute of Marine Science, University of Miami	Abundance and distribution of pink shrimp larvae on the Tortugas Shelf of Florida	June 30, 1963
Institute of Marine Science, University of Miami	The juvenile phase of the life history of the pink shrimp, *Penaeus duorarum*, on the Everglades National Park nursery grounds	June 30, 1963
Gulf Coast Research Laboratory	Abundance of postlarval shrimp in Mississippi Sound and adjacent waters	November 1, 1963
University of Southwestern Louisiana	Distribution of postlarval shrimp in Vermilion Bay, La.	February 14, 1964
Institute of Marine Science, University of Texas	Seasonal distribution of adult and larval shrimp in Aransas Pass (Texas) Inlet	March 15, 1964

Population Distribution and Spawning

One objective of the shrimp research program is to gain a better understanding of the biology and life history of adult populations in offshore waters. To do this, the size and sex composition and spawning condition of the various species are being surveyed on a seasonal and areal basis.

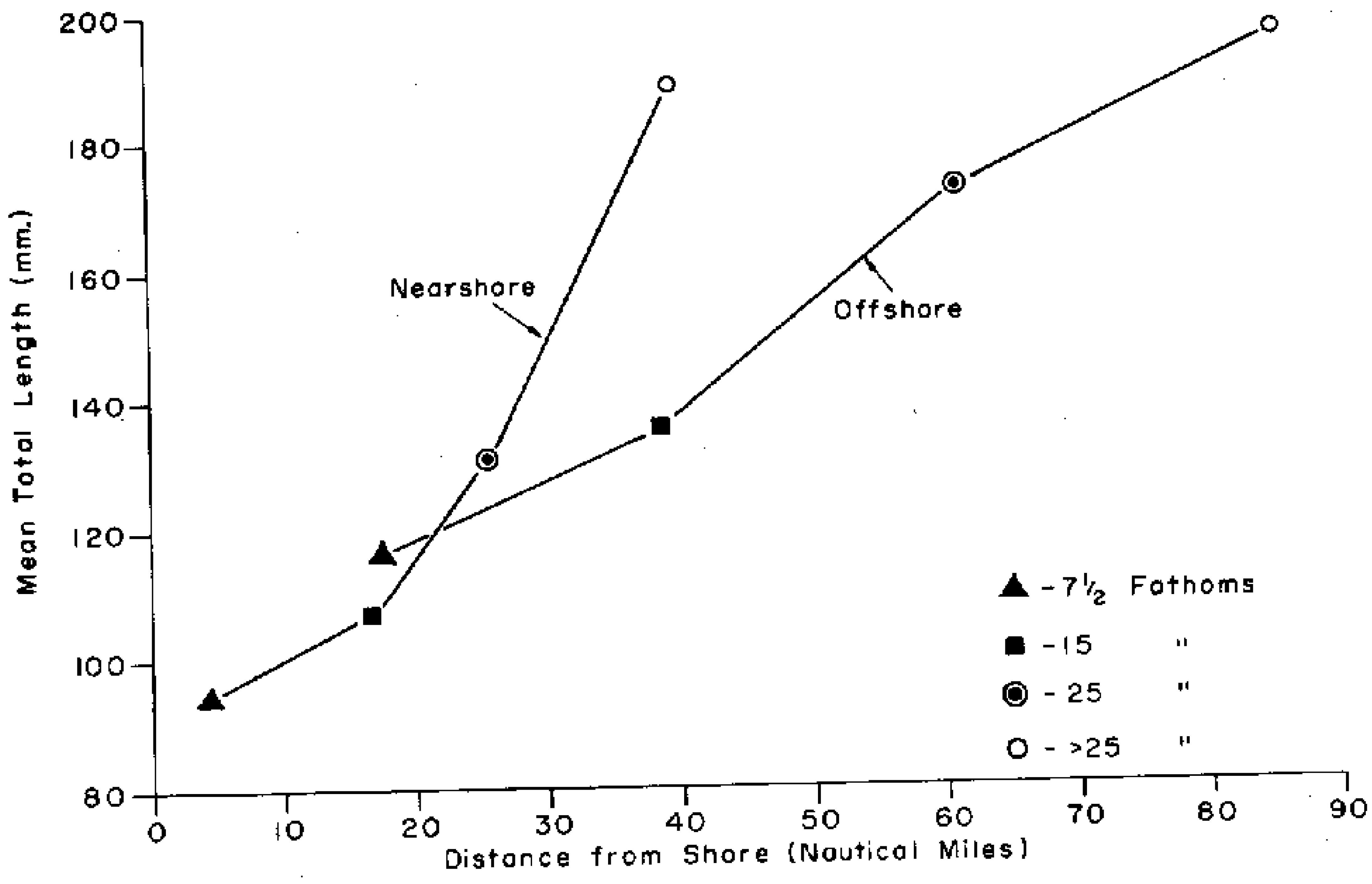
During the 12 research cruises made between January and December 1962, 579 1-hr. trawl hauls were made at established stations on the continental shelf between the Mississippi River Delta and Brownsville, Tex. Although 12 kinds of penaeid shrimp were taken, only 49 percent of the total catch consisted of species having commercial importance. This percentage is similar to that observed during experimental trawling operations in 1961. Of the three commercial species taken, brown shrimp contributed the bulk of the sample catch (88 percent), followed by white shrimp (10 percent), and pink shrimp (2 percent).

The catch per unit of effort for brown shrimp was somewhat higher in the survey area east of Galveston from January through June. Coincident with offshore movements of subadults from the inshore nursery areas in July, the catch per unit of effort increased in



Catch of brown shrimp per standard unit of sampling effort, 1962.

all areas at $7\frac{1}{2}$ and 15 fathoms. The increase in catch per unit of effort from these depths was greatest west of Galveston and remained highest in that area from July through December. The data for July 1962 indicate



Relationship between size of brown shrimp and depth as well as distance from shore, July 1962.

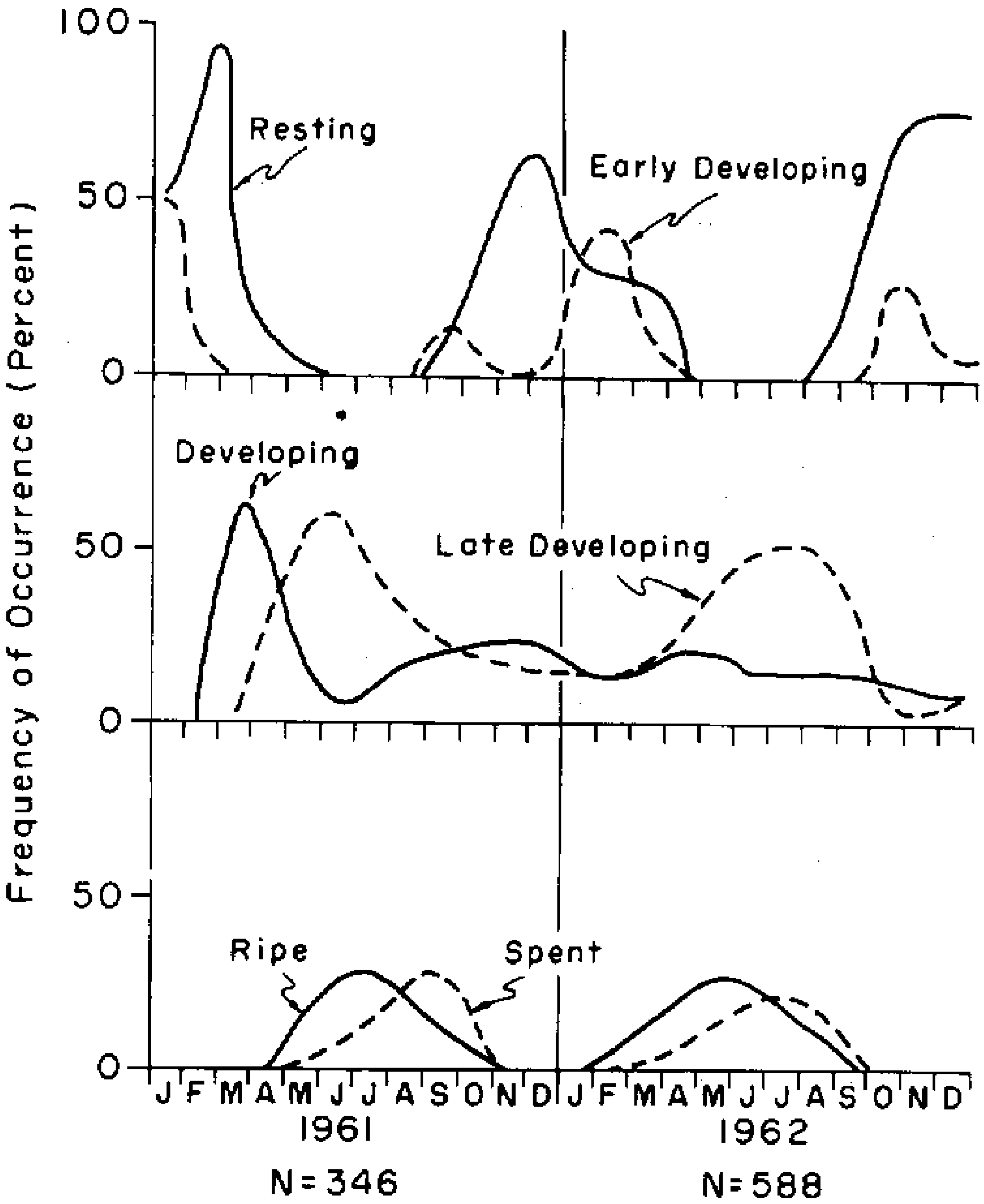
that the size distribution of brown shrimp is related to both distance from shore and water depth. Shrimp taken at a given depth near shore are smaller on the average than shrimp taken at the same depth farther offshore.

Samples of shrimp ovary tissue, dissected and fixed in the field, were brought to the laboratory for preparation into stained slide mounts and determination of stage of maturity. Developmental stages in order of increasing maturity include: "underdeveloped," "early developing," "developing," "late developing," "ripe," "spent," and "resting" (or dormant). Most white shrimp females measuring 140 mm. or more in total length possessed "developing" or more mature ovaries. In the winter, however, a large percentage of females of all lengths had "resting" ovaries or appeared to be greatly retarded in their ovary development.

During the 1961 survey, when 11 stations in the Freeport, Tex.-Cameron, La., area were occupied at 3-week intervals, white shrimp were found almost exclusively at the four $7\frac{1}{2}$-fathom stations. In January and February, the few females examined possessed "resting" or "early developing" ovaries, but by mid-March, the majority had advanced to the "developing" stage. During April, the percentage of females with "developing" ovaries declined as an increasing number entered the "late-developing" stage. Spawning in $7\frac{1}{2}$ fathoms, as indicated by the presence of females with "ripe" and recently "spent" ovaries, was underway by early May, became most intense during June and July, and ended about mid-October.

In 1962, the survey area was expanded to include waters off all of the Texas and western Louisiana coasts. In general, female white shrimp sampled at the $7\frac{1}{2}$-fathom stations within this same period of time all possessed ovaries in comparable stages of development regardless of geographic location. The pattern of ovary development in 1962 was very similar to that observed during 1961 in both seasonal sequence and percentage composition of ovary stages. Spawning was evident at least 2 weeks earlier in 1962, as ripe and spent females were found in mid-April of that year.

Ovary samples from white shrimp caught at 15 fathoms were obtained in sufficient numbers during January, February, and March 1962 to follow the sequence of ovary maturation and initial stages of spawning in these deeper waters. White shrimp were found in 15 fathoms on the four westernmost transects and along the third and fifth transects of the east. (Refer to figure on page 8.) As in 1961, they were rarely taken in waters deeper than $7\frac{1}{2}$ fathoms in the Freeport-Cameron area. In all cases, females from the deeper stations were larger and more advanced in their ovary development. During January 1962, most of these females were in the "resting," "early-developing," or in "developing" stages. (See figure.) By February, many females



Stages of ovary development in white shrimp 140 mm. (total length) or longer taken at $7\frac{1}{2}$ fathoms off Texas and Louisiana, 1961-62.

were in the "late-developing" stage, and in March, the majority had ovaries in the "late-developing" stage. Spawning began in the deeper water in March, several weeks earlier than at the $7\frac{1}{2}$-fathom stations.

William C. Renfro, Project Leader
Harold A. Brusher

Identification of Shrimp Larvae

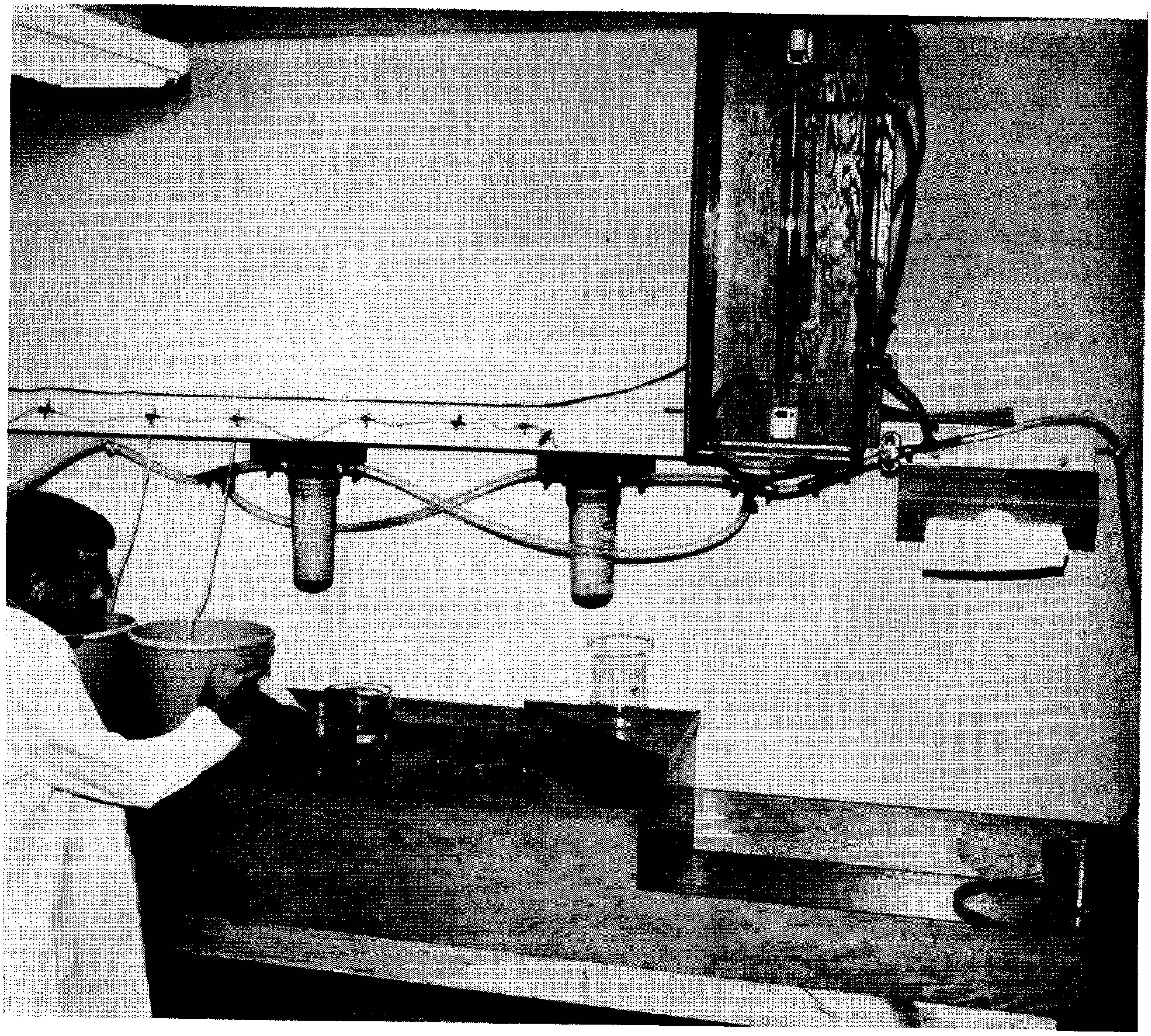
Considerable progress has been made in the development of methods for identifying the larvae of penaeid shrimps at all life history stages. Larvae that occur in plankton samples taken from the Gulf of Mexico can now be readily classified to genus, but there still remains the primary problem of separating, with certainty, larvae within the genus Penaeus. The three species of major commercial importance in the Gulf of Mexico are included in this genus, and study of their preexploitation dynamics will be hindered until this problem is solved. Since the larval development of the pink shrimp, P. duorarum, is already known in some detail, the major effort of this project is being directed toward rearing larvae of the brown and white shrimp, P. aztecus and P. setiferus, from the egg through the postlarval stage. Information, however, is also being obtained on the larval stages of other species of penaeid shrimp. At the same time, methods of rearing large numbers of larvae to be used in future physiological studies are also undergoing development.

To serve as potential foods for larval shrimp, cultures of 17 micro-organisms were started. Several types of media were inoculated with these micro-organisms to determine which would be most suitable for mass culturing. Before attempting to obtain larvae of the shrimp species of major interest, live mysis-stage larvae of Trachypeneus spp. were secured from the plankton, and preliminary feeding experiments using these micro-organisms were initiated. Feeding the mysis with brine shrimp (Artemia) nauplii and diatoms (Skeletonema sp. and Eucampia sp.) proved successful. Mass cultures of these diatoms were subsequently established for utilization in future rearing experiments.

On April 29, 1963, ripe female brown shrimp and rock shrimp (Sicyonia brevirostris) were obtained from experimental trawl hauls and taken to the laboratory. Two brown shrimp and one rock shrimp spawned on May 2. An additional rock shrimp spawned on May 5. The latter event was in sharp contrast with previous experience wherein shrimp which did not spawn on the first or second night after they were brought to the laboratory either aborted or resorbed their eggs.

The brown shrimp eggs developed active egg nauplii, but the rate of hatching was very poor. Only eight reached the first protozoeal stage, and all died before undergoing another molt.

The rock shrimp spawn of May 5 hatched successfully, but development terminated suddenly and the larvae died during the transition from the fifth nauplii to first protozoeal stage. The rock shrimp spawn of May 2 was more successful, and larvae were reared through to postlarvae 32 days later. Specimens of each stage were preserved for descriptive purposes.



Water table and water-treatment apparatus
used in shrimp rearing studies.

The rock shrimp larvae were reared in a fiberglass aquarium holding 80 liters of well-aerated standing water. Salinity varied from 24.9‰ to 27.4‰, and temperature from 21.0° to 24.5° C. (70° to 76° F.). Experiments were run to determine the effects of various foods, temperatures, media, size of rearing container, and handling on larval development. With one exception, all attempts to rear the larvae in containers other than the one they were hatched in met with failure. As a result, very little information was obtained for the factors investigated.

Harry L. Cook, Project Leader

Larval Distribution and Abundance

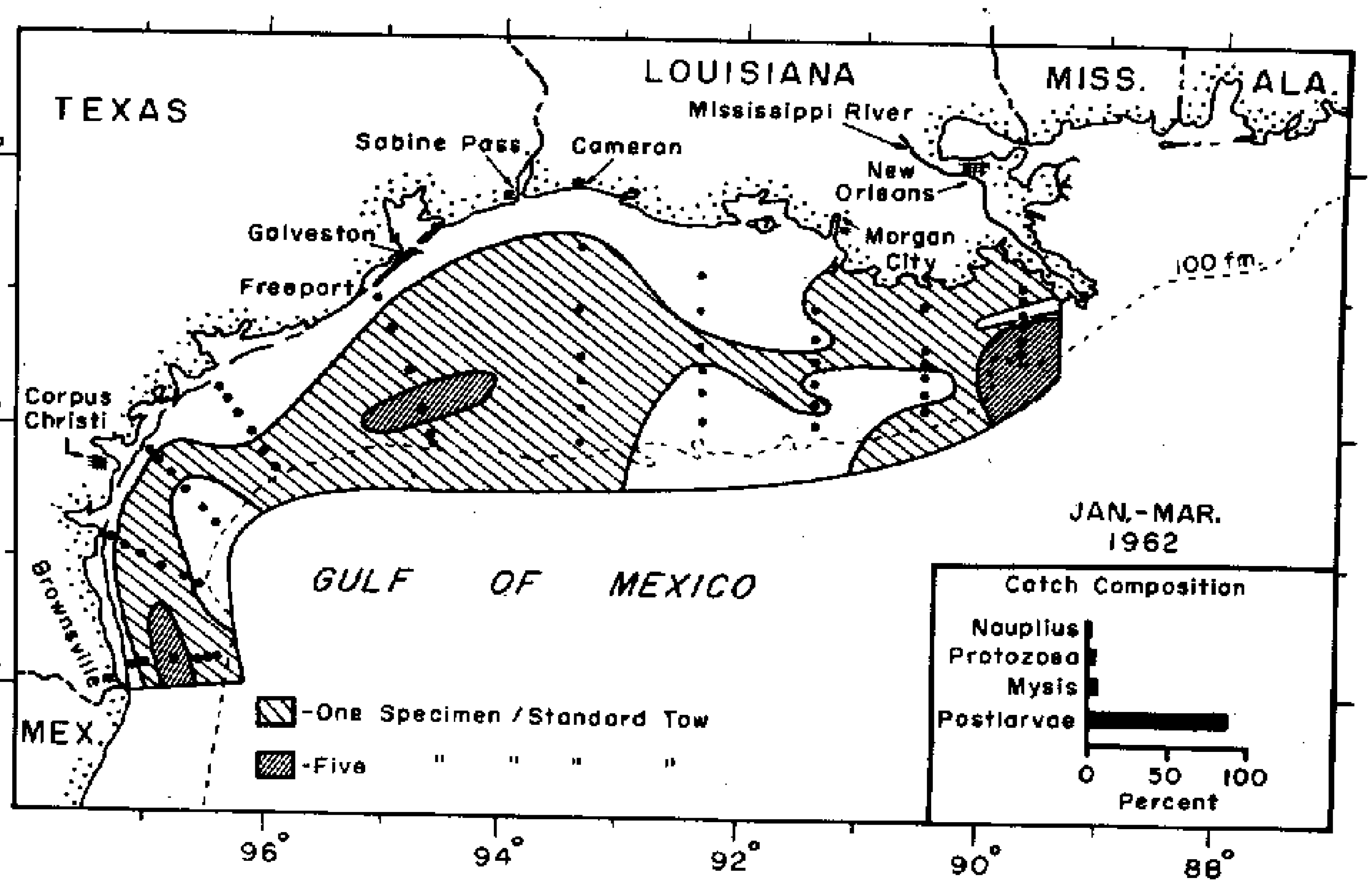
Since January 1962, plankton samples have been collected monthly at 60 stations located in the Gulf of Mexico between the Mississippi River Delta and Brownsville, Tex. Station depths range from $7\frac{1}{2}$ fathoms to 60 fathoms. At each station, a 20-min., "step-oblique" plankton haul is made with a Gulf-V sampler. The occurrence and number of larval and early postlarval shrimp in the samples provide seasonal information concerning distribution, relative abundance, spawning activity, and survival rate.

All samples collected through August 1962 (446) have been examined. Since the duration of each sampling operation occasionally varied somewhat, the resulting data are reported, for convenience of analysis, as the number of larval and postlarval shrimp per standard 10-min. haul.

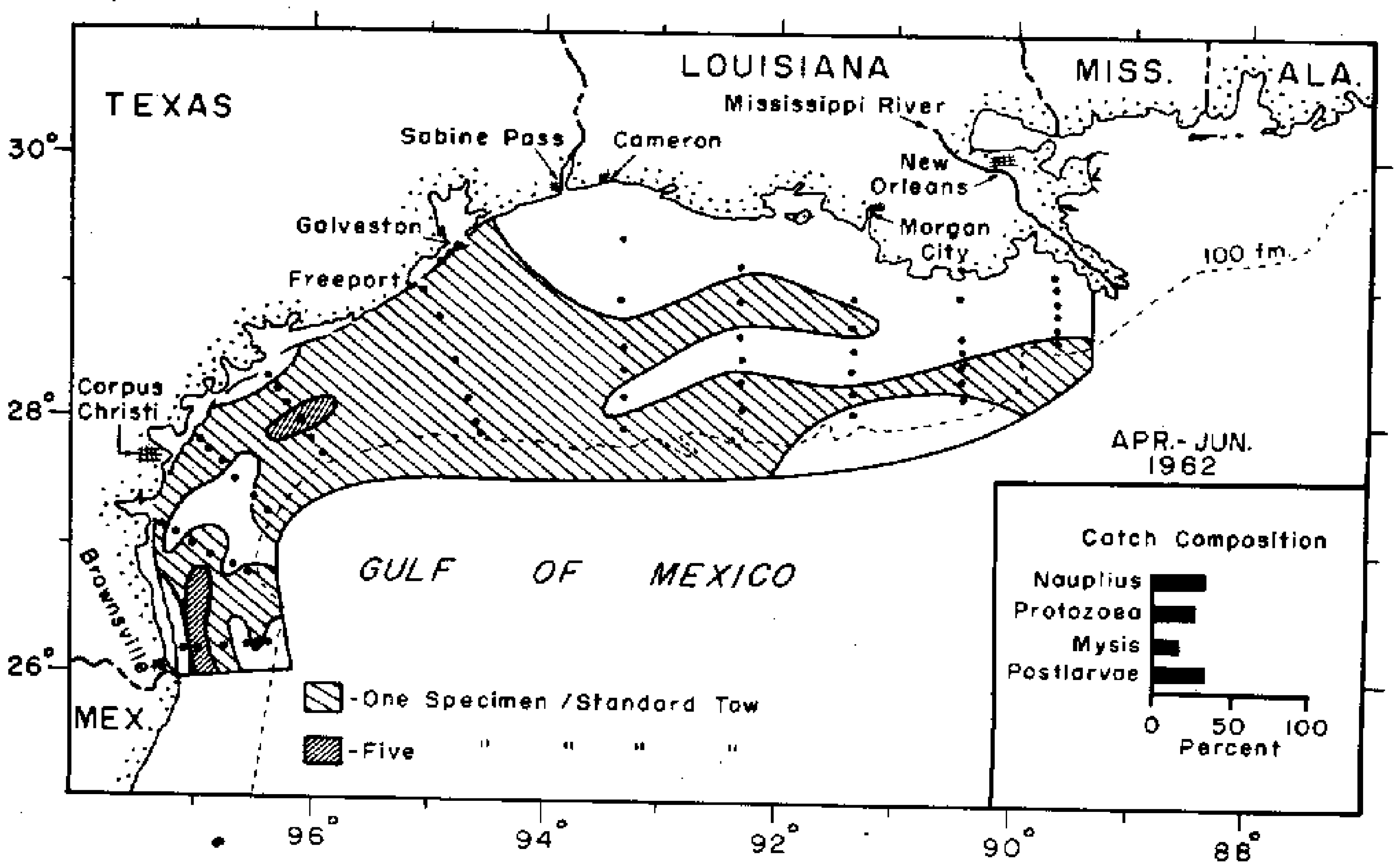
Penaeus spp. made up 13 percent of the total 8-mo. catch (8,712) of larval and postlarval Penaeidae. The remaining 87 percent consisted of *Trachypeneus* spp. (39 percent), *Sicyonia* spp. (22 percent), *Solenocera* spp. (19 percent), and *Parapenaeus* spp. (7 percent).

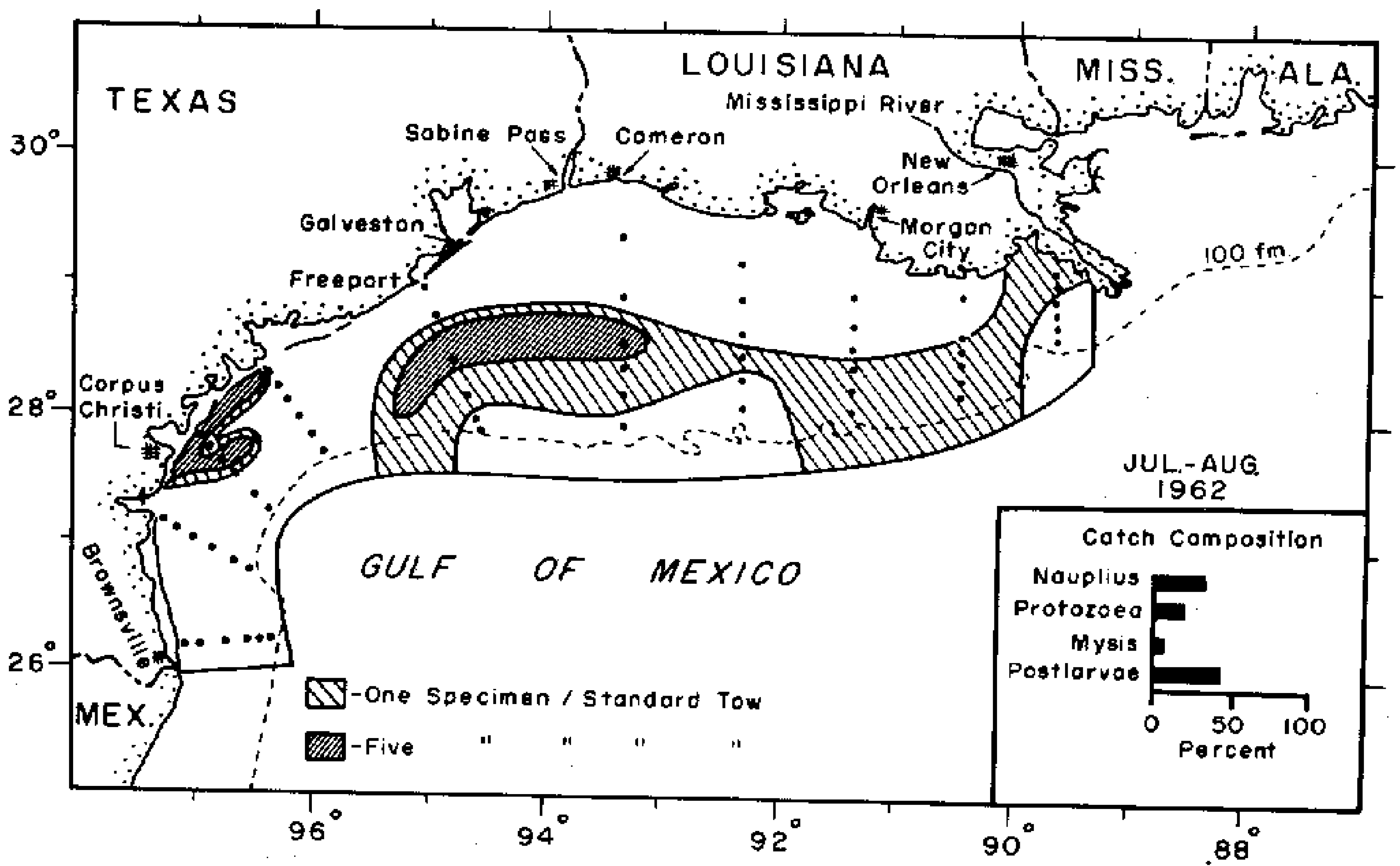
During the period January-March 1962, planktonic stages of *Penaeus* spp. were found throughout the sampling area. (See figure next page.) The larger concentrations were restricted to three areas, namely, the waters off Brownsville, the area represented by a 35-fathom station south of Galveston, and at the 35- to 60-fathom stations near the Mississippi River. Approximately 90 percent of the catch of *Penaeus* spp. consisted of postlarval shrimp with the nauplial, protozoeal, and mysis stages making up the balance.

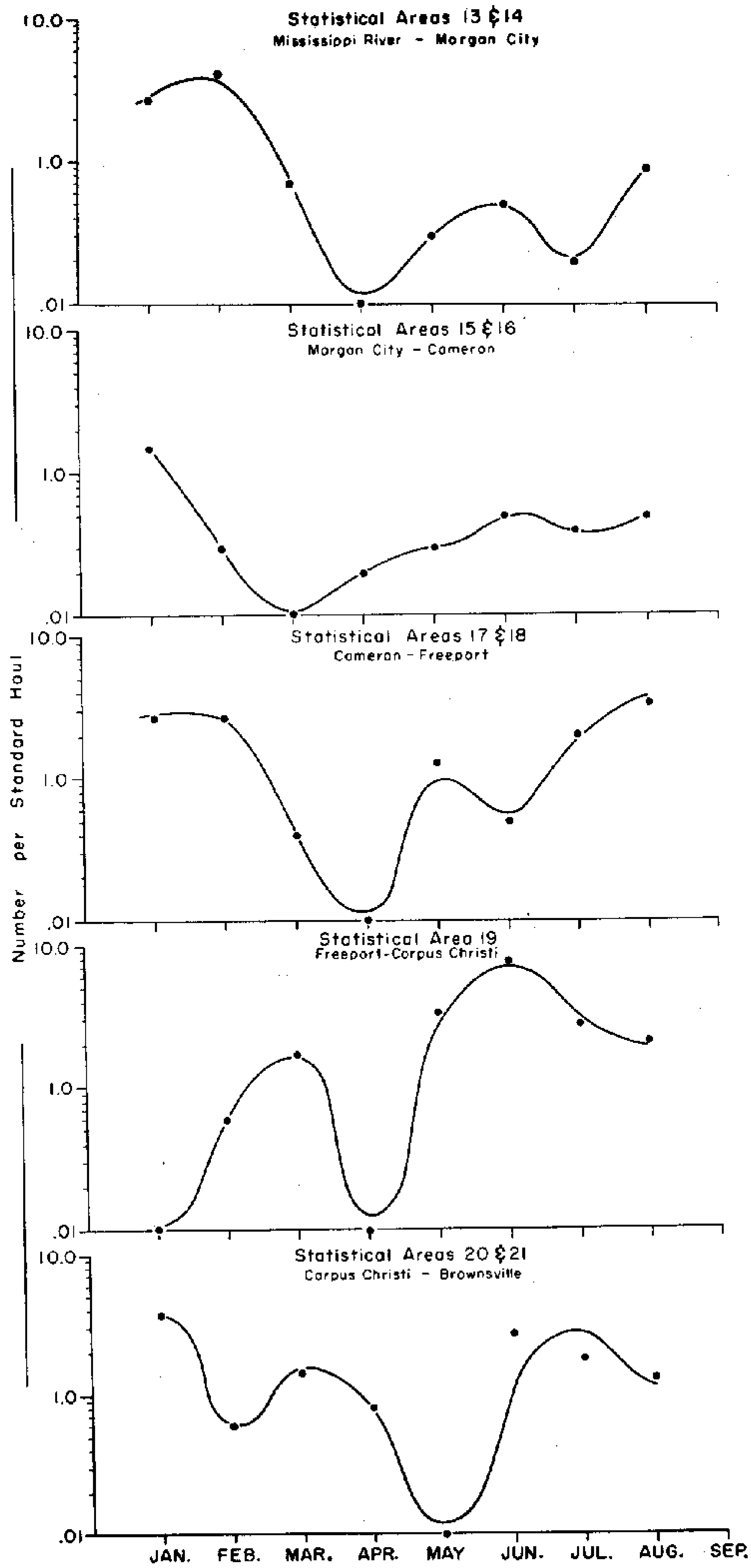
The distributional pattern during April-June 1962 differed somewhat from that of the preceding 3 mo. In the waters west of Galveston, planktonic stages occurred over a large portion of the sampling area while to the east, their distribution was limited to two narrow zones, one of which extended eastward to the Ship Shoal area and was bounded by the 15- and 35-fathom contours, and another which extended to the Mississippi River between the 45- and 60-fathom contours. (See figure on page 19.) The greater concentrations occurred in an area extending approximately 30 miles north of Brownsville between the 15- and 35-fathom contours and southwest of Galveston at one 35-fathom station. Although all planktonic stages were encountered, the increase of nauplii and protozoea taken during the period probably indicates an increase in spawning intensity.



Distribution of planktonic stages of Penaeus spp. in the northern Gulf of Mexico during the period January-August, 1962.







The abundance of planktonic stages of *Penaeus* spp. off Texas and Louisiana during the first 8 mo. of 1962.

Spawning intensity, as suggested by the presence of small numbers of nauplii and protozoea, was low during January-March. It then began to increase in April and appeared to reach a peak in June.

Sample Catch of Penaeus Larvae and Postlarvae, 1962

Stage	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Nauplius	5	0	0	0	7	88	49	60
Protozoea	20	15	10	25	23	43	31	31
Mysis	15	10	5	0	41	7	32	9
Postlarvae	195	165	80	5	16	47	51	91
All stages	235	190	95	30	87	185	163	191

From the area between Freeport, Tex., and Cameron, La., 2 yr. of comparative data are available. An obvious difference between each year is the season when lowest abundance occurred. In 1961, the minimum level was reached in January followed by a steady increase in numbers through August. In contrast, the minimum level of abundance in 1962 occurred in April, after which the numbers of planktonic Penaeus increased until in August they approximated the level of abundance observed in 1961. Considering the available data, it appears that the seasonal trends of abundance in 1961 and 1962 were similar, the only difference being in the matter of timing. (See figure next page.)

Planktonic stages of unexploited species, i.e., Trachypeneus spp., Sicyonia spp., Solenocera spp., and Parapenaeus spp., were present in waters off Louisiana and Texas from January through August 1962. Protozoeal and mysis stages made up the greater part of the catch with only a few nauplii and postlarvae recorded for Trachypeneus spp. and Sicyonia spp. Species representing both of these genera occurred throughout the sampling area, although the numbers of Trachypeneus spp. decreased slightly in the area just north of Brownsville whereas the concentration of Sicyonia spp. was greatest in this region. Analysis of the data by station depth suggested that Trachypeneus spp. and Sicyonia spp. are predominantly shallow-water forms, their catch per unit effort having decreased as depth at sampling locations increased.

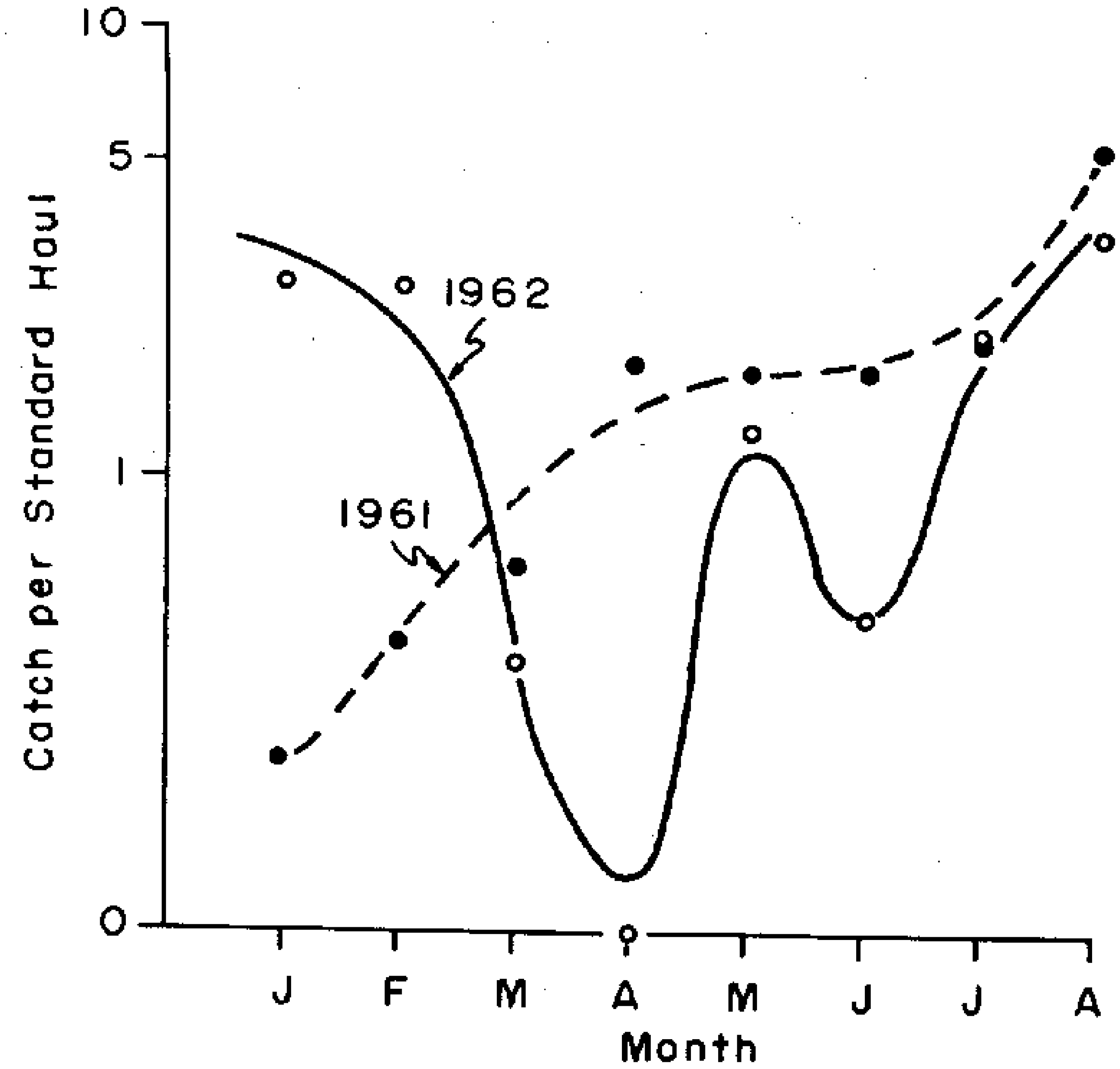
Except in two small areas, one off eastern Texas and western Louisiana, and another off the Mississippi River, no planktonic-stage shrimp were found beyond the 25-fathom contour east of Galveston during July-August 1962. The greater concentrations occurred north of Brownsville at the 7½-, 15-, and 25-fathom stations, and southeast of Galveston at two 25-fathom stations. The catch consisted primarily of nauplial and postlarval stages. Between the Mississippi River and Galveston, a sharp decline in abundance occurred during the period January-April, while in the area west of Galveston, a similar decline was noted between March and May. Subsequent increases in abundance were noted in each area with the highest peaks occurring in the central and western portions.

A further breakdown of relative abundance indicates that, although Penaeus spp. occurred at all stations, the average catch per standard haul was greater inside the 35-fathom contour.

Catch per Standard Haul of Planktonic-Stage Penaeus, 1962

Station depth (fathoms)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Average
7½	1.6	1.0	1.2	0.0	0.8	4.6	1.7	4.1	1.9
15	1.2	1.8	1.5	0.0	0.5	1.6	1.1	1.7	1.2
25	2.9	1.3	0.5	0.0	1.3	1.8	3.1	2.4	1.8
35	4.5	3.0	0.3	1.2	2.5	0.5	0.8	0.7	1.5
45	2.2	1.7	1.0	0.3	0.5	0.9	0.6	0.8	.9
60	1.4	1.6	0.5	0.0	0.6	0.9	0.7	0.8	.8

During the months of January, February, and March 1962, samples catches of Penaeus spp. consisted predominantly of postlarvae. It was also during this period that the movement of postlarvae through Galveston Entrance into Galveston Bay became evident. The sharp decrease in April noted in offshore waters preceded the postlarval movement into the bay by 1 mo.



The abundance of planktonic stages of Penaeus spp. offshore between Cameron, La., and Freeport, Tex., 1961-62.

Parapenaeus spp. and Solenocera spp. were also distributed throughout the entire sampling area, but with the greatest concentration in the western section. These shrimp appear to be predominantly deep-water species as there was a decrease in their average catch with a decrease in station depth.

Catch per Standard Haul by Depth of Planktonic-Stage, Noncommercial Penaeidae, January-August 1962

Genus	Depth (fathoms)					
	$7\frac{1}{2}$	15	25	35	45	60
Trachypeneus spp.	12.0	4.6	5.5	2.1	0.9	0.5
Sicyonia spp.	8.0	1.9	1.6	0.7	0.7	0.8
Solenocera spp.	0.1	0.3	1.3	4.4	2.4	3.3
Parapenaeus spp.	0.0	0.8	0.2	1.3	1.3	1.5

Trachypeneus spp., with approximately the same areal and depth distribution as Sicyonia spp., showed an increase in abundance between March and August. Sicyonia spp., however, did not exhibit any appreciable increase until May and then continued at a relatively high level of abundance through August. Solenocera spp. remained at a relatively uniform level of abundance during January-March and then increased in numbers between April and August. Parapenaeus spp., unlike the other species, had its peak abundance during January and February.

Monthly Catch per Standard Haul of Planktonic-Stage, Noncommercial Penaeidae, 1962.

Genus	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Trachypeneus spp.	3.1	0.7	2.8	1.6	2.9	2.9	6.5	10.2
Sicyonia spp.	1.5	0.6	0.6	0.1	1.1	1.9	5.4	6.3
Solenocera spp.	1.8	1.8	0.7	1.6	2.7	1.4	2.3	3.1
Parapenaeus spp.	1.4	2.3	0.6	0.1	0.7	0.2	0.5	0.2

Robert F. Temple, Project Leader
David L. Harrington
Clarence C. Fischer

Currents on the Continental Shelf of the Northwestern Gulf of Mexico

In addition to investigating the purely biological aspects of shrimp life history, we are also studying the influence of various environmental factors on populations of commercially important shrimp. This study is attempting to determine the role water currents play in the movement of young shrimp from offshore spawning grounds to inshore nursery areas.

The general pattern of circulation in the northern Gulf of Mexico has been deduced by others from current charts of the U. S. Naval Oceanographic Office, which are based on reports of ships' drift averaged over a long period of time. Our study undertakes to describe water currents while simultaneously making observations on adult as well as larval shrimp distribution, abundance, and survival.

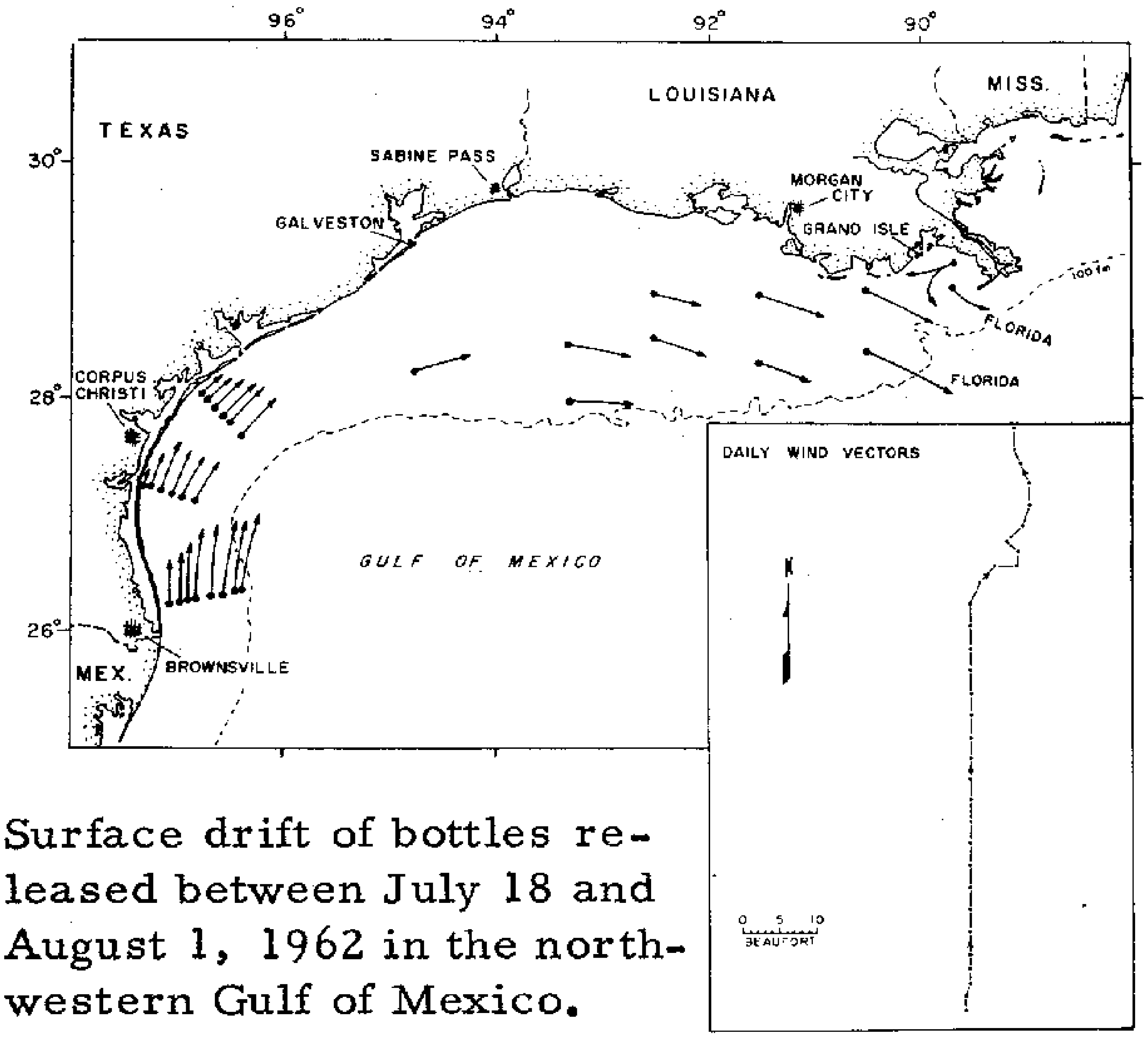
The use of drift bottles to describe current patterns in an area associated with a generally even coastline, such as that of the northwestern Gulf of Mexico, has usually met with indifferent success. This has not been the case in the present study. Despite the lack of headland and peninsula features, as well as little permanent human habitation along much of the coast, bottle-card returns as high as 52 percent (for the March 1962 releases) have been obtained.

In February 1962, surface currents as determined from bottle recoveries, were westerly and alongshore, with velocities ranging from 8 to 13 miles per day. Near Brownsville, Tex., where our $7\frac{1}{2}$-fathom sampling station is only $1\frac{1}{2}$ miles from shore, a longshore countercurrent with a velocity of 9 miles per day was observed. Nearshore waters just south of Corpus Christi also showed countercurrents, but with velocities of only about 1 or 2 miles per day. In this area of weak currents, a few bottles drifted in the opposite (or southwesterly) direction. There was no evidence of an offshore northeasterly current at any station, and several bottles released off Brownsville drifted as far south as Cabo Rojo, 50 miles south of Tampico, Mexico.

In March 1962, a northeasterly current began to appear and to converge with the southwesterly current off Brownsville. It was also evident at the 35- to 60-fathom research stations off central Texas and Louisiana. This current apparently contributes to the Gulf Stream, as bottles released at stations in its path were carried to eastern Florida beaches.

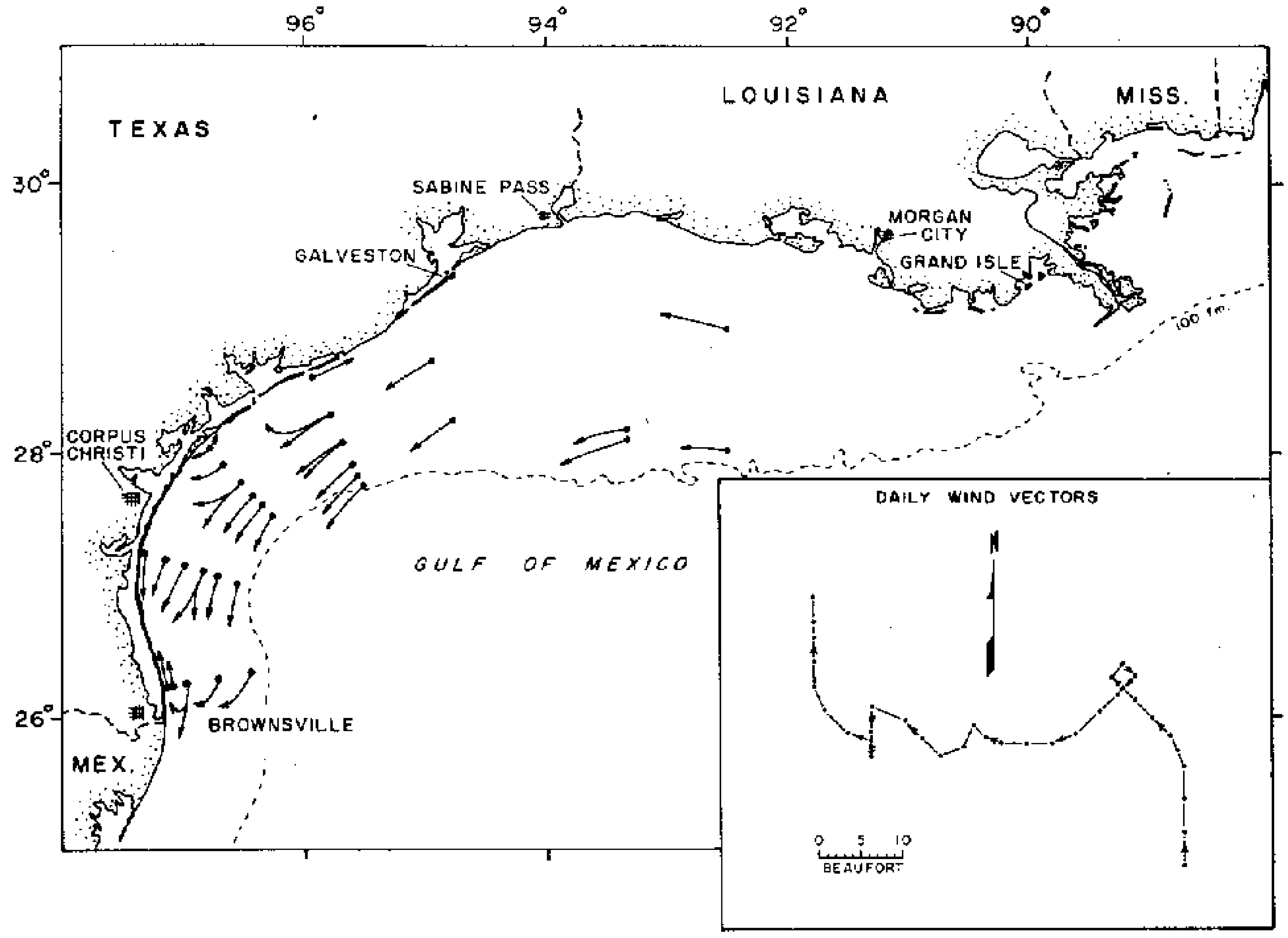
During February and March 1962, monthly wind vectors, while generally southerly, had a large northerly component. As the season progressed, this component disappeared, and the wind vectors became strongly southerly. Under the influence of these winds, the convergence along the south Texas coast began to move northeastward, and by May and June 1962, the surface currents were strongly (directly) onshore off the central Texas coast and obliquely onshore (NNE.) along the Louisiana coast.

In July, under the continuing influence of strong southerly winds, the surface currents between Brownsville, Tex., and the Mississippi River Delta changed to alongshore, northeasterly and easterly.



Surface drift of bottles released between July 18 and August 1, 1962 in the northwestern Gulf of Mexico.

This condition prevailed only a short time, and, by September, the surface currents were again westerly and alongshore, turning to the southwest along the south Texas coast. Coincident with the shift in surface water currents, the southerly component of the prevailing winds diminished somewhat, whereas the northern and eastern components became more prominent. This trend continued until November, when the resultant of the prevailing winds became northeasterly and remained in that sector until February 1963, at which time a shift to the south became apparent.



Surface drift of bottles released between September 7 and 25, 1962, in the northwestern Gulf of Mexico.

Coincident with this shift in the prevailing winds, the convergences noted off Brownsville in March 1963 began to reappear, and, by June 1963, surface currents were again strongly onshore along the central Texas coast and obliquely onshore (NNE.) off the Louisiana coast.

Upon examining the data from the present drift-bottle studies, the surface current charts of the U. S. Naval Oceanographic Office, and the wind records of the U. S. Weather Bureau, it became apparent that the pattern of change in surface currents in the northwestern Gulf of Mexico is much the same each year. The variation is a matter of timing and this, in turn, is believed to be largely a function of prevailing winds. For instance, if northerlies are stronger than usual during the winter and their influence is apparent until late spring, then there is a delay in the establishment of the onshore surface drift and the subsequent change to northeast longshore currents. Conversely, short periods or a weak series of northerly winds would encourage an early change from longshore westerly currents to first onshore and later easterly longshore surface currents.

J. Bruce Kimsey, Project Leader
Robert F. Temple

Abundance of Postlarval and Juvenile Shrimp

Postlarvae In addition to semiweekly collections of postlarval shrimp taken at Galveston Entrance, samples are now routinely obtained with standard collecting gear at Port Isabel, Port Aransas, and Sabine Pass (Tex.); Caminada Pass (La.); Bay St. Louis (Miss.); and Mullet Key in Tampa Bay (Fla.). Data from catches at these stations will be used to assess the reliability of established measures of postlarval abundance, which show promise as indicators of future abundance of juvenile brown shrimp on the nursery grounds and of adults offshore.

Catch of Postlarvae during the First Half of 1963.[1/]

Location	Number of samples					Number of postlarvae per sample				
	Feb.	Mar.	Apr.	May	June	Feb.	Mar.	Apr.	May	June
Port Isabel	4	4	4	4	4	15	29	4	13	14
Port Aransas	4	3	4	5	4	4	51	10	3	16
Galveston Entrance	8	27	62	27	27	0	273	237	107	550
Sabine Pass	0	4	4	5	4	0	25	57	47	263
Caminada Pass	4	4	4	5	4	30	24	12	8	8
Bay St. Louis	4	4	4	5	2	1	23	6	87	88
Mullet Key	4	4	4	4	4	1	0	0	2	18

1/ No postlarvae were taken in January.

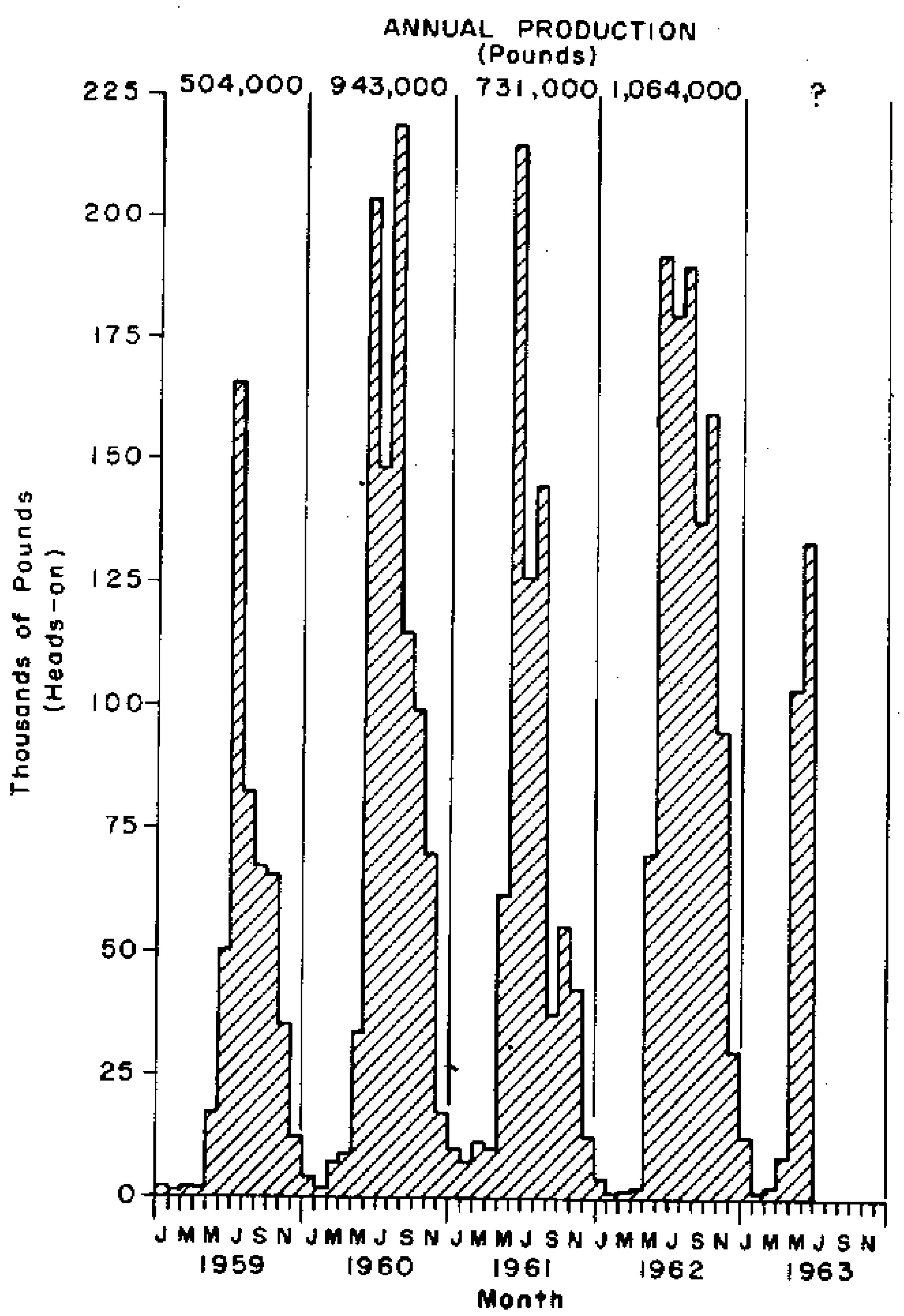
To obtain information regarding the day-night occurrence of postlarval shrimp, the possible correlation between tidal flow and postlarval abundance, and the reliability of the sampling gear, a 96-hr. survey was made during the first week of April near Galveston's north jetty. Three standard-net hauls were made at intervals of 2 hr. Hydrological and meteorological observations were made in addition to sampling for postlarvae.

Preliminary analysis of the data shows that nearly 70 percent of the postlarvae taken during the survey were caught at night between 8 p.m. and 6 a.m. The mean number of postlarvae taken in day and night tows was 486 and 998 animals, respectively.

To determine whether or not the gear was adequately sampling the available animals, three consecutive tows were made every 2 hr. Overall, the average number of postlarvae caught in the first tow was 727, in the second 712, and in the third 788. The average catch for all tows combined was 742 postlarvae. The uniformity of these catches attests to the reliability of the small beam net as a sampling device.

The first white shrimp postlarvae of the year were taken on April 24, 1963, at the Sabine Pass station and on April 30 at Galveston Entrance. This was about 2 weeks earlier than white postlarvae have appeared in the last 4 yr.

Juveniles Commercial bait-shrimp fishermen harvested an estimated 1,063,000 pounds of juvenile shrimp from Galveston Bay in 1962, an increase of 45 percent over the 1961 catch. This production surpasses that for any year during the 4 yr. the bait fishery has been given extensive statistical coverage. (Refer to figure.) Catch per unit of effort was up by only 9 percent compared with that of 1961, however, indicating that demand rather than greater availability of juvenile shrimp was primarily responsible for the increase. The number of active bait dealers increased from 92 in 1962 to 106 in 1963 (+15 percent). Several fishing camps destroyed by Hurricane Carla were rebuilt.



Annual production by commercial bait shrimp fishery of Galveston Bay.

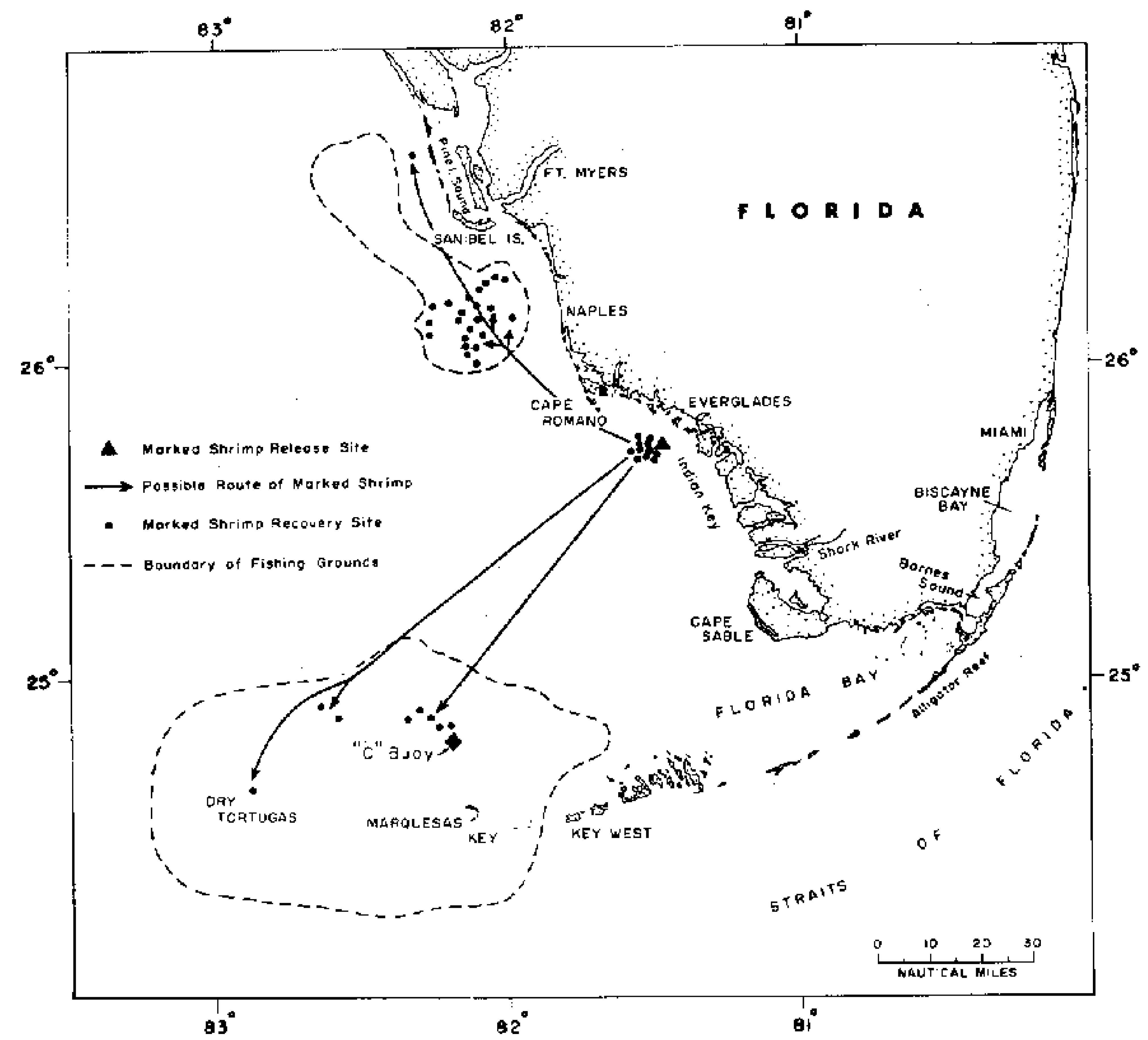
The annual bait shrimp catch in Galveston Bay for 1962 consisted of 57 percent white and 42 percent brown shrimp. The remaining 1 percent of the total catch was mainly Trachypeneus spp. and pink shrimp. Apparently due to a shortage of shrimp in those areas, very little bait shrimp was transported from Matagorda Bay and Sabine Lake to supply Galveston Bay anglers during the winter.

In addition to the survey that has been conducted in the Galveston Bay area since 1959, statistical coverage of the bait shrimp fishery in the Sabine Pass-Sabine Lake system was initiated in May 1963. Nine dealers and 10 small trawlers were found to be actively engaged in this fishery. Live bait shrimp are not in great demand by anglers in this area, and only three dealers have facilities for keeping them alive. Much of the catch is frozen and marketed as bait through grocery stores and tackle houses in Port Arthur, Beaumont, and Orange, Tex.

Kenneth N. Baxter, Project Leader
Carlton H. Furr

Major objectives of pink shrimp research conducted in south Florida waters have been to describe the geographic distribution of the Tortugas pink shrimp population and to assess the utility of biological stains as marking agents in studies to determine shrimp migrations, growth, and mortality.

Mark-Recapture Experiments Between August 27 and September 5, 1962, 19,800 pink shrimp were marked with a biological stain (Trypan blue) and released near Indian Key, Fla. Most of the recaptures from this release were taken on the southern portion of the Sanibel fishing grounds. Others were caught on the northern portion and on the Tortugas



Recapture sites of marked pink shrimp released near Indian Key, Fla., in August and September, 1962.

grounds. The pattern of recoveries shows that young shrimp diverge widely in their movements from the Indian Key region, and suggests the existence of an unexploited portion of offshore stocks in the region between the Sanibel and Tortugas grounds where much of the rough bottom cannot be economically fished with conventional shrimp trawling gear.

In December 1962, 2,350 small pink shrimp were marked and released in the eastern section of the Tortugas fishing grounds. In the following 3-mo. period, dispersion of this group was in a predominantly westward direction into deeper water. This observation corroborates those made earlier in the same area.

In March 1962, 2,496 pink shrimp were captured, marked with fast green dye, and released on the Sanibel fishing grounds. Between March 21 and October 1, 1962, 563 of the marked shrimp were returned. Results of this experiment are still being analyzed.

Experiments with Accessory Marks   Machine inks, when used in conjunction with biological stains, may increase the number of shrimp mark-recapture experiments which can be conducted concurrently in one area. The rate of survival of shrimp marked with both a biological stain and a machine ink was compared with that of unmarked individuals in tank experiments. Although the "double-marked" shrimp suffered slightly more mortality than the unmarked (control) shrimp immediately after marking, and the mortality varied with the ink injection site, there was no significant difference in survival among marked and unmarked shrimp after 24 hr.

Survey of Genus *Penaeus*   Two thousand shrimp of the genus *Penaeus*, collected at various sites in south Florida, were examined to determine the incidence of species other than the pink shrimp, *Penaeus duorarum*. Only pink shrimp were found in samples from the Tortugas trawling grounds although some *Penaeus brasiliensis* were found in eastern Florida Bay, a recognized nursery area for Tortugas shrimp. Brown shrimp, *P. aztecus*, were found on the northern Sanibel grounds in 30 ft. of water, and south of Marathon in about 200 ft. of water. These occurrences represent extensions of the range of this species in waters off south Florida.

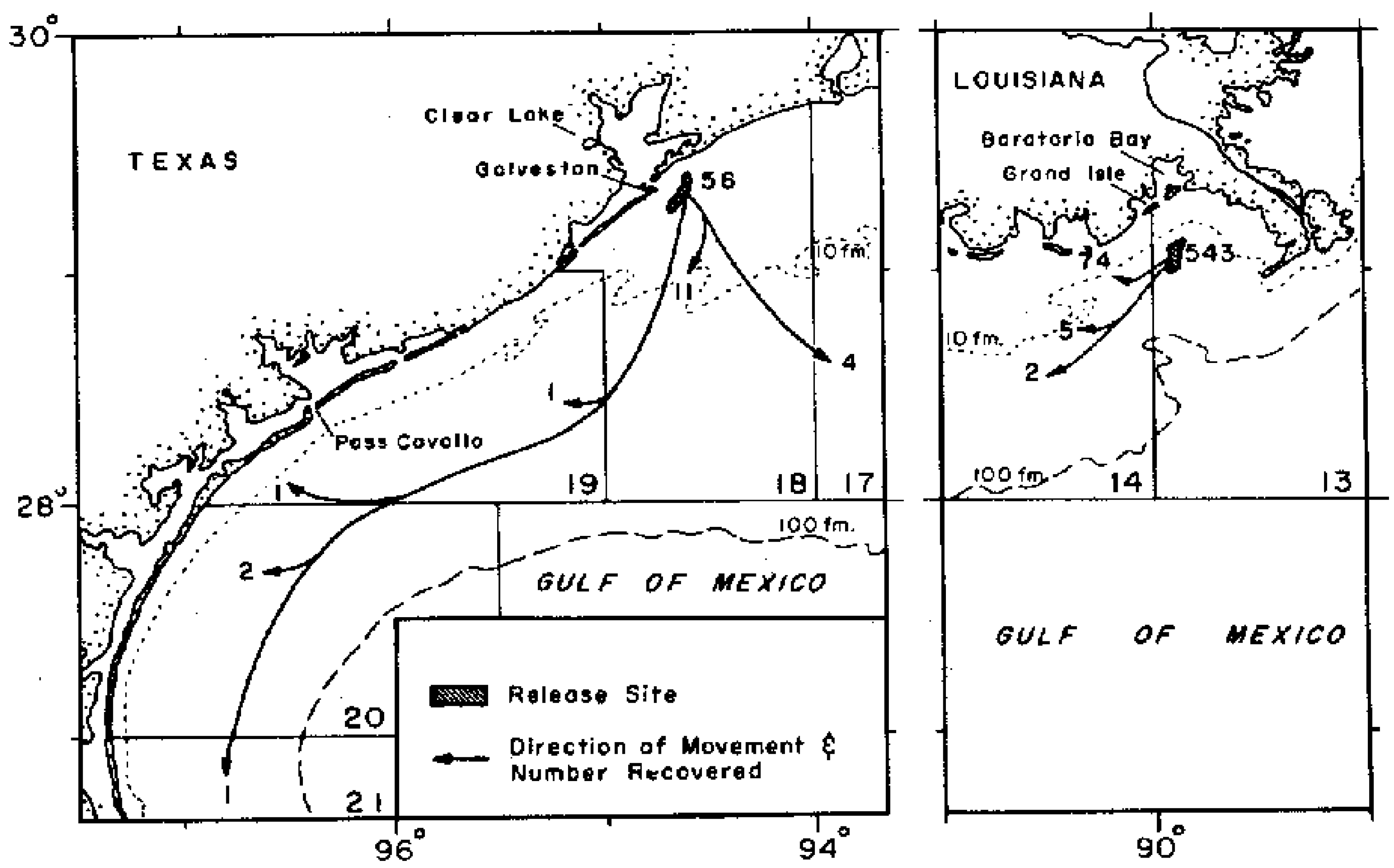
Thomas J. Costello, Project Leader
Donald M. Allen

Brown and White Shrimp Mortality Studies

A major objective of the shrimp research program is to determine the optimum level of exploitation for commercial shrimp stocks in the Gulf of Mexico. Mark-recapture experiments to describe population movements and to measure growth and mortality are being conducted with brown and white shrimp in the northern Gulf.

Mark-Recapture Experiments The first experiment with brown shrimp off the northern Gulf coast was initiated in April 1962. Four more studies, two with brown shrimp and two with white shrimp, began during July and September 1962, respectively.

In April 1962, slightly over 2,400 brown shrimp were marked (stained) with fast green FCF and released in a 100-square-mile area southeast of Pass Cavallo, Tex., in statistical area 19. An additional 1,690 shrimp tagged with Petersen disk tags were released in areas 18 and 20. Between April 1962 and February 1963, 153 stained shrimp (6 percent) and 87 tagged shrimp (5 percent) were returned. No tagged shrimp were recovered after December 1962. For the period and area under consideration, adult brown shrimp did not move great distances, as more than 90 percent of the shrimp were recaptured within 30 nautical miles of the release areas. (See accompanying figures.) The longest recorded



Direction and distance of movement of marked brown shrimp released in July 1962.

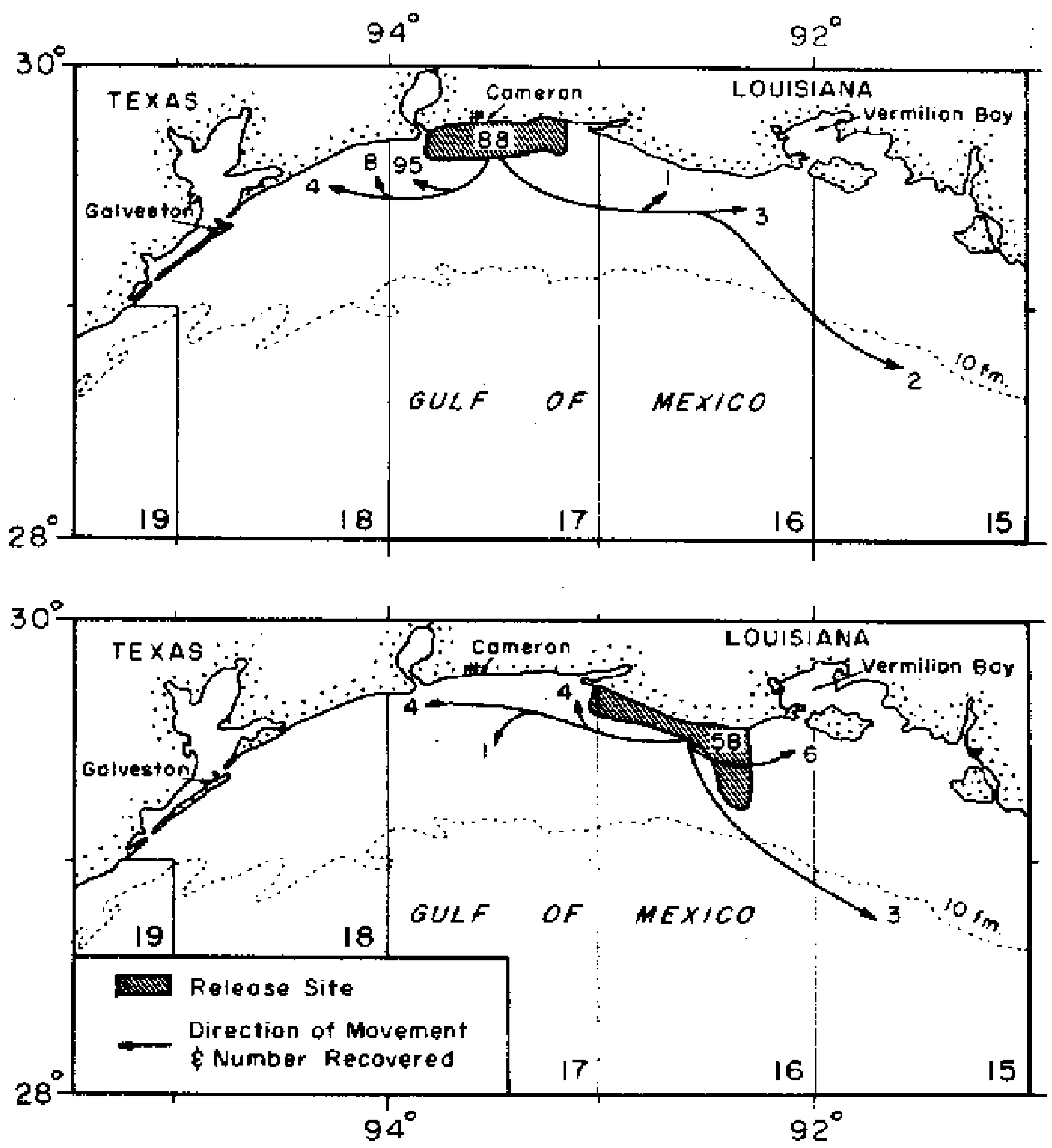
movement was 68 miles. Excursions were random relative to the shoreline with little or no inshore or offshore movement indicated. The marked groups are believed to have represented a single population. Preliminary analysis of the resulting data suggests that during the period April-August, natural mortality was more than twice the mortality due to fishing.

In July 1962, brown shrimp drawn from narrowly defined size groups were marked and released as follows: 2,370 off Grand Isle, La., in statistical area 13; and 2,973 off Galveston, Tex., in statistical area 18. They were marked with either a green or blue biological stain, or with a biological stain and a fluorescent pigment which can be identified under ultraviolet light. During the Grand Isle and Galveston experiments, respectively, 624 (26 percent) and 74 (3 percent) stained shrimp were subsequently recovered. No significant difference in the number of returns from the two types of marks was noted.

Little information on movements, growth, and mortality was obtained due to the unforeseen shortness of both experiments and to the low number of recoveries from the experiment initiated off Galveston. Over 98 percent of the shrimp recovered off Louisiana were recaptured less than 30 nautical miles from the area of release, with the remaining 2 percent having traveled less than 60 miles. The latter shrimp had moved offshore and to the west. Almost 88 percent of the experimental shrimp released off Galveston were recaptured less than 30 miles from the area of release. Four shrimp were recaptured to the east in 20 fathoms of water, however, and 5 had traveled more than 60 miles in a westerly direction. The greatest distance recorded was 195 miles. These observations indicate that the small brown shrimp which seasonally migrate from Galveston Bay probably contribute to the offshore fishery at nearly all points along the Texas coast.

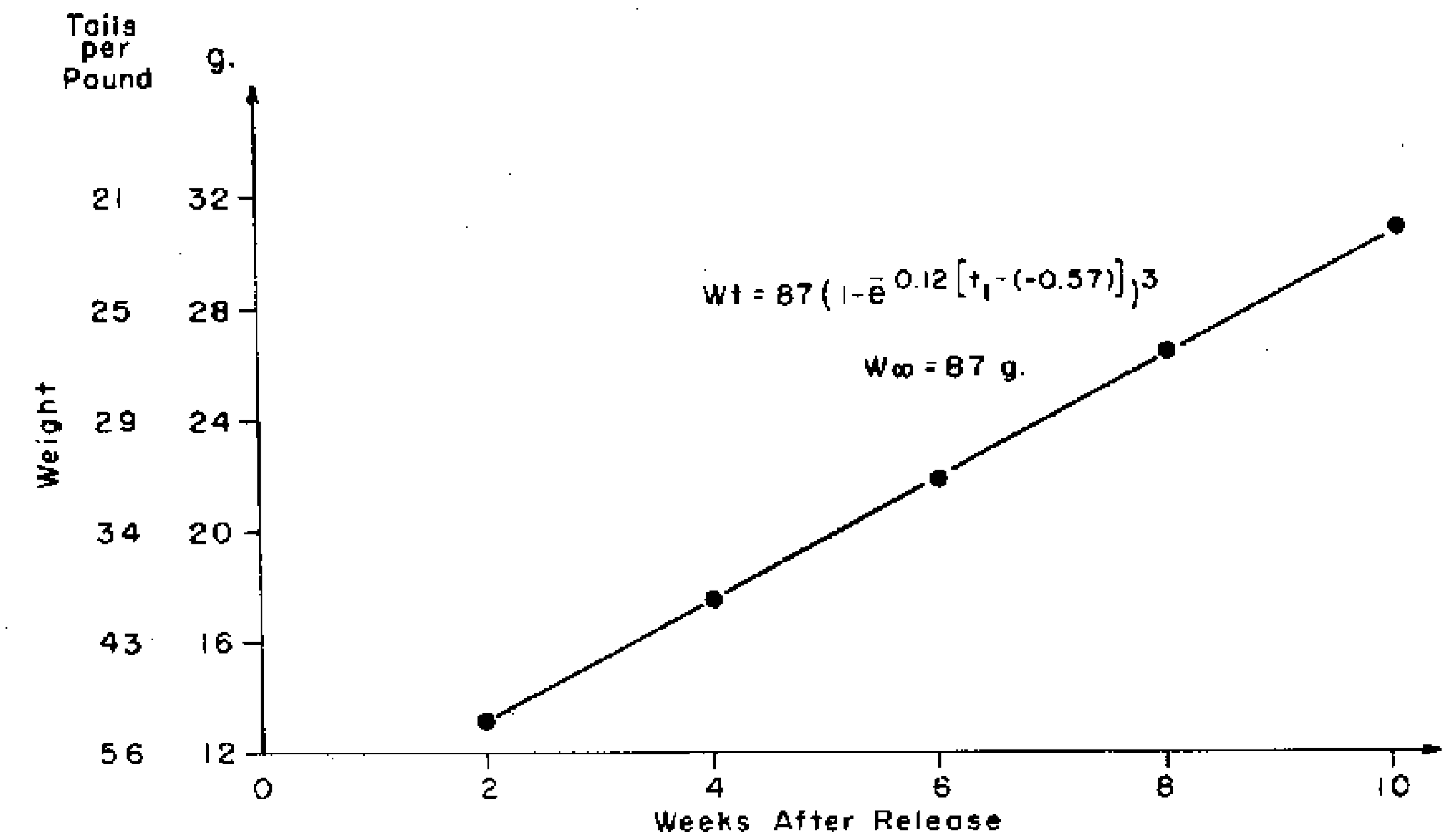
One factor which can cause estimates of fishing mortality to be different from the true value is the incomplete reporting by fishermen of the capture of marked shrimp. A preliminary estimate of this loss was obtained during the Grand Isle experiment. Further refinement along these lines will be made in experiments scheduled for 1963.

In late September 1962, 1,905 white shrimp, ranging in total length from 147 mm. to 156 mm., were stained with fast green FCF and released in statistical area 16 off Louisiana. Another group of 2,291 white shrimp representing two size categories (total length ranging from 115 mm. to 124 mm., and from 134 mm. to 143 mm.) was stained with Trypan blue and released in area 17. Between September 1962 and January 1963, recoveries from both areas amounted to 275 (6.6 percent). For the period under consideration, it appears that movement of the marked shrimp was restricted. It is also concluded from these results that the two marked groups represented a single population.



Direction and distance of movement of marked white shrimp released in September 1962.

After fitting the von Bertalanffy growth function to the mean weight (sexes combined) of the recaptured shrimp, it was estimated that during the fall, white shrimp of the sizes included in the experiment grew in length from 120 mm. (52-count, heads off) to about 131 mm. (38-count) in 2 weeks, and to 159 mm. (21-count) in 8 weeks.



Growth of marked white shrimp released off western Louisiana in September 1962.

In addition to providing information on growth, these recapture data will also be used to estimate fishing and natural mortality.

<u>Accessory Marks</u> To date, only two primary stains, Trypan blue and fast green FCF, have been found suitable for marking penaeid shrimps. The number of experiments that can be conducted in the same region during the same season is thereby restricted. To increase the scope of the staining technique, laboratory experiments are underway to find additional stains.

Primary marks, i.e., stains such as Trypan blue which persist in the shrimp's gills, provide a distinct coloration readily detected by fishermen. Secondary or accessory marks are not so obvious and can only be identified by visual or fluorometric examination in the laboratory. During the year, a number of dyes and fluorescent pigments were tested for use as either primary or secondary marks. No additional suitable primary marks were found. Five fluorescent pigments proved suitable as secondary marks when used with one of the two acceptable biological stains. These fluorescent marks did not fade, were not shed from the shrimp during molting, and were easily detected under ultraviolet light up to 160 days after marking. Initial mortality occurred within 24 hr. after marking and is attributed solely to handling and not to any effects of the fluorescent material. It did not appear that the fluorescent pigments had any adverse, long-term effect on survival. The five pigments can be readily differentiated and thereby increase from 2 to 12 the number of stains or stain combinations which can be identified and used to mark shrimp.

Edward F. Klima, Project Leader
Kenneth W. Osborn

Commercial Catch Sampling

A project to undertake systematic sampling of commercial shrimp catches was initiated in January 1962. Fishery Biologists were assigned sampling duties at the ports of Morgan City, La., and Galveston and Aransas Pass, Tex. More recently, additional agents have been stationed at Brownsville, Tex., Houma, La., Pascagoula, Miss., and Tampa and Key West, Fla.

The biologists work closely with agents of the Branch of Statistics located in their respective areas and are responsible for sampling landings for size and species composition as well as obtaining interview information pertaining to fishing areas and effort. They also perform other functions depending on the particular requirements in each area. These include field studies to determine the extent to which small shrimp are discarded at sea, aiding in the handling of marked shrimp recaptured during growth and mortality experiments, periodic collection of postlarval shrimp for preseason abundance estimates, and compilation of catch and effort information from selected "study groups" of shrimp trawlers.

The volume of work accomplished and the quality of the information gathered by the port sampler are dependent to a great extent upon his skill and speed in obtaining interviews and in making measurements, his knowledge of the movement of the fleet with regard to weather conditions and availability of shrimp, and upon the cooperation given him by shrimp dealers and vessel captains.

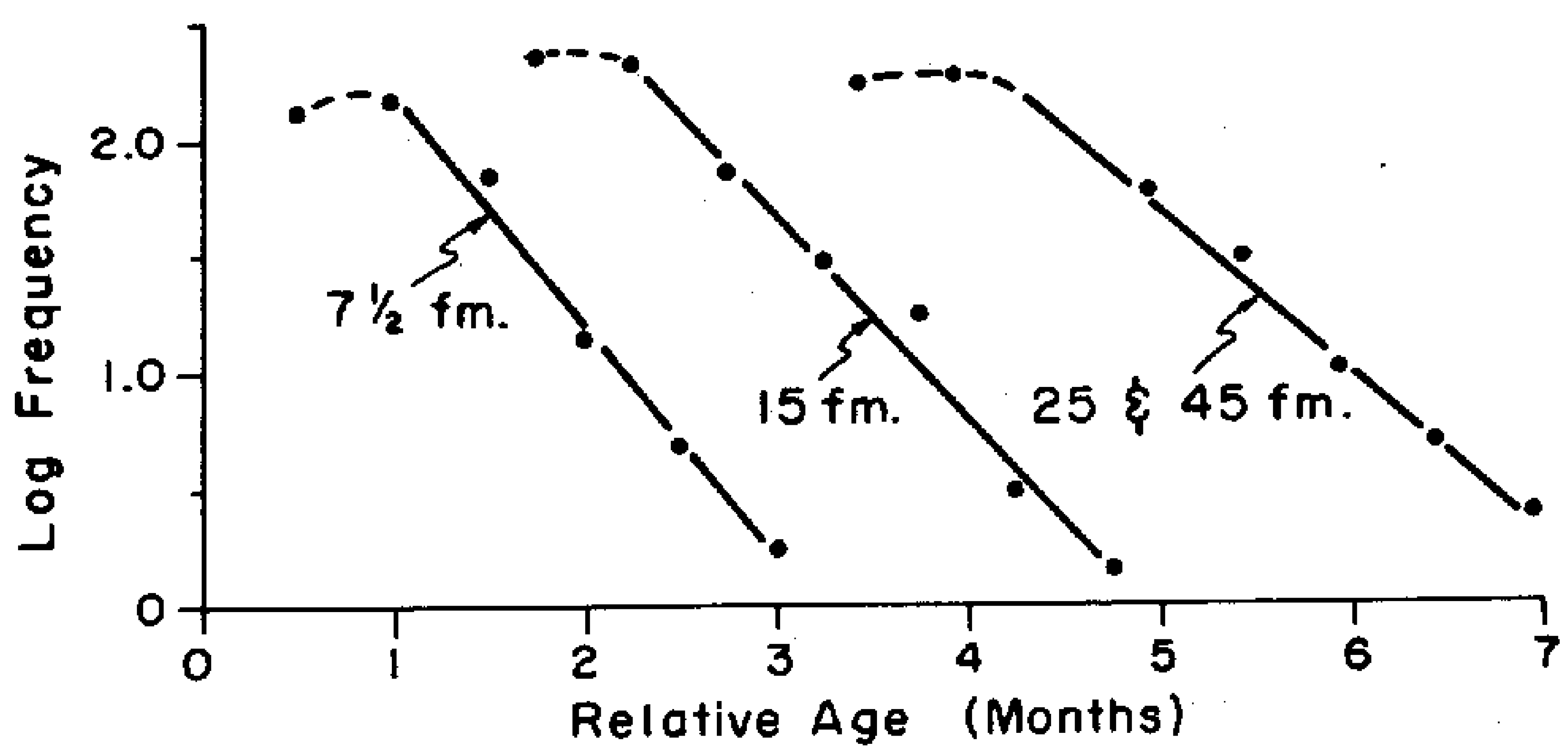
On the basis of sample material obtained from July 1962 through March 1963 and without regard to differences between areas or species, about 72 percent of the total fishing effort was expended and 73 percent of the vessel catch was made during the hours of darkness. The catch of shrimp per hour's fishing averaged 20.3 pounds for day fishing and 21.9 pounds at night. Most of the night fishing was for brown and pink shrimp, whereas daylight fishing was concentrated on white shrimp.

Ray S. Wheeler, Project Leader
Charles R. Frith
James M. Lyon
Thomas W. Turnipseed
Charles E. Knight
Joseph A. Benigno
Robert C. Benton
J. Harold Hudson

Population Dynamics

A major responsibility of many commercial fishery investigations is to assess the effect that fishing practices have on exploited stocks. Several techniques have been devised to answer this question though each has certain limitations. In the case of shrimp populations, considerable success has been achieved by means of mark and recapture experiments. Because it is not feasible to conduct such experiments on all shrimp stocks of interest, there remains a need for a simple method by which mortality rates can be determined at regular intervals and then related to fishing practices. The analysis of catch curves based on size-frequency distributions holds some promise of providing comparable mortality estimates for shrimp populations on a continuing basis. The present report deals with preliminary efforts in this direction.

Conventional catch curves portray the frequency with which various age groups occur in a catch and provide an estimate of each group's rate of decline (or mortality rate). Unfortunately, there is no way to age individual shrimp, and it is necessary to adjust size-frequency distributions to relative age. This adjustment, enabling true rates of decline to be determined even though actual age is unknown, is accomplished by taking into account the rate of shrimp growth in each size category and then changing the scale on the abscissa (x-axis) from units of size to units of time. (See figure.)



Catch curves for brown shrimp sampled in 1962.

To illustrate, length-frequency data are used from male brown shrimp caught at specified depths during research cruises off the Texas coast. Since the life history of brown shrimp includes a juvenile stage in bays or estuaries followed by migration to offshore depths, it is necessary to consider the catch at each depth interval separately. The data at hand indicate that the size of shrimp at depths of 25 and 45 fathoms does not differ significantly. This fact suggests that seasonal migration is not an important cause of differences in the frequency with which size groups enter catches made at depths greater than 25 fathoms. In other words, the slope of the catch curve constructed for shrimp from 25 and 45 fathoms is interpreted to provide an estimate of total mortality, whereas the slopes of curves from lesser depths include losses and gains due to migration as well as losses due to mortality. By subtracting the total mortality rate from the rate of decline determined from the $7\frac{1}{2}$- and 15-fathom catch curves, we can estimate rates of migration from these depths. Thus:

Depth in fathoms	$7\frac{1}{2}$	15	25-45
Total rate of decline per month	1.00	0.87	0.66
Mortality rate per month	0.66	0.66	0.66
Migration rate per month	0.37	0.21	-

Although the method is somewhat crude at this point, the estimated mortality rate corresponds closely to estimates obtained from mark and recapture experiments. The estimated rate of decline at the $7\frac{1}{2}$-fathom depth may at first appear excessive, but in view of the fact that adult brown shrimp normally move beyond this depth, it is not unreasonable. Several aspects of the technique require further investigation, including rates of movement between depth intervals as well as the influence of varying fishing intensities at each depth. Even without knowledge of these quantities, however, it is anticipated that length measurements taken from commercial landings can be used to gain insight into the subject of mortality rates under varying environmental or fishing conditions.

Richard J. Berry, Project Leader

INDUSTRIAL FISHERY PROGRAM

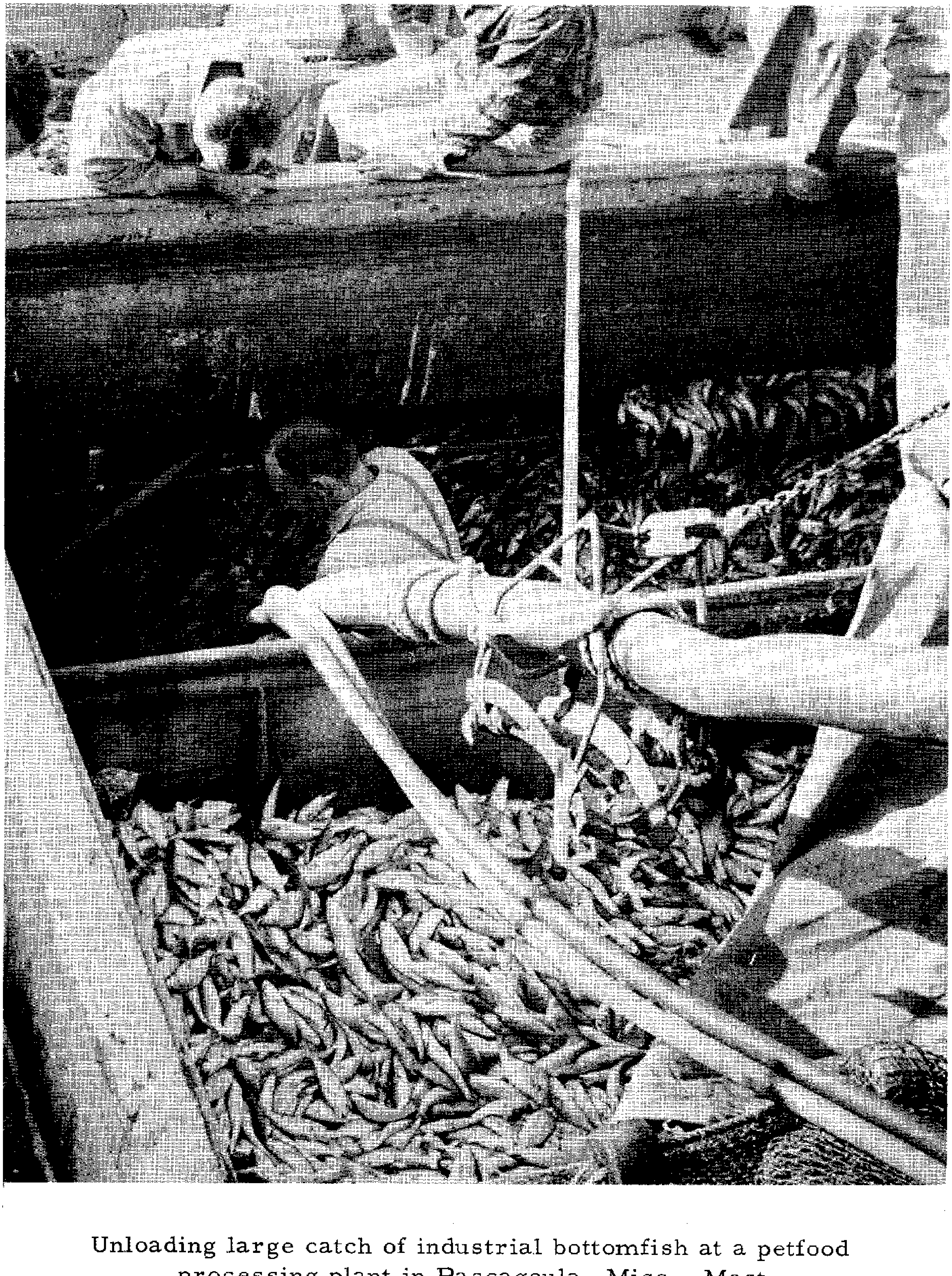
Joseph H. Kutkuhn, Program Leader

By definition, an industrial fishery is one in which a species or group of species is harvested and processed to supply what is referred to as an "industrial" market. Contrasted to one through which fishery products are channeled for purposes of human consumption, this market supplies: (1) the chemical industry with fish oils and solubles; (2) a greatly expanded animal-food supplement industry with fish meal; and (3) a rapidly developing petfood industry with reduced fish solids.

Two distinct industrial fisheries are well established in the northern Gulf coast area: the fishery for menhaden, and that for miscellaneous bottomfishes otherwise classed as "trash" species. The program of biological research at the Galveston Laboratory and its field stations gives attention, however, only to bottomfish resources that now support commercial fisheries or exhibit the potential to do so. Investigation of Gulf menhaden resources continues to be a responsibility of the Bureau's laboratory at Beaufort, N. C.

The industrial bottomfish fishery, which did not attain significant proportions until 1958, depends upon populations of a wide variety of species that have never gained prominence as food or sport fishes. It operates in the region of the Mississippi River Delta where these species (predominantly sciaenids of small average size) seem to reach peak density. All fishing takes place inside 20 fathoms and is more or less restricted to that area lying within 150 miles on either side of the Mississippi River. Practically all of the catch goes into the production of petfood and animal foods in general.

Our research program began in 1958 just after the fishery's inception and has since been coordinated with activities of the Bureau's Branch of Statistics. The latter agency compiles catch statistics while we supply information on fishing operations and the composition of landings. The first 2 years' research at the Laboratory's field station in Pascagoula, Miss., which consisted of inventorying the kinds of fishes supporting this now important fishery, disclosed that four or five out of a hundred or more species predominate in catches throughout the year. More recently, emphasis has been shifted from merely determining species composition to conducting detailed studies of the life histories of the dominant forms. Simultaneously, an increasing amount of effort is being directed toward measuring, as the fishery develops, the effects of fishing on supplies of top-ranked species.

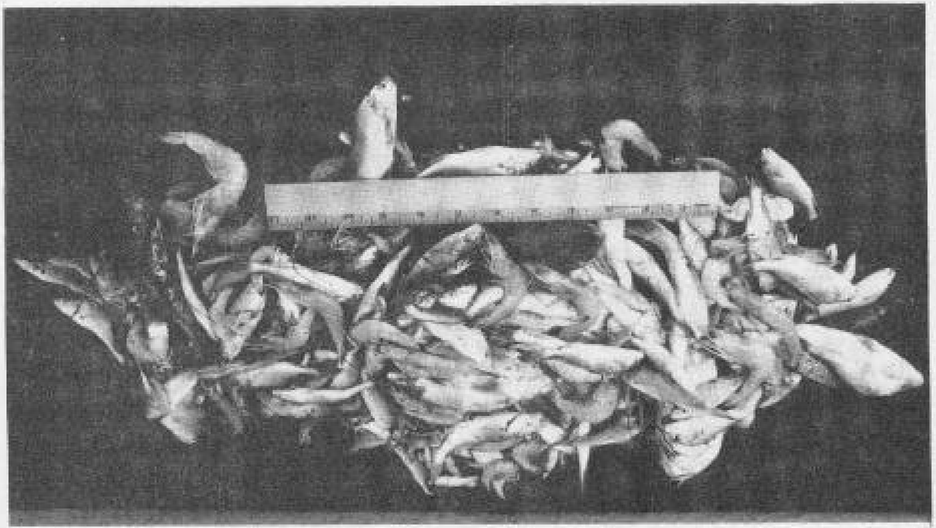


Unloading large catch of industrial bottomfish at a petfood processing plant in Pascagoula, Miss. Most of the fish in view are Atlantic croakers.

The Bureau of Commercial Fisheries is just as interested in developing new fisheries as it is in maintaining established ones. Of additional interest along the Gulf coast is the matter of diversification - the possibility that during periods of slack activity in the shrimp fishery, trawling gear could be used to harvest profitably other marine forms. Accordingly, we are also pursuing a program of research aimed at determining the commercial potential of industrial-type bottomfishes off the western Louisiana and Texas coasts. Field work is coordinated with activities of the Shrimp Fishery Program, and we are now compiling a wealth of biological information from systematic samples of fishes taken during research vessel operations between the Delta and the mouth of the Rio Grande River.

Major objectives of this project are to determine the coastal and depth distribution, as well as the seasonal occurrence and abundance of bottomfishes showing promise of supporting an industrial fishery in the western Gulf area. In addition, basic work on the life histories of the more common species is also underway. It is still a little too early to tell whether, from a seasonal standpoint, the collective abundance of these forms is sufficiently great to permit development of a profitable fishing operation.

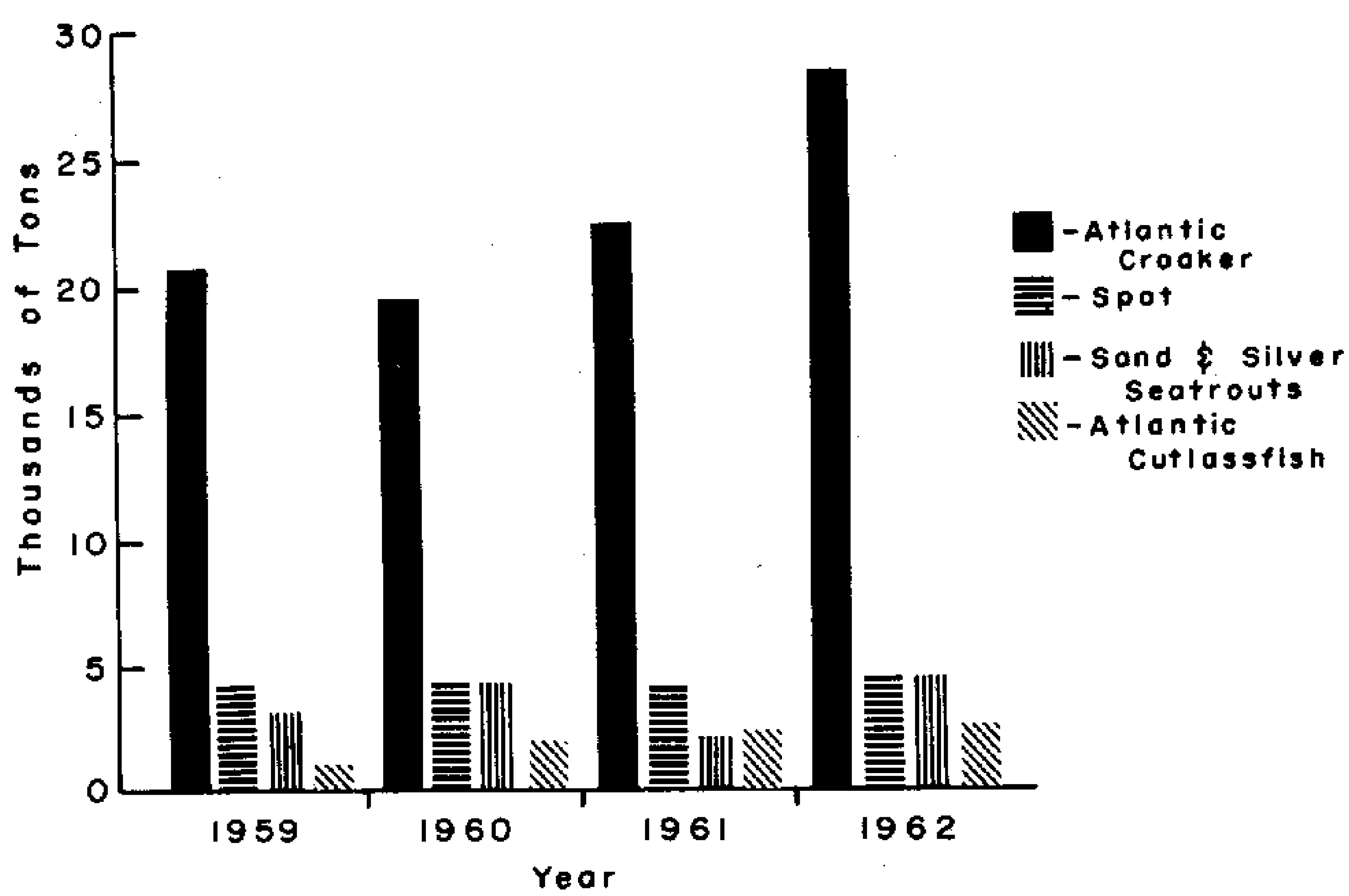
Typical mixed catch of shrimp and industrial-type bottomfishes. "Trash" fish will sometimes outweigh shrimp in ratio of 5 to 1.



The Fishery   Compared with production the previous year, landings in 1962 by the industrial otter-trawl fleet increased 28 percent from 38,450 tons to a record 49,230 tons. Examination of the 1961 and 1962 catch and effort data, which reflected about 24 percent of the total fleet activity for the 2-yr. period, showed (1) that actual fishing time in 1962 increased from approximately 69,000 to 85,000 hr. while the catch per hour remained the same (0.5 ton) and (2) that the number of fishing trips increased from 1,984 to 2,859 although the catch per trip decreased from 19 to 17 tons. Most of the effort increase occurred during the winter and spring in the 4- to 13-fathom depth range off Ship Shoal and Grand Isle, La., and off Gulf Shores, Ala. Fishing effort during 1962 was largely concentrated in the Gulf Shores area (24 percent); off Horn, Petit Bois, Dauphin, and Chandeleur Islands (24 percent); and near Ship Shoal (20 percent). The average depth of fishing varied from 11 fathoms in March to 4 fathoms in August. The maximum depth reported was 19 fathoms.

The industrial bottomfish catch was utilized for petfood (86 percent), fish meal (8 percent), and mink food and crab bait (6 percent). Fish meal production increased 7 percent over that of 1961 despite the fact that processing operations were terminated after 9 mo. One firm engaged in manufacturing petfood also closed its plant in September, reducing to four the number of such units in operation on the north central Gulf coast at the close of 1962.

In 1962, the Atlantic croaker, Micropogon undulatus, contributed an estimated 58 percent, or 28,303 tons, to the total landings of industrial-type bottomfishes and continued its upward production trend that began in 1961. (See graph.) Collectively, spot, Leiostomus xanthurus,

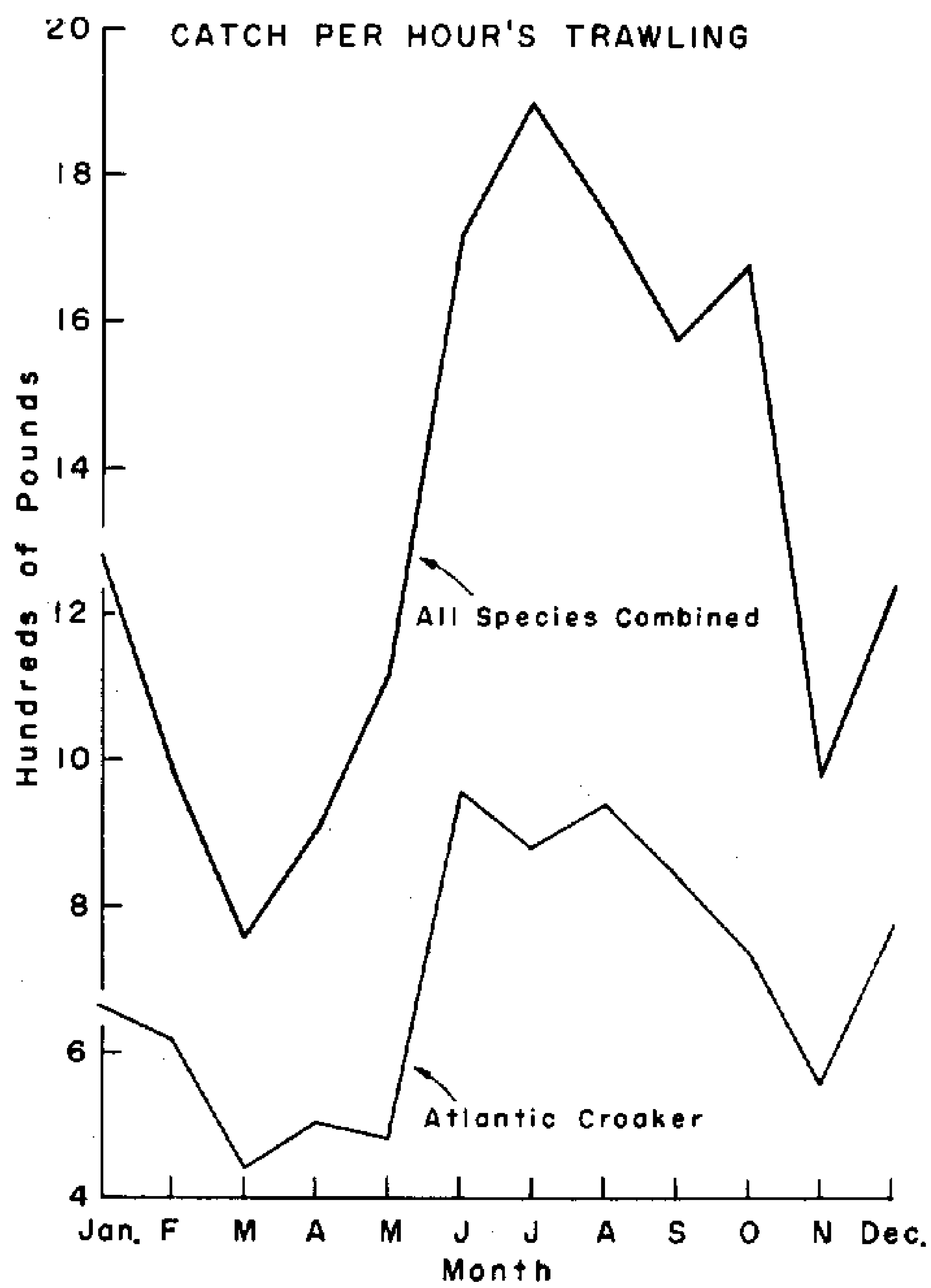


Comparative landings of dominant species taken by the industrial bottomfish fishery from the north central Gulf of Mexico, 1959-62.

sand and silver seatrouts, Cynoscion arenarius and C. nothus combined, and Atlantic cutlassfish, Trichiurus lepturus, accounted for 23 percent of all landings. The contribution of each of these species has remained relatively stable since 1959.

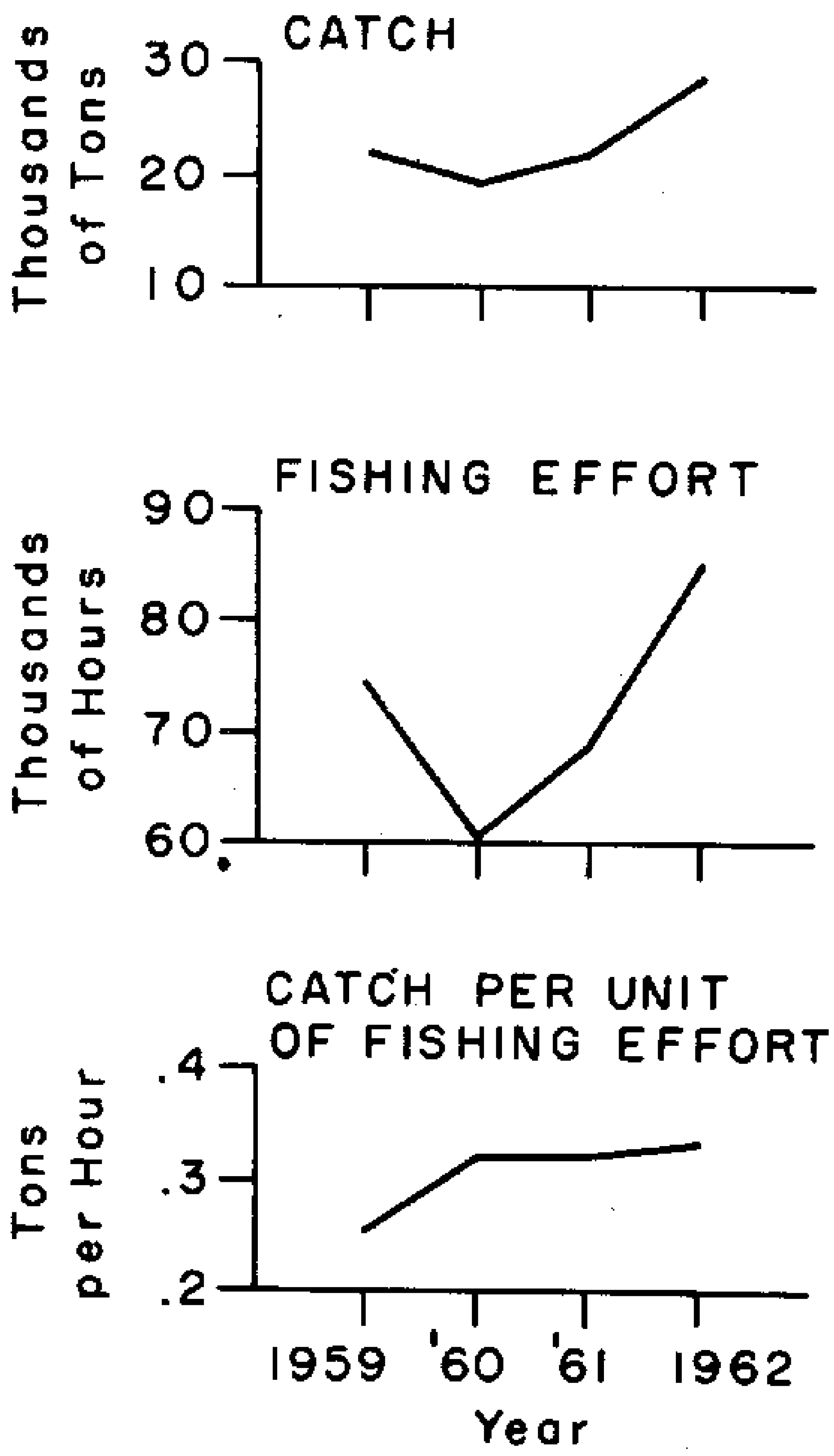
Life History Studies - Atlantic Croaker   Off the north central Gulf coast, the croaker is a normal component in otter-trawl catches during each season of the year and is the principal species landed. The average monthly percentage of croaker by weight in industrial bottomfish catches from 1959 through 1962 varied from about 52 percent in the spring and summer to 58 percent during the winter.

Catch per unit of effort data suggest that the croaker, being the preponderant contributing species, is largely responsible for the marked seasonal variation in fishing success of the industrial trawler fleet. Employing values computed from data obtained over the period 1959-62, the accompanying graph compares the monthly average catch per hour for croaker with the average catch per hour for all species combined. Seasonal fluctuations in apparent croaker abundance are shown to be quite dramatic with the minimum catch per hour occurring in the spring (March-May) and a maximum return materializing during the summer (June-August). A secondary peak in abundance occurs in the winter (December-January).



Monthly trends in the average catch of industrial bottomfish off the north central Gulf coast. Values are computed from data obtained over the period 1959-62.

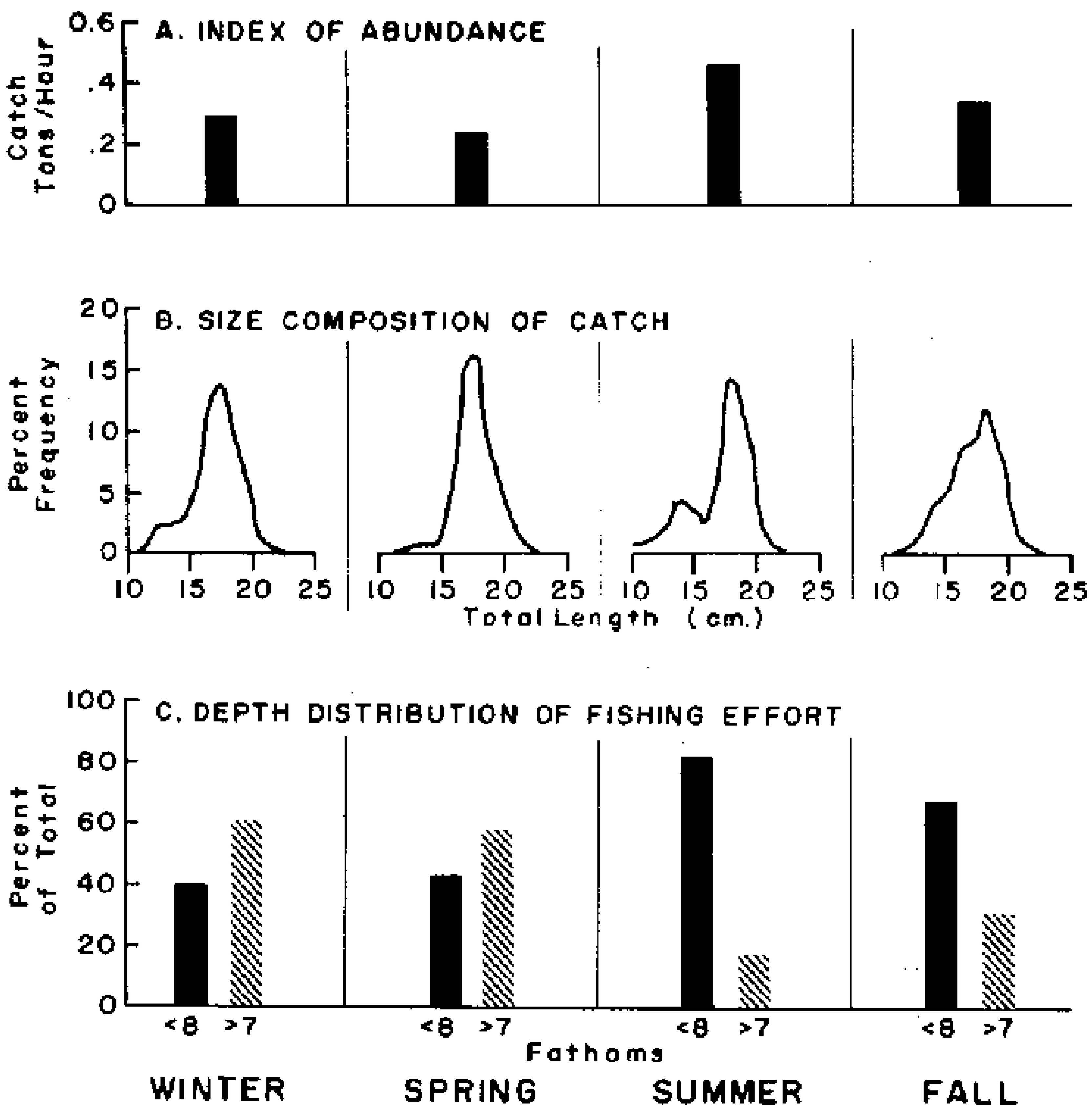
Industrial fishery statistics associated with annual croaker production from 1959 through 1962 show that the catch of this species has increased over 8,700 tons since 1960. (See figure.) Since the catch per



Statistics associated with the harvest of Atlantic croaker by the Gulf coast's industrial bottomfish fishery, 1959-62.

fishing hour remained almost the same (about 0.33 ton), it is evident that the increased croaker harvest was due chiefly to the corresponding effort increase of 24,000 hr. Continued surveillance of the industrial bottomfish fishery should reveal whether increasing fishing pressure, including that contributed coincidentally by the shrimp fleet, has begun to affect adversely the potential of the croaker resource in the north central Gulf of Mexico.

Production in the industrial bottomfish fishery is governed not only by seasonal variation in the relative abundance of croaker, but by seasonal differences in the depth distribution of the croaker's two major size (or age) groups as well. The accompanying figure discloses that the overall catch per hour's trawling as calculated from 1959 through 1962 was minimal in the spring (averaging 0.23 ton), increased twofold and reached a maximum in the summer (0.46 ton), and then decreased during the fall (0.34 ton) and winter (0.25 ton). Size composition data from 1962 reveal that fish with a modal length of 17.5 to 18.0 cm. (2-yr.-olds) were dominant in the catch every season, and that fish with a modal length of 12.5 cm. (1-yr.-olds) first appeared in winter and subsequently contributed to summer and fall catches. A plot of its distribution by depth for the 4-yr. period 1959-62 reveals that fishing effort is generally light on the nearshore grounds (in waters less than 8 fathoms deep) during winter and spring, but becomes increasingly heavy within the same depth range during summer and fall.



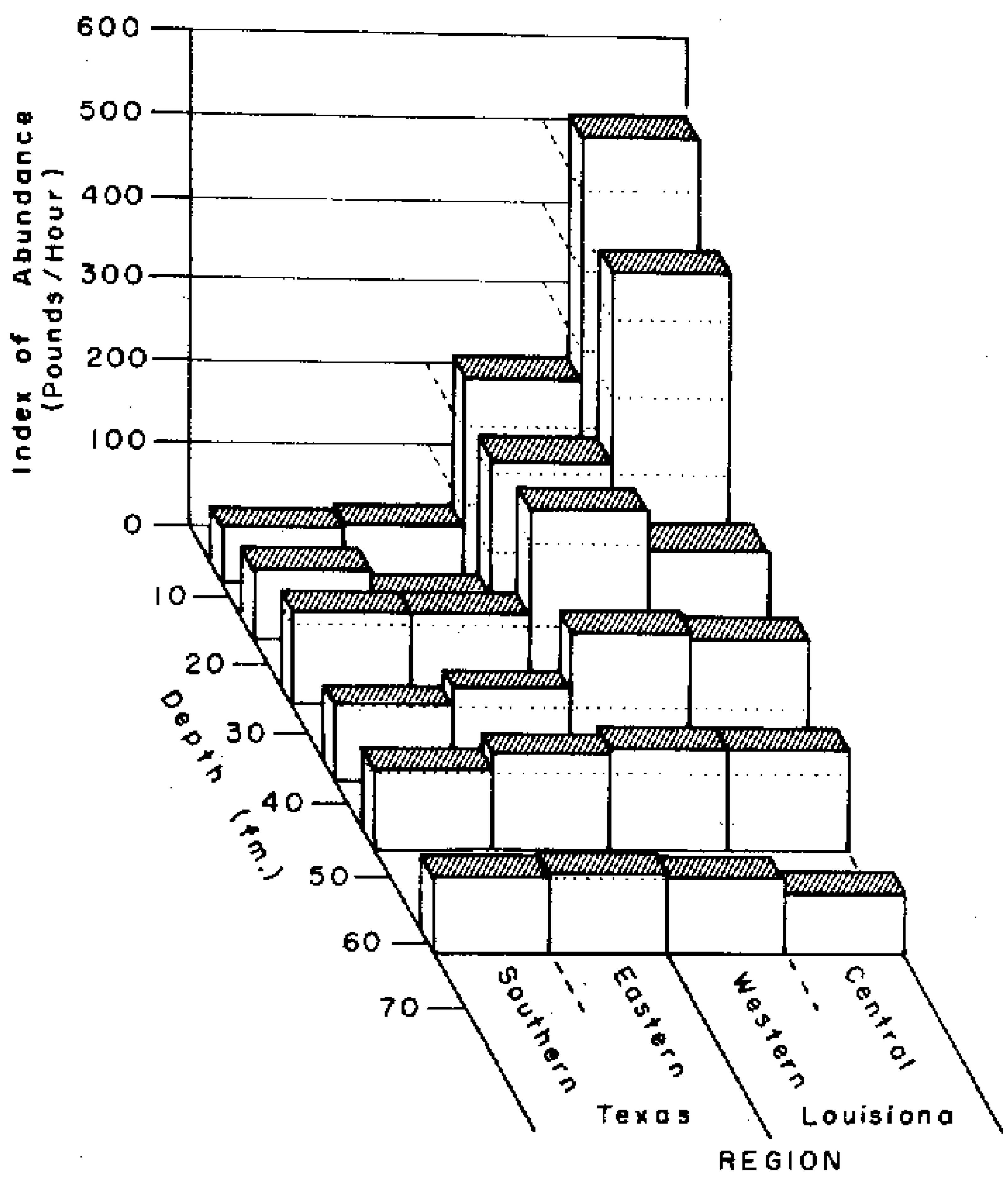
Seasonal patterns of abundance and size composition of, and depths of fishing for, the Atlantic croaker resource in the north central Gulf of Mexico.

Relative abundance, age composition, and depth distribution exhibit a pattern from which seasonal distribution and movements of croaker age groups can be inferred. The 1-yr.-olds first appear close to shore (inside the 8-fathom contour) in winter and are presumed to have recently moved out of local estuaries where they undergo early development. Two-year-old and some older fish, which are dispersed over the offshore fishing grounds (8-32 fathoms) in the winter and spring, assemble in compact schools together with yearling fish on the inshore grounds during the summer months but then move offshore again in the fall.

Examination of the overall average catch per fishing hour for 1960, 1961, and 1962 suggests that the croaker is twice as abundant (0.74 ton) during the summer in 1 to 7 fathoms west of the Mississippi River Delta (Ship Shoal, La., to Southwest Pass, La.) as it is in comparable depths east of the Delta (Pass a Loutre, La., to Gulf Shores, Ala.). Of the total bottomfish catch made west of the Delta during these 3 yr., the croaker constituted an average of 61 percent by weight. To the total catch made east of the Delta, the croaker contributed only 42 percent.

Charles M. Roithmayr, Project Leader

Samples of bottomfish for species composition studies continued to be collected every month from the Gulf of Mexico at 50 to 60 stations located between Southwest Pass, La., and Brazos Santiago, Tex., in depths ranging from $7\frac{1}{2}$ to 60 fathoms. (See figure on page 8.) These stations, established by the Shrimp Fishery Program whose assistance in obtaining bottomfish material is gratefully acknowledged, permitted sampling over a much larger portion of the Gulf's continental shelf than was formerly possible. The procedure at each station consisted of recording the total weight of the sample fish catch and then "randomly" drawing therefrom about a 4-lb. subsample. All catches were made by a 45-ft. (flat), 2-in.-mesh trawl fitted with rollers and towed for 1 hr.

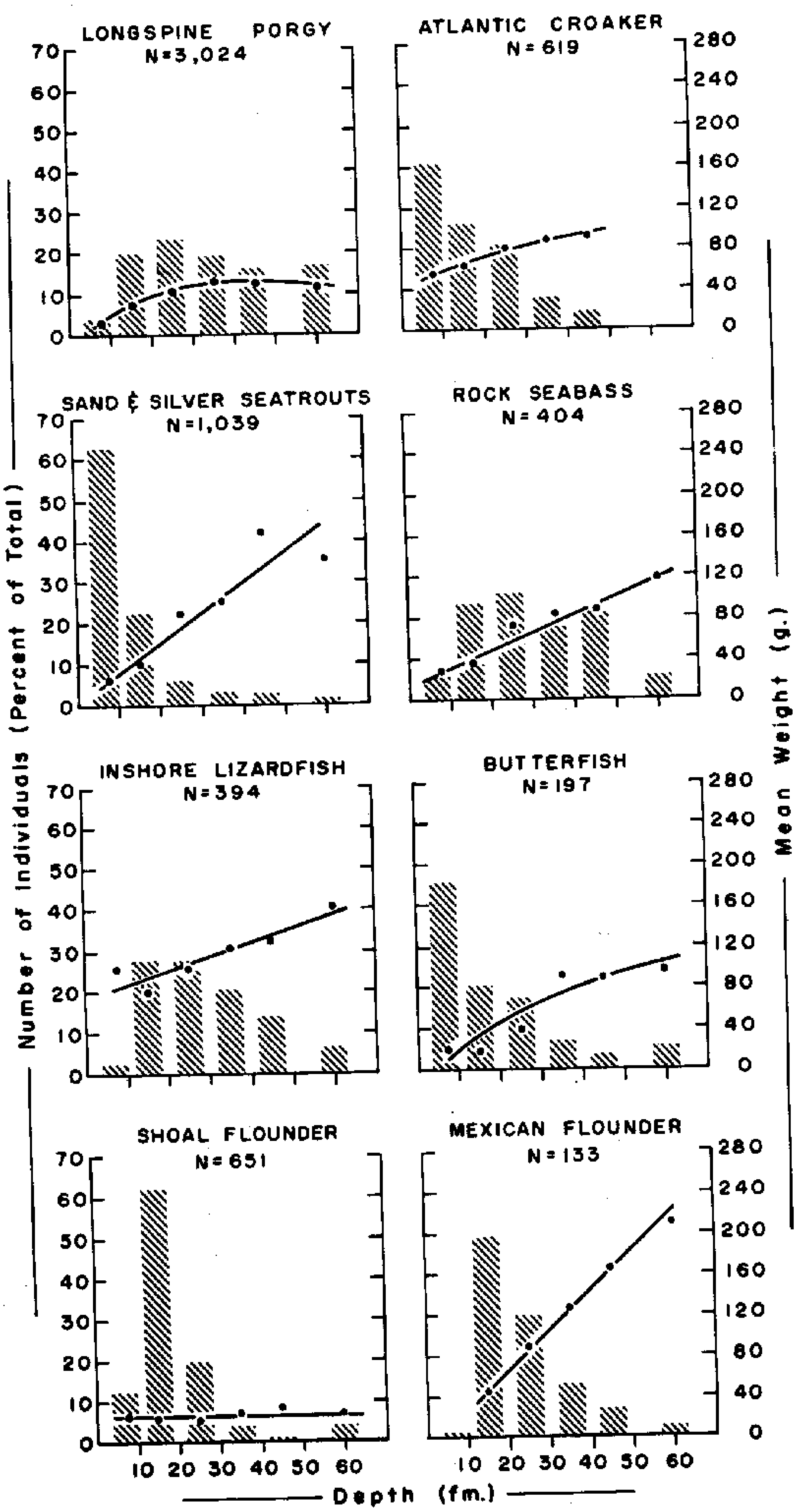


Relative abundance of western Gulf bottomfishes by depth and region, 1962.

Abundance Relative to Coastal Area and Depth The average catch of all species per unit of sampling effort in 1962 was generally much greater at stations located off Louisiana than at those along the Texas coast. (See figure.) The largest average catches off Texas came from depths of 25 to 45 fathoms, whereas off Louisiana they usually came from shallower water. Overall, best hauls were made at the shallow stations between Ship Shoal and Southwest Pass off Central Louisiana. (Note: Trends in seasonal abundance of western Gulf bottomfishes have been discussed in earlier reports.)

Distribution and Size vs. Depth Density distribution and average size, both as related to depth, are shown in the accompanying figure (next page) for eight common bottomfishes occurring in the sample catches. Plotted values represent combined monthly data obtained during the period January-July 1962. The apportionment of sampling effort according to depth was as follows:

Depth (fathom):	$7\frac{1}{2}$	15	25	35	45	60
Effort (hr.):	51	55	53	49	50	44



Relative number (bar) and mean weight (line) at depth of capture of common, industrial-type bottomfishes occurring on the continental shelf of the western Gulf of Mexico. Samples were obtained on survey cruises made during the period January-July, 1962.

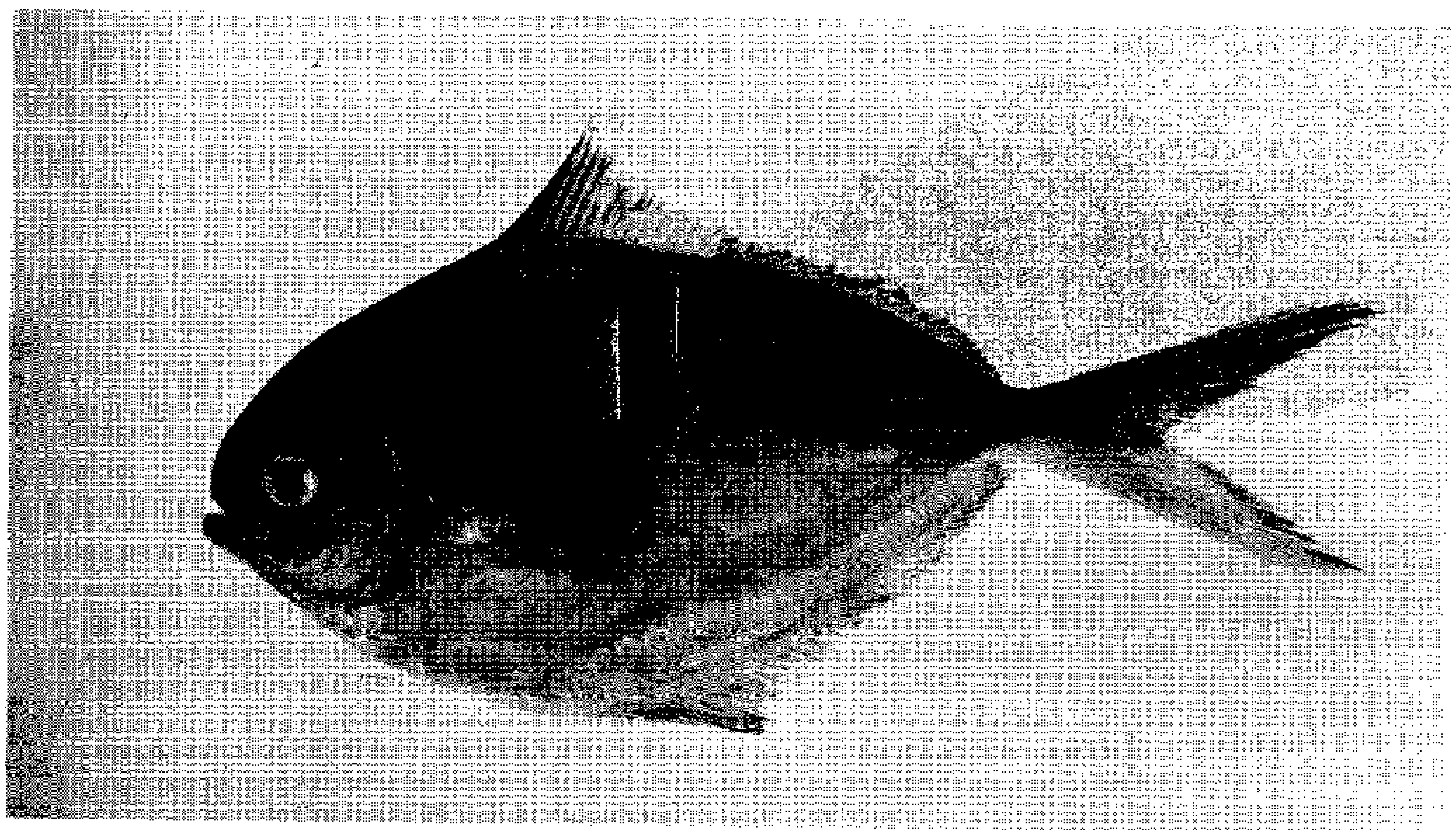
The longspine porgy Stenotomus caprinus, occurred more frequently throughout the survey period than any other species and was relatively numerous in samples from all but the shallowest stations. Specimens taken from $7\frac{1}{2}$ to 15 fathoms had lower average weights than those from deeper waters, although no increase in average weight with depth was observed for porgies captured beyond 35 fathoms.

Sand and silver seatrouts, Cynoscion arenarius and C. nothus combined, and the Atlantic croaker, Micropogon undulatus, were most abundant in collections from the shallowest, or $7\frac{1}{2}$-fathom stations. Both the seatrouts and croaker, while decreasing in number in samples taken from progressively deeper waters, increased in average weight. The increase in size with depth was greatest for the two seatrouts.

Parenthetically, shallow waters less than $7\frac{1}{2}$ fathoms which cover about one-fourth of the western Gulf's continental shelf and appear to harbor the greater portion of its croaker and seatrout resources, were not represented in the survey pattern. This observation suggests that in more extensive studies involving the biology and dynamics of these important species, sampling inside the $7\frac{1}{2}$-fathom contour will be necessary.

Like the longspine porgy, the inshore lizardfish, Synodus foetens, and the rock seabass, Centropristis philadelphicus, were moderately abundant from a wide range of depths. These species also displayed greater average weights when taken from deeper water. Although its relative numbers decreased rapidly with increasing depth, the butterfish, Poronotus triacanthus, also tended to be of larger size at greater sampling depths.

The shoal and Mexican flounders, Syacium gunteri and Cyclopsetta chittendeni, both occurred most frequently in samples from the 15-fathom stations although Mexican flounders were also fairly common at 25 fathoms. Shoal flounders from all depths had about the same average weight whereas Mexican flounders caught at greater depths were generally larger.



Butterfish, Poronotus

The foregoing observations indicate that with increasing depth, a decrease in numbers accompanied by an increase in average size characterizes many of the common, shallow-water bottomfishes of the western Gulf.

Variability of Samples Preliminary attempts to assess variability in trawl hauls have indicated that hour of collection is one source of variation (attributable to marked differences in the diurnal activity of certain species) that warrants special attention in our continuing efforts to improve sampling efficiency. Some of the species that exhibited such variation are major components of the bottomfish resource (e.g., the seatrouts and croaker). Further investigation will therefore be made to determine whether the diurnal activity patterns of these and other species are sufficiently consistent to be compensated for by adjustments in sampling procedure.

Donald Moore, Project Leader

ESTUARINE PROGRAM

Charles R. Chapman, Program Leader

Most of the commercially important fish and shellfish that are now harvested from the Gulf of Mexico typically spend at least part of their lives in a brackish-water or estuarine environment, represented at the edge of the Gulf by a complex of bays, "lakes," lagoons, bayous, and marshes in which the saline water of the ocean mixes with the fresh water discharged by a multitude of rivers and streams. Widespread evidence that our estuaries are rapidly being altered through their development for industrial, navigational, agricultural, residential, and miscellaneous commercial purposes is giving rise to concern about their probable fate and that of their fishery resources. With more and more attention being focused on this problem, the Estuarine Program was initiated in 1959 to undertake research that would lead to a better understanding of the real and potential effects of such activity.

Processing and analysis of biological and hydrological data collected in the Galveston Bay area since 1959 were initiated during the fiscal year. All hydrological data have now been organized in tabular form for distribution, together with maps showing collection locations, to other governmental agencies requesting such information. Biological data have been partially analyzed, with those obtained in 1961 providing the basis for a special contribution presented elsewhere in this report.

Modification (by dredging) of estuarine environment in Galveston County, Tex.

Research in estuarine ecology was expanded during the fiscal year. Emphasis is gradually being shifted from routine investigation of the general biology of estuarine species to detailed study of the dynamics of their populations. Cooperative arrangements have been made with the Corps of Engineers and Texas Water Pollution

Forty-foot vessel TOMMY BOX is fitted with power equipment for sampling in deeper portions of estuarine areas.

Control Board for the exchange of hydrological data collected in the Galveston Bay area. This consolidated data-gathering effort is resulting in better definition of the estuary's hydrological characteristics.

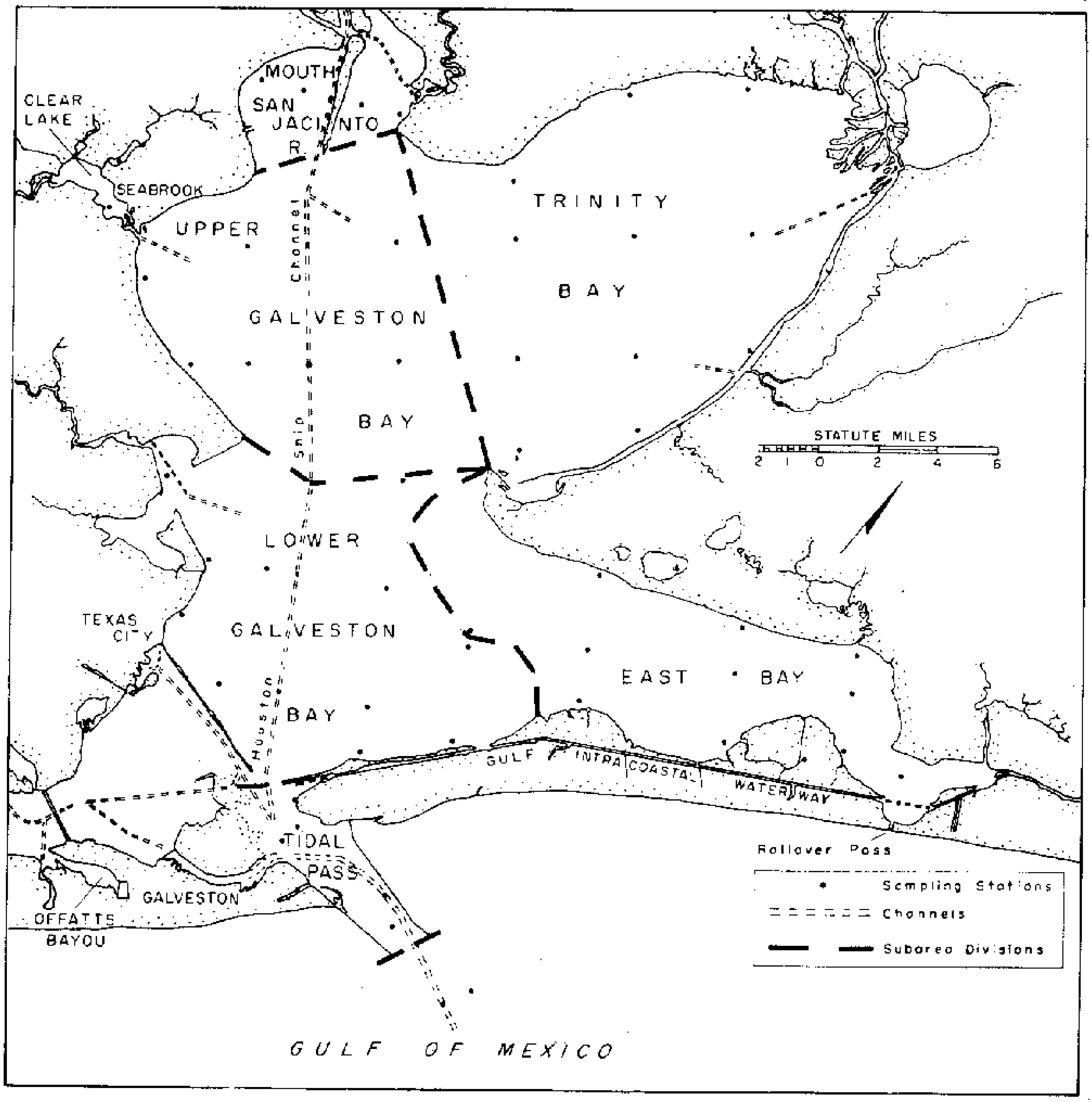
Review of proposed water development projects continued to require considerable effort. The Branch of River Basin Studies was assisted in the evaluation of nearly 140 engineering projects, including two of major importance (the Texas Basins Project and the Matagorda Ship Channel Project), that could conceivably affect the biological productivity of Texas estuaries. Program personnel also assisted this agency in developing interim study requirements and plans on the Mississippi River-Gulf Outlet Project in Louisiana.

Demands upon water resources along the Gulf coast are rapidly producing drastic physical and chemical changes in estuaries and marshes. Because of the need to understand the effects of such changes upon stocks of fish and shellfish which thrive in these brackish-water areas, this project was initiated in 1959 as part of an overall program of estuarine research.

The Study Area and Its Subdivision The first phase of the project was designed to inventory and to determine seasonal changes in relative abundance and size composition of the species of fish and shellfish inhabiting three selected areas of the Galveston Bay system; namely, Offatts Bayou, Clear Lake, and Trinity Bay. Tabulation and preliminary analysis of resulting biological and hydrological data demonstrated a need to enlarge the scope and area of study. Consequently, without suspending any of the work already underway, ways and means of expanding this study to include the entire system were explored during the latter half of 1962. Particularly desirable were a better definition of habitat types within an estuarine complex and some measure of their relative importance to various commercial as well as noncommercial estuarine species. Sampling stations were eventually located, and appropriate sampling and collection-processing methods were developed. The revised and enlarged project became fully operational on January 1, 1963.

For comparative purposes, the Galveston Bay system is now divided into nine subareas, each of which is characterized by two to five distinct habitat types. These subareas include the near-shore Gulf of Mexico at the ends of the Galveston jetties, the tidal pass, lower Galveston Bay, upper Galveston Bay, the mouth of the San Jacinto River. Trinity Bay, East Bay, the Gulf Intracoastal Waterway, and the Houston Ship Channel. (See map next page.) Habitat types include: (1) channels, (2) open water, (3) shoreline zones, (4) connecting bayous, adjacent small lakes or tertiary bays, and (5) special habitat subdivisions such as major oyster reefs. Sampling stations in marshes adjacent to subareas will be added in January 1964.

Biological and Hydrological Indices Biological samples are collected twice each month with 10-ft. trawls at 65 locations and with plankton nets at 34 locations. As required, trammel nets, gill nets, and seines are used at selected locations. From sample inspection, we determine for each population of the major fish and shellfish species, its distribution, growth pattern, size composition, and density. To establish a level of importance and value for each subarea and habitat type, these biological features are then related to indices of hydrological and hydrographical conditions obtained concurrently.



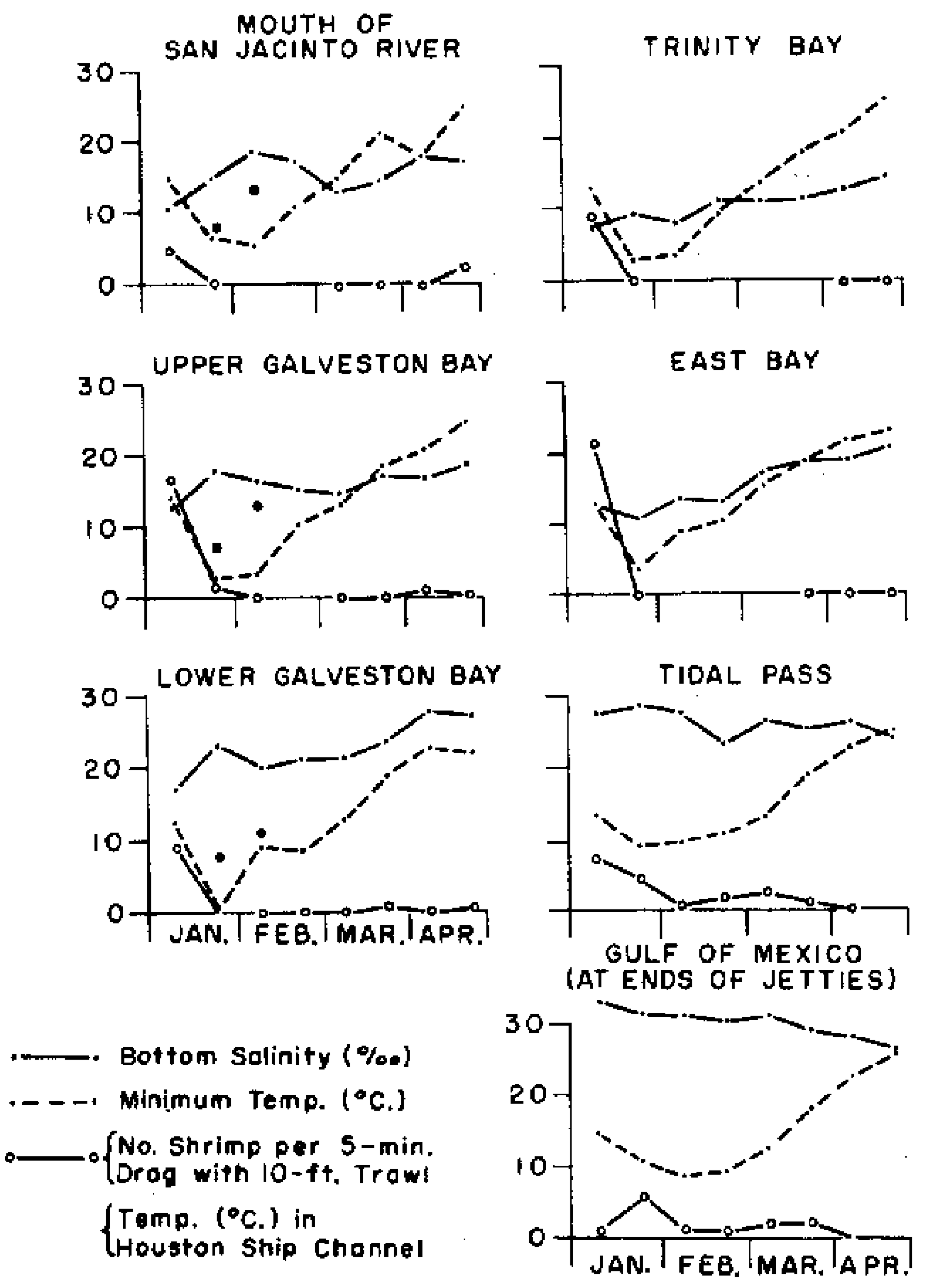
Map of Galveston Bay System showing subareas and location of sampling stations.

The hydrological section of the project involves participation in a cooperative field program with the U. S. Army Corps of Engineers and the Texas Water Pollution Control Board. We sample twice monthly for salinity, conductivity, and temperature at each of 68 stations, and for water currents at selected stations. A survey of bottom sediments and turbidity conditions is planned and will begin shortly. Corps of Engineers personnel sample for salinity, turbidity, and water currents. In addition, they also record water elevation and tidal stage continuously at 23 stations throughout the system and conduct a synoptic survey of vertical salinity distribution in the Houston Ship Channel. In cooperation with the U. S. Coast and Geodetic Survey, the Corps is also completing a hydrographic survey of the entire bay system. Additional information on the relationship between tributary inflow and salinity will be provided by study of the Galveston Bay model recently erected at the Corps' Waterways Experiment Station in Vicksburg, Miss.

The Texas Water Pollution Control Board is now planning an extensive survey of pollution in Galveston Bay and, insofar as it is deemed feasible to do so, will sample for water quality at our station locations.

By means of automated data-processing techniques, biological and hydrological measurements are tabulated separately for each station and sampling period, then combined within approximate units of space and time to reflect subarea and habitat totals on semimonthly, monthly, seasonal, and annual bases. Tabular data are then analyzed for areal and seasonal differences in (1) the physical environment; (2) the density, size composition, and growth rate of biological populations; and (3) the relationships between hydrological (abiotic) factors and various sample measures that indicate the status of biological populations.

Preliminary Findings Since the project was revised in January, some preliminary results have been obtained that are of interest. Examination of the first 4 months' data has revealed, for instance, that the Houston Ship Channel effectively separates the east and west portions of lower and upper Galveston Bay, as well as the area at the mouth of the San Jacinto River. Salinity differences as great as 7‰ occurred in open bay waters on each side of the channel. In addition, a well-defined salinity gradient, detectable under minimum and maximum salinity conditions, prevailed in the channel and open bay from the Gulf of Mexico to the head of Trinity Bay. Greatest variation in salinity occurred in Trinity Bay nearest the source of fresh water and in lower Galveston Bay nearest the source of salt water.



Temperature, salinity and sample catch of white shrimp in the Galveston Bay System, 1963.

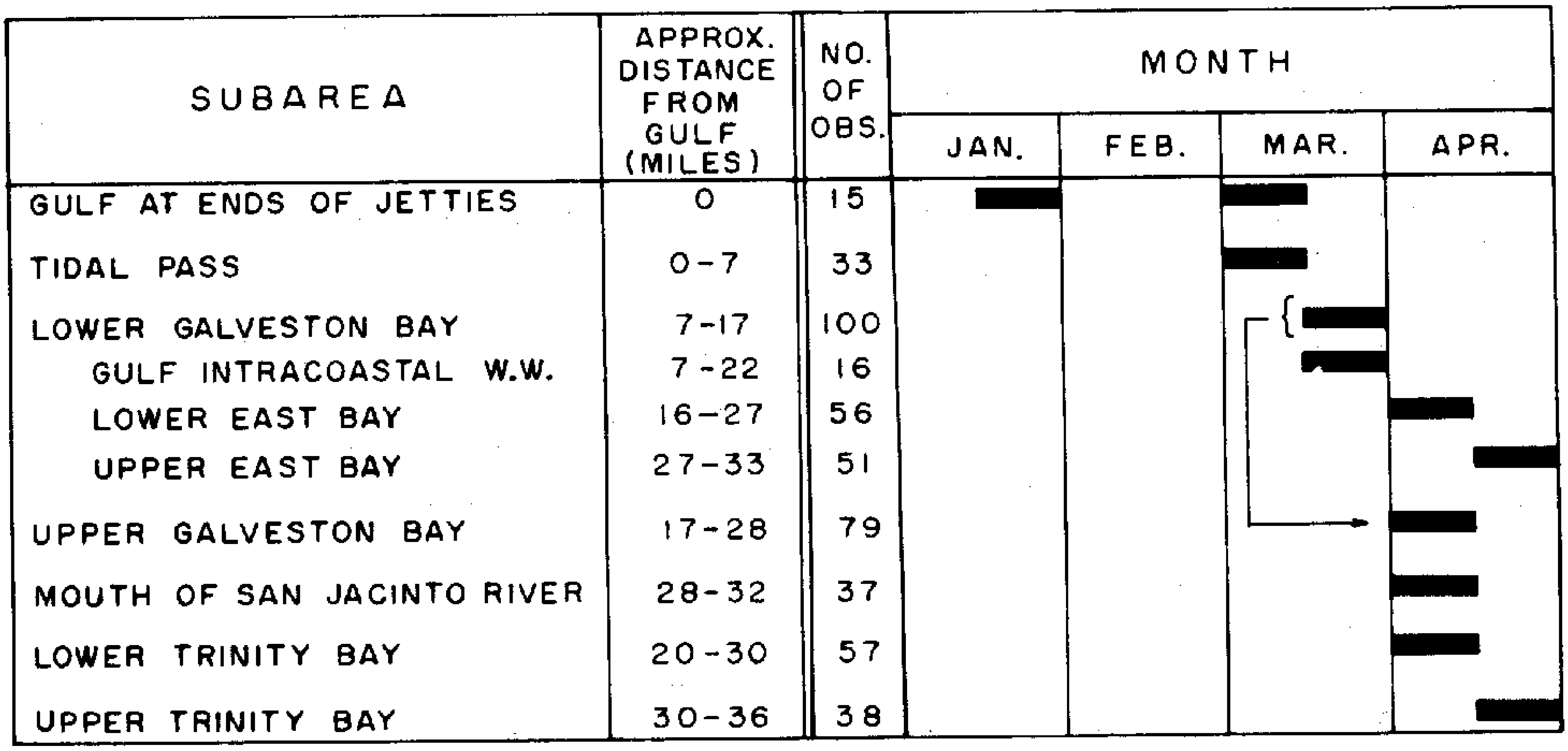
Small white shrimp averaging less than 3.0 g. were plentiful throughout the bay system until mid-January at which time a cold front moving across the area from the north caused a rapid drop in water temperature. Almost immediately we experienced a marked decline in the number of shrimp caught during sampling operations. (Refer to accompanying figure.) Prior to the "norther," the minimum bottom temperature ranged from 12° to 15° C. (54° to 59° F.). Shortly afterward, lows of 0.4° to 6.6° C. (33° to 44° F.) were recorded in the bay system, and 9.0° C. (48° F.) in the near-shore

Gulf and tidal pass. Temperatures did not drop as low (minimum about 7.0° C.) or later rise as slowly in the 40-ft.-deep Houston Ship Channel as they did in the surrounding waters of upper and lower Galveston Bay and of the area at the mouth of the San Jacinto River. Thereafter, the numbers of white shrimp in the bay declined until by early February none were being caught in East Bay, Trinity Bay, or at the mouth of the San Jacinto River. Very few were taken elsewhere in the bay system at this time and then only in areas close to the Houston Ship Channel. Small numbers continued to be caught in the tidal pass and near-shore Gulf where the water temperature remained somewhat higher.

The scarcity of small white shrimp in the bays following the return to higher temperatures in late February suggests that either a high mortality was suffered during the seige of cold weather, or that the population had moved with minimum loss to the Gulf at its onset. Probably the former event occurred, as shrimp captured in the bays during the period of minimum temperature were stunned and apparently dying. Had most of the population evacuated the bay system, such movement would have been reflected in increased sample catches in the constriction of the tidal pass and in the channel. The small increase in the sample catch from the Gulf near the ends of the jetties possibly resulted from shrimp leaving the area of the tidal pass and lower Houston Ship Channel. It is suggested that water temperatures as low as 9.0° C. decidedly affect the general physiology of these small white shrimp and that a sustained low of about 4.0° C. may be lethal.

Sorting sample catches of fish and invertebrates. Subsequent measurements will be used in study of estuarine ecology.

Additional speculation has arisen over the appearance of large white shrimp (larger than 30-count, many 10- to 12-count, heads-on) in Galveston Bay each spring. The question posed is: Do these large shrimp overwinter and continue their development in the estuary, or do they reenter the bay in the spring after having migrated to the Gulf during the previous winter? The accompanying figure indicates that the



First occurrence of white shrimp larger than 30-count (heads-on) in the Galveston Bay System, 1963.

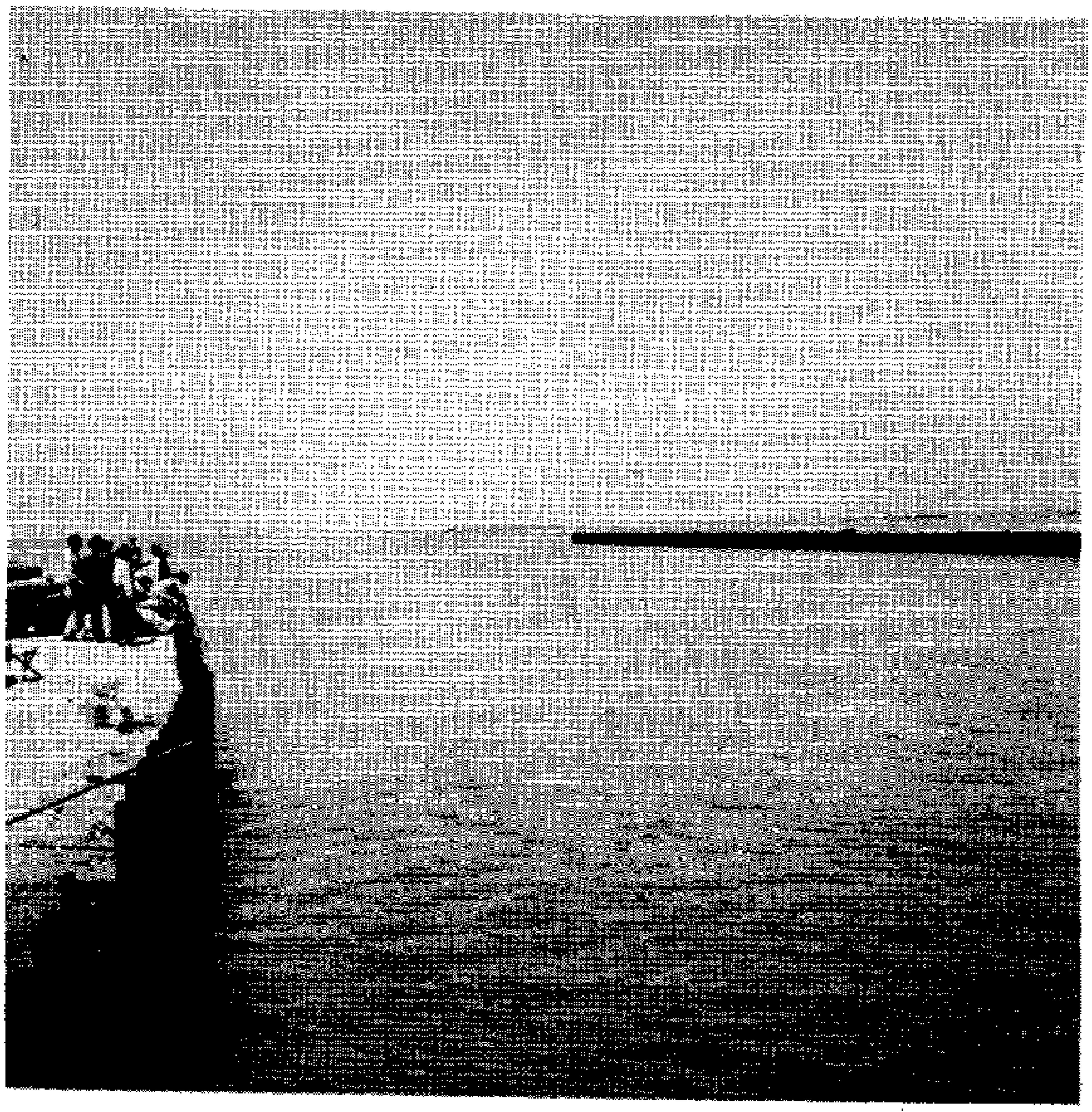
large shrimp in question reentered the bay system from the Gulf. Furthermore, after entering the tidal pass in early March, it apparently took them about 6 weeks to reach upper Trinity Bay and the northern part of East Bay, some 30 miles away. This represented a maximum "direct" movement of about 3/4 miles per day after they entered the estuary.

Charles R. Chapman, Acting
Project Leader
Jack C. Parker
Cornelius R. Mock
Robert D. Ringo
Edward J. Pullen
Anthony Inglis (Transferred
January 1963)
Charles H. Koski (Transferred
August 1962)

Effects of Engineering Projects on Estuaries

The value of estuaries as breeding, feeding, and nursery areas for many commercially important species of finfish and shellfish is well known to both the bay fisherman and to the professional biologist. This value is reflected, for example, in Texas fishery landings of which approximately 98 percent by weight consists of species in some way dependent on estuaries.

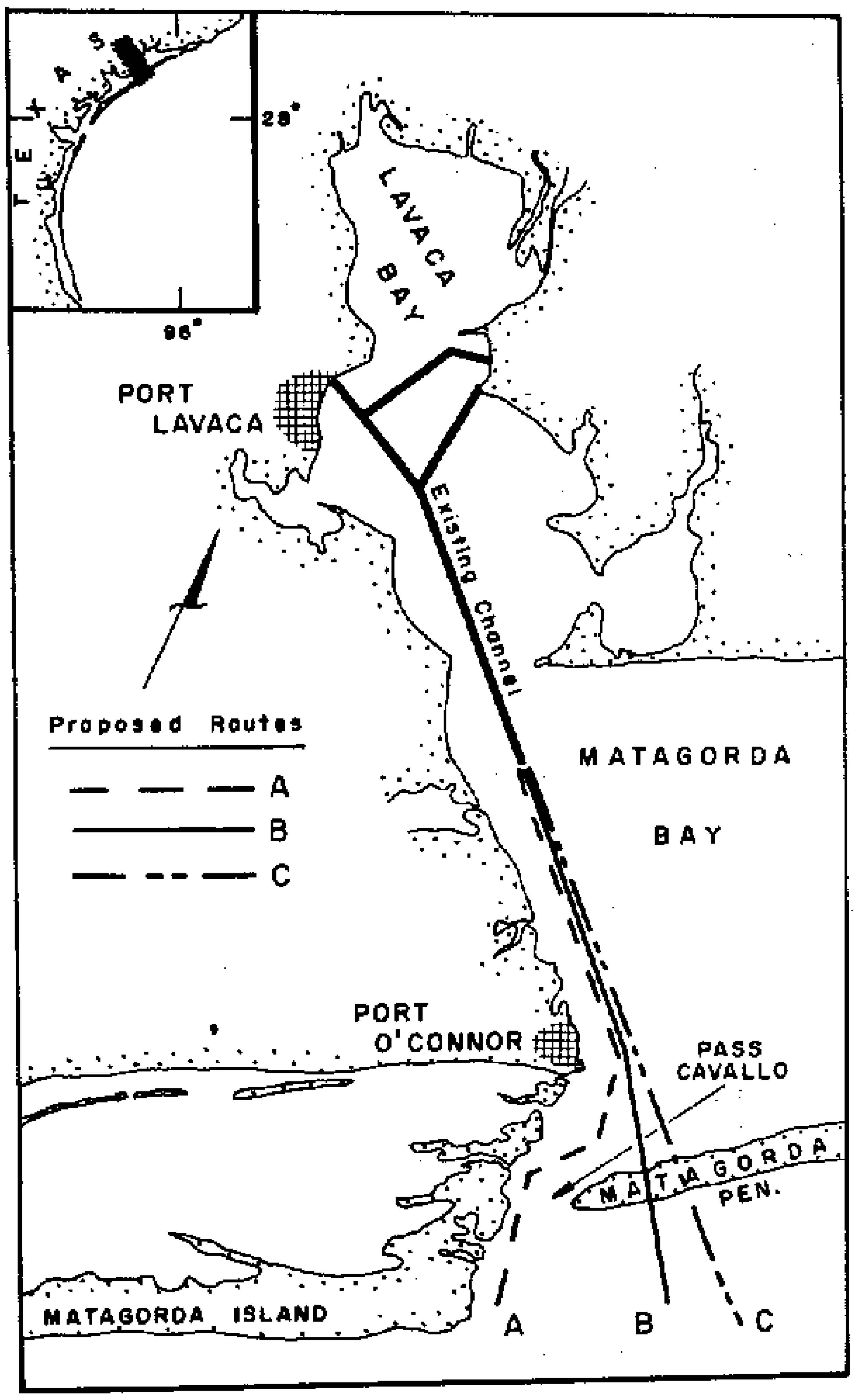
The estuary represents a habitat type known as an ecotone - a "buffer zone" or zone of transition - between the fresh water of river systems and the salt water of the sea. Such a habitat is characteristically a dynamic one, being readily susceptible to change through natural or artificial alterations of the controlling environment. Among the latter are alterations attributable to the many and varied forms of water-development and other projects, such as impoundments on rivers and streams, the draining of marshes, or channel construction and real estate developments in the estuaries themselves. The cumulative effects of these projects upon the estuaries and associated commercial fish production are likely to be extensive.



Rollover Pass, a man-made cut leading from the Gulf of Mexico into East Bay, Tex. This project is unique in that it was constructed as a fishery project to permit passage of fish between the two bodies of water. A major sport fishing site and harvest area was created.

Even though our present knowledge does not usually permit us to make accurate predictions of the effects of most of these and other types of projects upon the estuarine environment, several kinds of changes may be foreseen. One of the more obvious is the alteration of water circulation and interchange due to segmentation of estuaries and tributaries by channels and the resulting spoil banks. Moreover, considerable physical loss of habitat is often an additional consequence.

Matagorda Bay Project   Matagorda Bay in Texas is an excellent example of an estuarine system that is undergoing change through channelization. A deep-draft navigational channel is at the present time being dredged from the 38-ft. contour in the Gulf of Mexico to Port Lavaca on the western margin of Lavaca Bay. (See map.)



Map showing location of the deep-draft Matagorda Ship Channel and the three proposed routes (route "C" was selected). Spoil from projects such as this interferes with water circulation needed to maintain suitable habitat in estuaries.

This development was an outgrowth of an original Corps of Engineers proposal to carry out maintenance dredging in the shallow-draft channel running from Port Lavaca to the 10-ft. contour in Matagorda Bay.

Before construction of the channel began, the Corps of Engineers built a model at its Waterways Experiment Station in Vicksburg, Miss., to determine: (1) the best location for the entrance channel; (2) the best route from the entrance to Port Lavaca; (3) such protective works as may be required in the interests of navigation and channel maintenance; and (4) the effects of the deep-draft channel on the salinity regimen of the bay system. Of the four criteria, the last is believed to be the most important from the standpoint of maintaining suitable estuarine habitat. Increased salinity within an estuarine system, such as Matagorda Bay, could restrict some fish and shellfish species from portions of the bay they previously used, while others would be occluded from the system altogether.

On the basis of data obtained from field and model studies, the channel will be dredged through Matagorda Peninsula at a point approximately 4 miles northeast of Pass Cavallo. To determine means of reducing water velocities, subsequent studies were made on spoil-mound arrangements on the bay side of the peninsula.

When data from the field were compared with those from the model, it was noted that rises in salinity of varying degree would be experienced in most parts of the bay system. These rises may be attributed to increased salt-water intrusion from the Gulf through both the deep channel and the added opening. Accordingly, the Bureau of Commercial Fisheries recommended that, if post-construction field surveys showed that salinity increases were of a magnitude to be harmful to fishery resources, a cooperative study should be conducted jointly by the Fish and Wildlife Service and the Corps of Engineers to determine the most practical means for correcting such adverse project effects.

<u>Texas Basins Project</u> The Texas Basins Project, which includes upland reservoirs and a large diversion canal, would modify tributary inflow into all estuarine systems of Texas except the Laguna Madre. Future development of the southern and western, arid and semiarid regions of the State depends upon the availability of additional fresh water. To satisfy this need, the project proposes to divert water from the rivers of eastern Texas.

Diverted waters would consist of "surplus" tributary inflow that remained after projected withdrawal requirements by residential, industrial, and irrigation interests in eastern Texas had been met. Diversion of this so-called surplus water would, however, deprive the estuarine habitat of river discharge that is necessary for its maintenance as a proper environment for the development of commercial and sport fishery resources. Adequate discharge for this purpose, and perhaps for pollution abatement as well, would probably be available only during years of excessive rainfall.

In view of the heavy existing and projected demands upon the water resources of the State of Texas, this project is expected to compound an already critical problem. Unless means can be found to provide sufficient fresh water for the estuaries to alleviate the critical situation that is anticipated, particularly during dry periods, estuarine fishery resources will very likely decline in the future. Perhaps the Texas Basins Project can supply a part of the needed water.

Other Projects and Problems In addition to large-scale diversion projects, fresh-water discharges into the estuaries can also be reduced through greater consumptive water usage and through increased total evaporation due to greater exposed surface areas in reservoirs and irrigation canals. Reduced fresh-water discharge may alter the suitability of estuarine areas by causing a rise in their salinity; by varying water interchange patterns; by draining surrounding marsh areas through the lowering of river levels; by altering silt deposition through reduced silt loads; and by reducing influx of nutrient materials required for maintaining productivity.

Runoff from high ground carries nutrients essential in the marsh and estuarine web of life.

Increased amounts of pesticides and other forms of pollutants from expanding agricultural and industrial interests may be expected to enter the estuaries in waste waters and runoff. Our expanding economy is encouraging the construction of numerous small navigation channels, the increased development of mineral resources, and miscellaneous commercial, real estate, and highway projects which may alter in varying degree the suitability of estuaries as habitat for fishes, molluscs, and crustaceans. These projects frequently require modification to minimize possible damage to the estuarine habitat and its biota.

When this becomes necessary, recommendations for corrective action are sent to the Branch of River Basin Studies (U. S. Fish and Wildlife Service) which, in turn, with the concurrence of the Texas Parks and Wildlife Department, requests the Corps of Engineers to require private applicants to modify the original plans. When oyster leases or extremely valuable estuarine habitat are endangered, the Corps of Engineers is requested to have the applicant secure the approval of the Texas Parks and Wildlife Department before initiating work on the project. General construction projects, a term including such items as small fills, wharf construction, bridge construction, etc., generally have minimum effects upon estuarine organisms. Recognizing the above problems, program personnel during the past year and under the present system of coordination with Federal and State conservation agencies made 136 appraisals of engineering projects potentially affecting estuarine habitats. Of this number, all but one involved Texas estuarine waters. The majority of these resulted from the more than 370 Corps of Engineers public notices and letters received during the year and screened to determine which projects would materially affect the estuarine environment. Sections of 57 Bureau of Sport Fisheries and Wildlife draft reports pertaining to this environment were also reviewed.

With the increasing number and complexity of engineering projects that require our evaluation and as our biological knowledge improves, it is becoming progressively more difficult to evaluate properly each project with the thoroughness required. If we are to keep pace with the exploding development in the estuaries, considerably more effort must be expended.

Richard A. Diener, Project Leader
Charles H. Koski (Transferred August 1962)

PHYSIOLOGY AND BEHAVIOR PROGRAM

David V. Aldrich, Program Leader

This program has continued to focus attention on the effects of experimentally controlled environmental factors on postlarval and juvenile shrimp. Work has been greatly augmented by the acquisition of additional laboratory space and four controlled-temperature rooms. The temperature rooms have ranges of 30°-60°, 50°-80°, 60°-90°, and 75°-105° F., respectively, and include a built-in, compressed-air system which provides aeration for large numbers of experimental animals. These facilities have for the first time made possible important studies on the influence of temperature on the growth, survival, and behavior of small commercial shrimp.

Results of a large-scale experiment designed to evaluate the effects of salinity and temperature on growth of postlarval "grooved" shrimp show that temperature can be much more effective than salinity in controlling growth. It is noteworthy that the ranges of temperature and salinity tested are similar to the naturally occuring ranges of these factors for shimp in the Galveston area.

Further evidence of differences between salinity and temperature effects on postlarval shrimp has been obtained from behavior experiments in which an animal's movements within a salinity or temperature gradient were observed. Although identical apparatus is used to contain either type of gradient, the shrimp are able to avoid lethal salinity levels but unable to avoid lethal low temperatures.

The new controlled-temperature rooms have also made it possible to begin studies on the effect of temperature on the molting frequency, general activity, and behavior of shrimp in salinity gradients. The results suggest that temperature is quite important in a variety of the biological activities of shrimp.

Tolerances Using the four new controlled-temperature rooms and three smaller incubators, we conducted the first large-scale study of the combined influence of salinity and temperature on the survival of postlarval "grooved" shrimp. Seven levels of temperature, 3°, 5°, 13°, 21°, 30°, 35°, and 43° C., (37°, 41°, 55°, 70°, 86°, 95°, and 109° F., respectively) and eight levels of salinity, 2‰, 5‰, 10‰, 18‰, 25‰, 35‰, 40‰, and 45‰, were tested in the 56 possible combinations. Each two-factor combination was evaluated in terms of the survival of 30 postlarvae exposed to the experimental condition for 24 hours. Each of the 1,680 experimental shrimp was enclosed in a small cage which prevented the animal from jumping out of the water or becoming a victim of cannibalism. The shrimp were introduced directly into the experimental salinity-temperature conditions without prior acclimation.

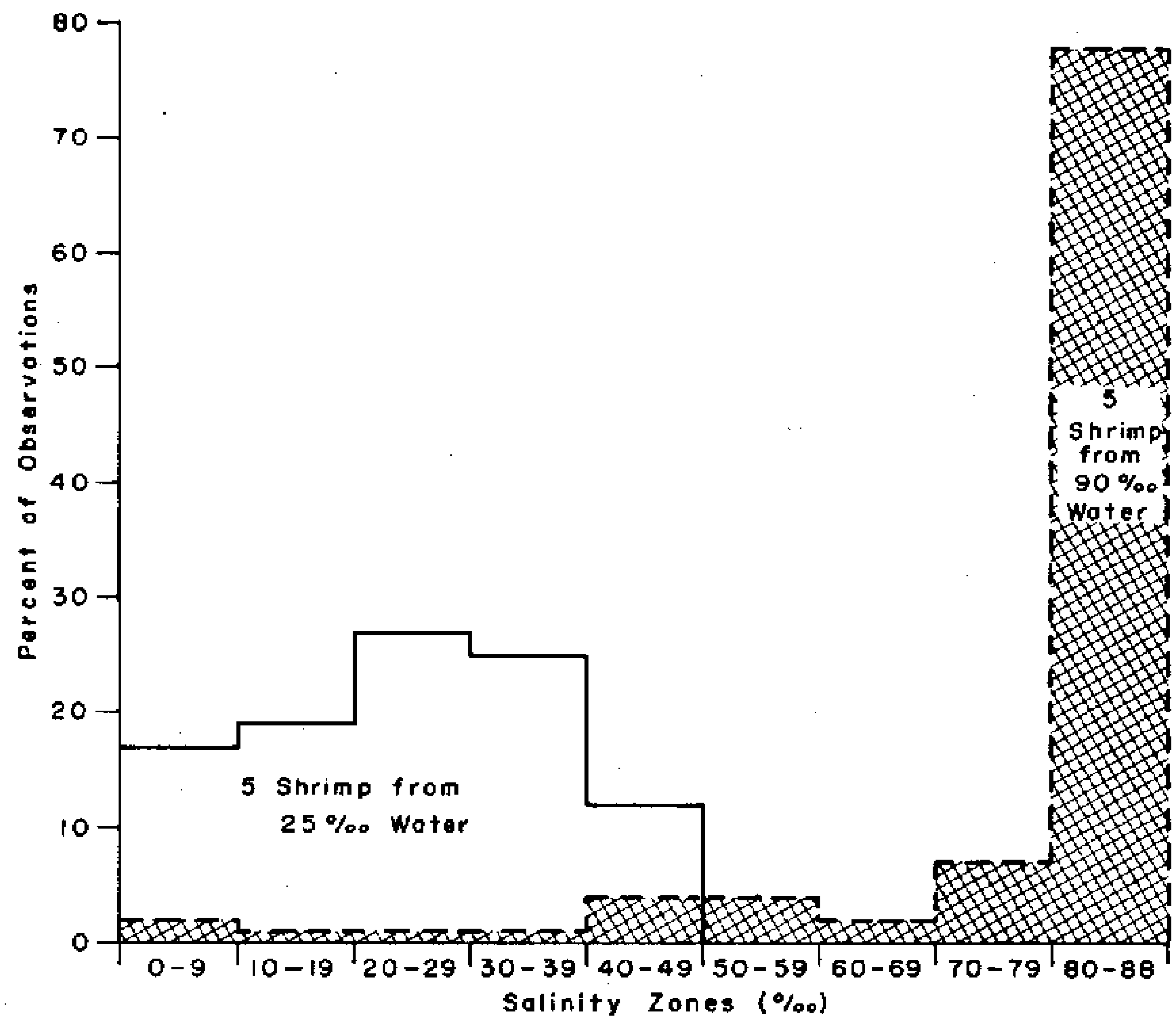
The results of this study, which demonstrated no survival at 3° or 43° C. regardless of salinity, support and extend those of our previous work. The overall range of salinity-temperature conditions in which 100 percent survival was obtained proved somewhat narrower than that observed in past studies. Three subsequent experiments served to recheck a number of the "critical" temperature-salinity combinations (those which gave survival rates greater than 0 and less than 100 percent). The results of these tests showed good intertest agreement and demonstrated the importance of two factors in survival assays: aeration at elevated temperatures and acclimation to extreme conditions. These two factors account for the difference in results between the large-scale experiment described above and previous work.

Results of a 24-hour survival study strongly support our previously reported suggestion that small juvenile brown shrimp ($1-1\frac{1}{2}$ in. total length) can tolerate considerable changes in temperature and salinity. Each of three groups of shrimp, grown at 77° F. from postlarval to juvenile size in salinities of 5‰, 25‰, and 40‰, respectively, was subdivided into nine equal groups which were exposed to 12°, 25°, or 34° C. (54°, 77°, or 93° F., respectively) and 5‰, 28‰, or 39‰ in all nine possible combinations. The overall survival was excellent (95 percent). Nearly all of the 5 percent mortality occurred in the group grown at 5‰ and exposed to 39‰ at 12° C. The high level of survival in this experiment becomes even more striking when we note that the temperature and salinity changes were immediate, providing the animals no opportunity for gradual acclimation.

Behavior During the year, a new conductivity cell was designed, constructed, and tested for use in measuring experimental salinity gradients.

Commercial conductivity cells tested earlier proved much less satisfactory due to their large size and closed construction. The new equipment fills our need for an instrument which measures conductivity at precise locations within a salinity gradient.

Using this equipment, an experiment was conducted to determine whether the previous salinity history of juvenile shrimp influences subsequent behavior in a continuous salinity gradient. Five shrimp held at 25‰ were introduced into a salinity gradient (4‰ - 88‰) together with five shrimp held at 90‰ (near the absolute limiting level for this animal). Observations made over a $1\frac{1}{2}$-hr. period at a uniform temperature showed a marked degree of difference between the salinity ranges of the two groups of animals. (See figure.) These results indicate a definite short-term influence of salinity history on



Influence of salinity history on distribution of postlarval grooved shrimp in a salinity gradient.

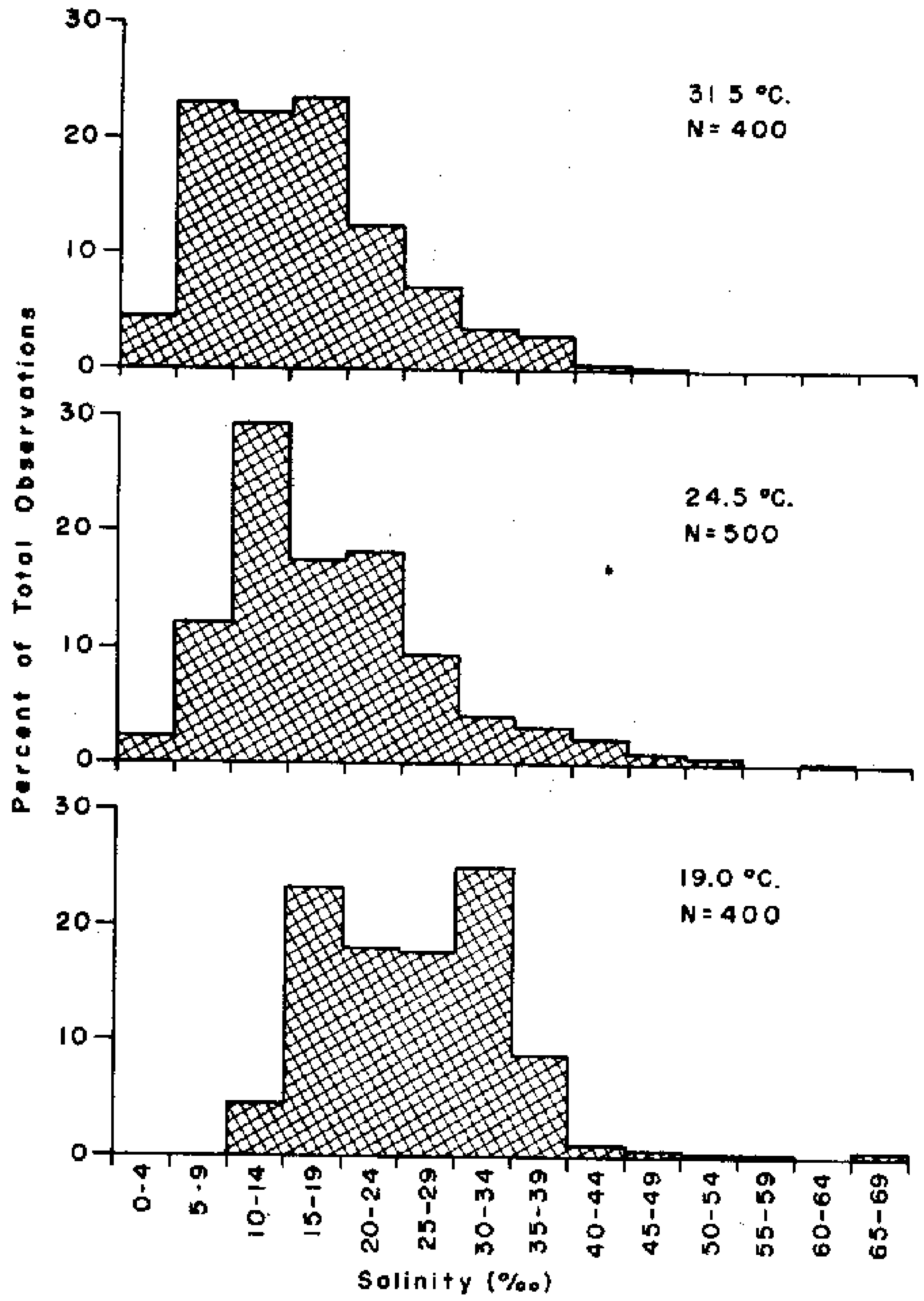
the salinity range subsequently selected and suggest that the capacity for salinity conditioning we previously reported for postlarval shrimp is also possessed by the juvenile. They also serve to emphasize that the salinity-preference range for young shrimp is not only broad, but flexible. Such characteristics would seem to be of great importance to shrimp during the estuarine phase of the life cycle.

The acquisition of automatic temperature recording equipment has made it possible to study the behavior of small shrimp in vertical temperature gradients. Although the experimental apparatus employed was identical to that used in testing shrimp responses to salinity gradients (previously reported), the results obtained were strikingly different. Whereas shrimp demonstrated a marked behavioral response to salinity gradients (avoiding salinities above 35‰), most of these animals have been found to be incapable of avoiding lethal low temperatures in temperature gradients. Thus, 32 of 37 shrimp tested became immobilized through cold narcosis before the end of the 25-min. observation period. These findings show that in a comparable apparatus the animals reacted to avoid unfavorable salinity levels but were unable to avoid incapacitating temperature levels.

Effects of temperature on postlarval shrimp have also been examined further. Each of 3 groups of 12 postlarvae (all 36 from the same field collection) was acclimated to and held at 19.0°, 24.5°, or 31.5° C. (66°, 76°, or 89° F., respectively) in a salinity of 25‰ - 26‰. The shrimp were checked twice daily for molting, and animals between molts were selected for studies of behavior in vertical salinity gradients. In the controlled-temperature rooms, each gradient was set up and maintained at the temperature at which the shrimp to be tested had been held. In this manner, four animals from each temperature group were individually studied in salinity gradients.

To date, the results of this work with shrimp have provided evidence of temperature effects on three distinct types of biological activity: (1) molting frequency, (2) gross activity, and (3) salinity selection in experimental gradients. The molting frequency at 19.0° was scarcely more than half that observed at 24.5° C. (5.2 vs. 2.8 days per molt, respectively). This information clearly ties in with results of the temperature-growth experiments discussed in the following report. The molting data for the 31.5° C. group proved unreliable, because the shrimp frequently molted and ate the shed exuviae between the twice-a-day checks. More frequent checks will have to be instituted to obtain this kind of evidence at elevated temperatures. Gross-activity estimates were based on the rate of vertical movement of shrimp in salinity gradients. Shrimp at 31.5° C. traveled twice as far per unit of time as shrimp at the lower temperatures.

Comparison of frequency distributions of the three temperature groups in salinity gradients suggested a definite pattern. Shrimp at 31.5° C. showed the lowest salinity distribution of the three groups while the animals tested at 19.0° had the highest salinity distribution.



Influence of temperature on the distribution of postlarval grooved shrimp in salinity gradients.

(See figure.) If this pattern can be supported with data from more animals, it will provide evidence of what may be an ecologically important behavioral mechanism in shrimp -- a pattern of temperature-salinity selection by which the animal would tend to avoid osmotic situations involving serious physiological stresses at a given temperature. Further work will investigate this possibility.

David V. Aldrich, Project Leader

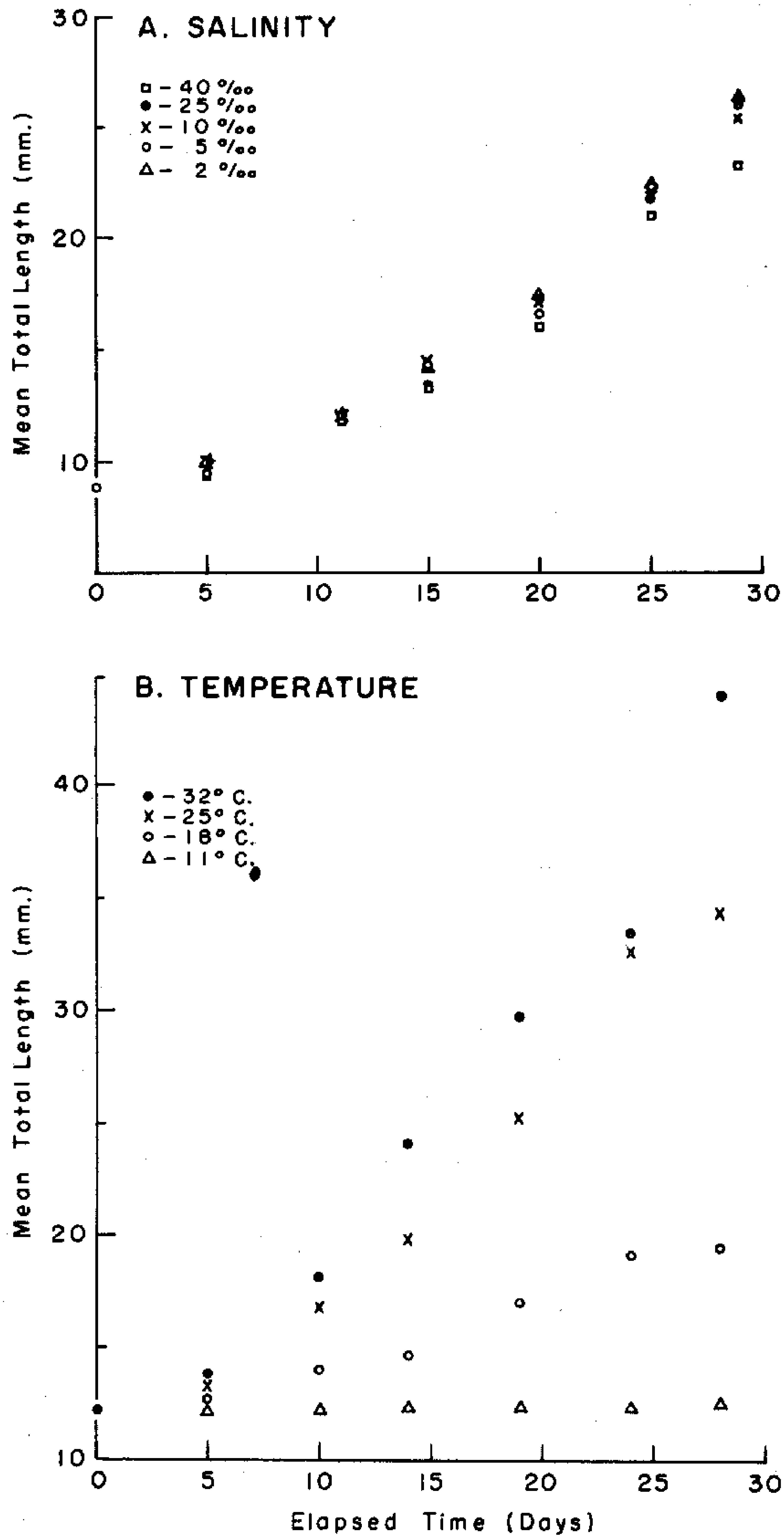
Growth and Metabolism

During the past year, several experiments with young shrimp were conducted using growth as a sensitive indicator of the suitability of controlled environments. The initial series tested the effects of salinity alone on growth of postlarval shrimp, both "grooved" and white. As indicated in the accompanying figure (next page), variation in salinity over the wide range of 2‰ to 40‰ had little effect on the growth rate of postlarvae held for approximately 30 days at 25° C. (77° F.). These experiments indicated that under the relatively restricted conditions of temperature and feeding imposed, salinity *per se* was not an important limiting factor in the growth of postlarval penaeids.

In March of this year, a large-scale growth experiment was initiated to test the effects of salinity at various temperatures. Five levels of salinity (2‰, 5‰, 15‰, 25‰, and 35‰) were used at each of four temperatures, 11°, 18°, 25°, and 32° C. (52°, 65°, 77°, and 90° F., respectively). Differences in growth associated with temperature were dramatically greater than those related to salinity. (See figures next page.) Essentially, no growth occurred at 11° C., while animals held at 32° C. increased slightly more than 1.0 mm. per day during the 28 days of the experiment, and those at 25° C. increased approximately 0.8 mm. per day during the same period.

Growth of individuals in experiments conducted this year has exceeded the growth observed at the same temperature and salinity last year. (Compare A and B in figure next page.) At 25° C. and 25‰ in 1963, the largest postlarva quadrupled its length and increased its weight hundredfold (12.1 mm. and 6.7 mg. to 46.5 mm. and 681.1 mg.) in 28 days. In 1961, at the same temperature and salinity, the greatest growth of an individual was only threefold in terms of length and sixtyfold in terms of weight (10.4 mm. and 4.5 mg. to 34.0 mm. and 262.8 mg.) over a 29-day period. Much of this increased growth must be attributed to the development of a better means of providing food. Although all experimental animals had been fed live brine shrimp nauplii as the exclusive diet, recently improved rearing techniques have made larger amounts of such food immediately available.

The variation in amount of food required by experimental animals was markedly related to temperature. Animals at 32° C. were still without food at times, even though they were given more than 100 times the amount of food provided those animals at 11° C. When the experiment was terminated, postlarvae at 32° C. were 60 times heavier than those at 11° C. Undoubtedly, most of the food was required for growth itself, but some food must also have been used to supply energy



Comparison of salinity and temperature effects on growth of small grooved shrimp.

for the increased activity observable at the higher temperature. These data serve to reemphasize the importance of an adequate food supply for rapidly growing young, and may indicate the ultimate value of the estuary as a place which can provide the vast amounts of food required for postlarval shrimp to develop quickly into juveniles and subadults before returning to the open sea.

It is of some interest that almost all animals survived for 28 days at 11° C. at salinity levels of 15‰ or above. At the two lowest levels, however, all animals died before completion of the experiment. At the intermediate temperatures of 18° and 25° C., almost 100 percent survival occurred at all salinity levels with the exception of those at 2‰. At 32° C., however, survival rate was considerably decreased at all levels except that of 35‰. At this high temperature, survival was apparently decreased both by stresses during acclimation and probably by cannibalism. These experiments further indicate the wide salinity tolerances exhibited by postlarvae and emphasize the important roles played by food supply and temperature, both in the growth and behavior of young shrimp.

The growth of individual postlarvae rather than of groups has also been studied during the past year, both with respect to the frequency of molting and to actual size attained. A group of 40 juvenile white shrimp, previously held in the laboratory for studies on molting frequency, was transferred to the recirculating estuarine-water system during the winter. Each individual was measured biweekly (total length from tip of rostrum to end of tail) and held in a $2\frac{1}{2}$-gal. aquarium with water supplied by the system. All experimental animals were fed ground shrimp and fish. During the 3 mo. of the experiment, little or no growth was observed for the 20 animals surviving the initial transfer. Temperatures during the period ranged from 11° to 18° C. In the spring of this year, the experiment was repeated using postlarval grooved shrimp. Temperatures at this time were 25° C. or above. During the first 30 days of the experiment, each of 22 surviving animals showed some growth, which ranged from 3.5 to 9.5 mm. Although growth rate was below that found for isolated postlarvae fed brine shrimp in the laboratory, these experiments further illustrate the effect of temperature upon the growth of postlarvae and juvenile shrimp.

Other growth experiments included a series to test the influence of the number of postlarvae per container upon growth rate. Standard 20-gal. aquaria were stocked with 25, 50, 100, or 200 postlarvae. The 30-day experiment indicated that best growth occurred with 50 animals, while growth rate decreased with either fewer or more animals. Food (brine shrimp nauplii) was provided in proportion to the number and size of animals. An increase in the number of animals above 50 per aquarium probably caused reduced growth because of crowding, whereas shrimp in aquaria of only 25 animals may have had to exert more effort to obtain food because of the relatively low density of the food supply.

Also undertaken during the year were other types of studies, the results of which will be given in later reports. This work included preliminary analyses of the pigments in the two common species of shrimp, further experiments with anesthetics for use in metabolism studies of shrimp, and preliminary studies of the types of amino acids present in the two species of shrimp.

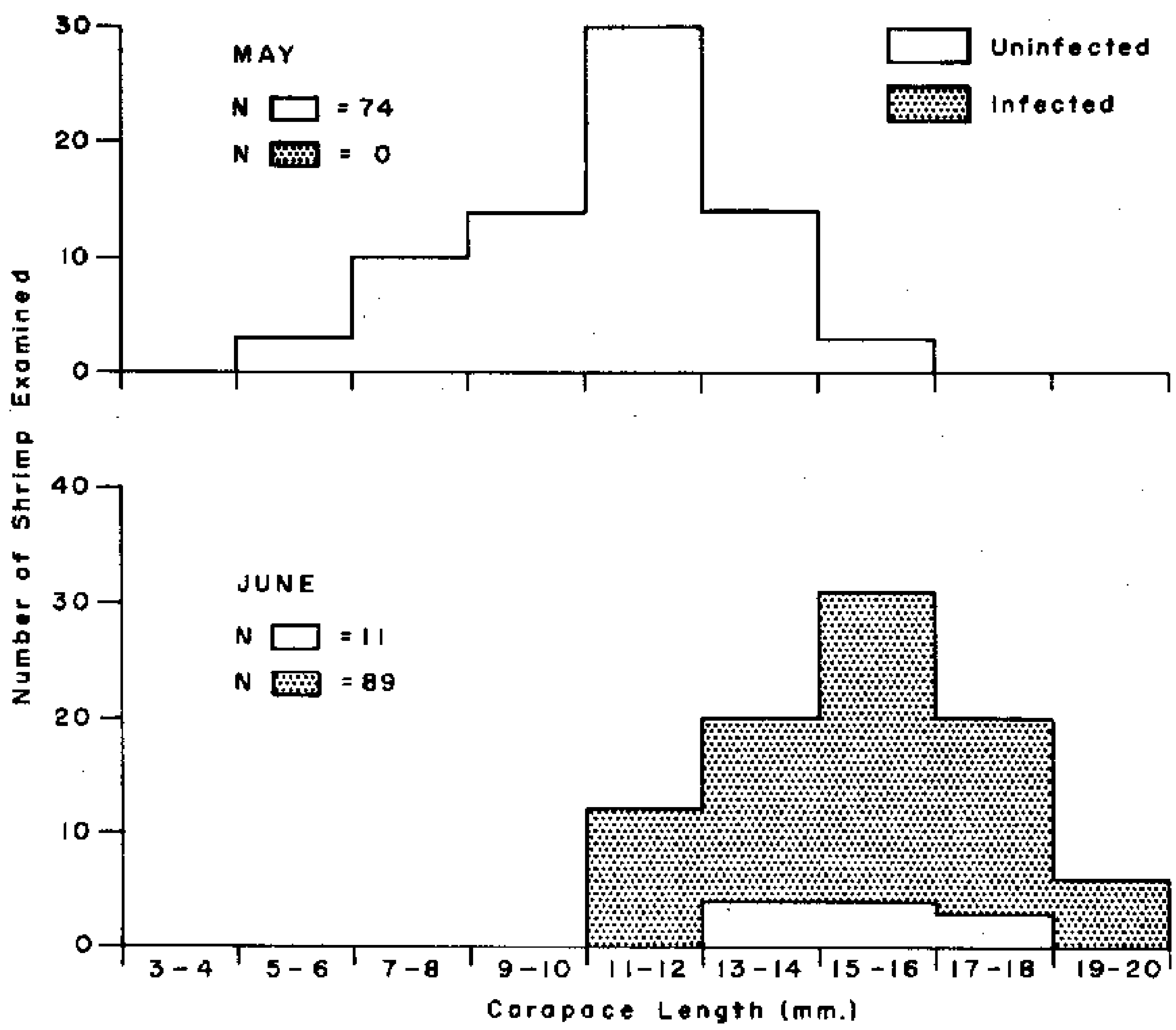
Zoula P. Zein-Eldin, Project Leader

Incidence and Potential Significance of *Prochristianella penaei*, A Cestode Parasite of Commercial Shrimp in Galveston Bay

David V. Aldrich

In 1959, routine examination of animals collected in Galveston Bay by the Estuarine Program revealed the presence of a small (1 mm. in diameter) white cystlike body in the hepatopancreas of juvenile brown shrimp, *Penaeus aztecus*. Detailed microscopic examination later proved the cyst to be an immature tapeworm of the order Trypanorhyncha, a group in which the adult stages are found only in the gut of elasmobranch fishes (sharks and rays), where they attach themselves by means of characteristic tentacles studded with hooks. Subsequently, several samples of shrimp were examined to determine whether this worm is a frequent parasite of commercial shrimp in the Galveston area. Individual shrimp were autopsied, the hepatopancreas being dissected into a petri dish and checked for parasites under a dissecting microscope. Results showed that approximately one of every two shrimp were infected, with the number of worms per individual host occasionally exceeding 20.

These positive results prompted a closer systematic look at monthly or semimonthly shrimp collections from Clear Lake, a secondary bay in the Galveston Bay system. An interesting pattern showed up in the May and June samples for both sampling years, 1960 and 1961. (See figure.) The first brown shrimp juveniles of the spring



Incidence of the parasite *Prochristianella penaei*, in brown shrimp from Clear Lake.

were found to be 100 percent uninfected in early May but only 11 percent of those collected 1 mo. later were free of tapeworms. Comparison of the size-frequency distributions of shrimp in these samples suggests that the same population was represented during the 2-mo. period. If the same population did occupy the Clear Lake area during the May-June sampling period, it is probable that the worm infection originated in the sampling area. It is rarely possible to localize geographically the source of parasitic infections in natural populations of such transient aquatic animals as the brown shrimp. Continued sampling and examination showed that the white shrimp, P. setiferus, is also quite susceptible to infection with this worm. However, fluctuations of size-frequency distributions and infection incidence from sample to sample were more irregular than those for brown shrimp in the spring.

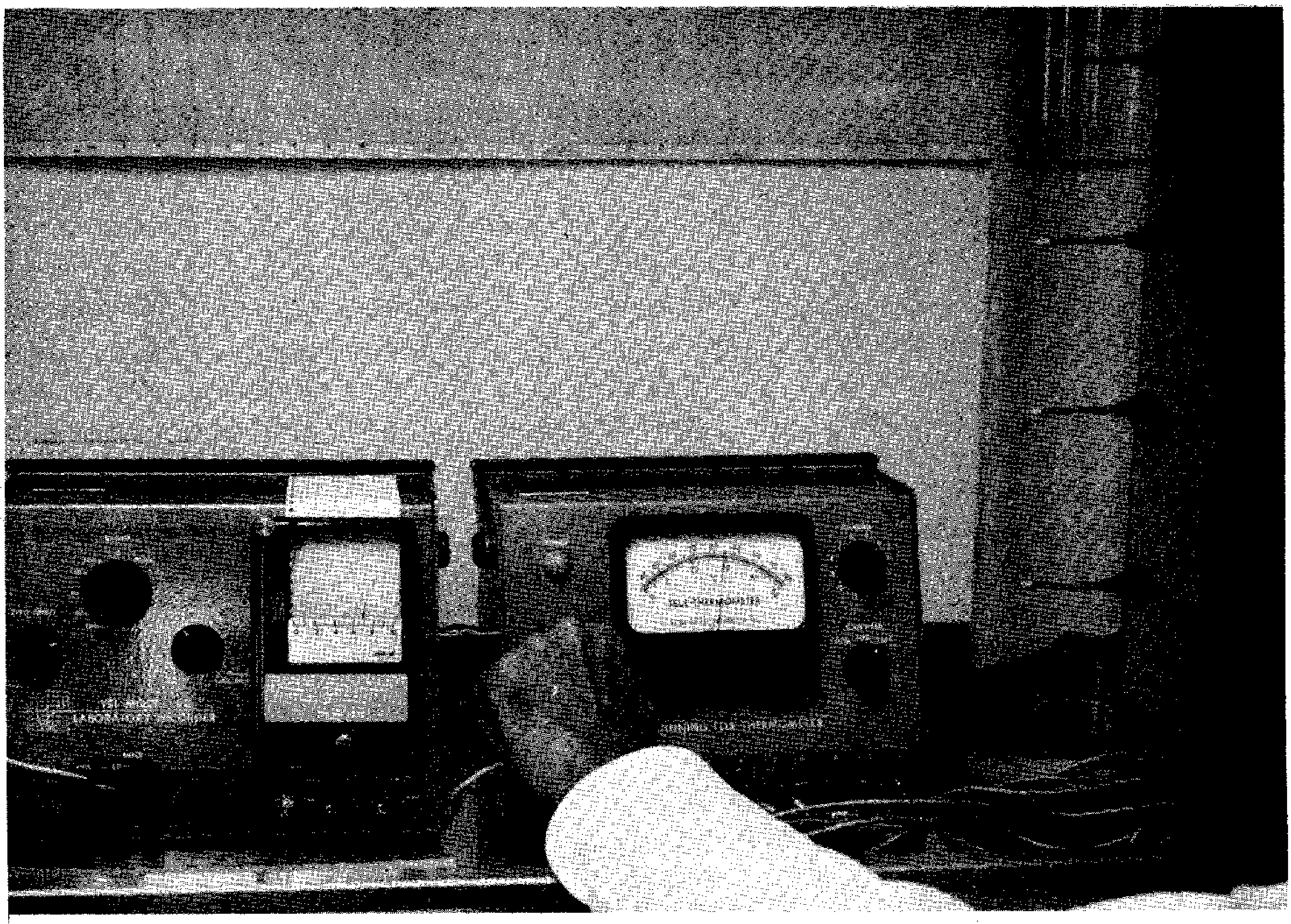
The incidence-of-infection figures provide interesting evidence of the frequency with which this cestode was encountered. Of 920 Clear Lake shrimp (including both the brown and white species) examined in 1960 and 1961, 450 (49 percent) were infected with Prochristianella penaei. During the same period, of 467 shrimp examined from Offatts Bayou, another portion of the Galveston Bay system, 252 (54 percent) were positive. It is clear that this tapeworm is a frequent parasite of white and brown shrimp in the Galveston Bay area.

Much of the potential significance of this parasite stems from the complex life cycle characteristic of this order of tapeworms. The life cycle of trypanorhynchs is thought to consist of egg, coracidium larva, procercoid larva, plerocercus larva, and adult. Each of the two larval stages is associated with its own distinct intermediate host, and infection of each host is achieved by eating the previous worm stage. Thus the adult worm can only develop in a final host which has eaten an infected second intermediate host (in this instance the shrimp) which, in turn, has eaten an infected first intermediate host. The latter becomes infected by ingesting the larva, which hatches from eggs released into the water with the final host's feces.

Although the life cycle of any parasite is of obvious interest to the parasitologist, the particularly complex life cycle which seems to characterize trypanorhynch tapeworms is also important to those who have an interest in any or all of the worm's three hosts, and their interrelationships. This is especially true in regard to the second intermediate host, because knowledge of its food habits and its predators will be provided as the worm's life cycle is defined. Since the tapeworm found in Galveston Bay shrimp is in its second intermediate stage and occurs very frequently, it is probable that the host for the first intermediate stage is an important natural food item for shrimp. In view of the present lack of information on the food habits of shrimp, efforts to find the first intermediate host of *Prochristianella penaei* could yield results of considerable interest to the shrimp biologist as well as to the parasitologist.

Depending on the species involved, intensity of infection, and the condition of the host, the gross effects of worm parasites on hosts may vary from none to extremely pathogenic. The possible effects of this parasite on host shrimp remain to be investigated.

The potential use of *Prochristianella penaei* as a biological tag to trace shrimp movements, growth, and mortality is yet another very important consideration. The utility of this approach would depend on (1) the duration of the infection in shrimp (which might be determined as part of life cycle studies), (2) the degree of pathogenicity associated with this infection, and (3) whether significant differences in incidence of infection could be associated with shrimp from various estuarine and offshore areas.



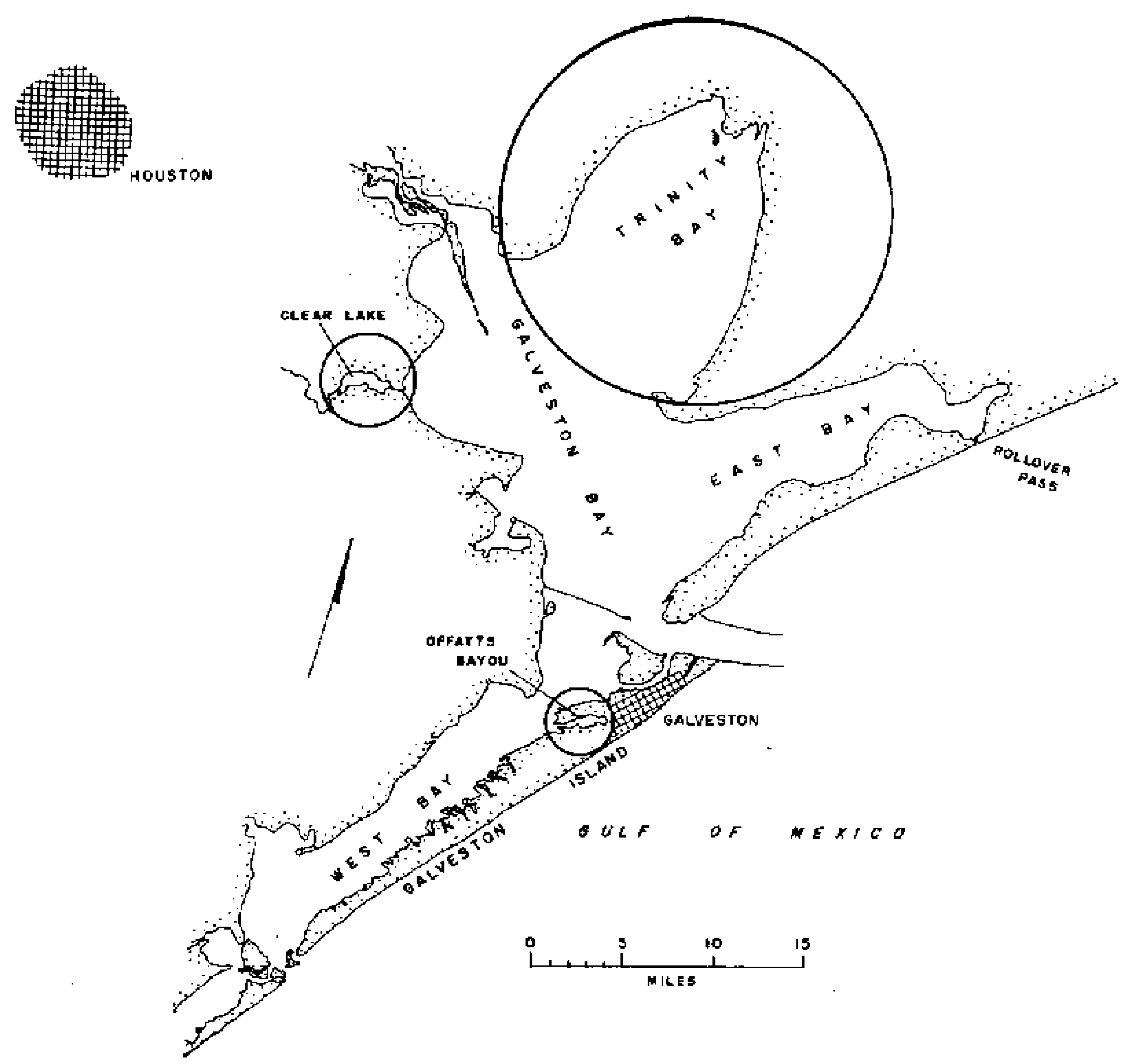
Checking experimental temperature gradient.

Biological Comparison of Trinity Bay and Clear Lake, Two Subdivisions of the Galveston Bay System - 1961

Charles R. Chapman

For a variety of reasons, construction projects are frequently more numerous in the readily accessible areas of estuarine complexes than in the remote, hard-to-reach sections. Also, their effects are more immediately apparent in small confined areas than in large expanses. Because of the differing situations under which these projects are developed, it is highly desirable, when forecasting a project's probable effects, to have for each estuarine subarea an index of its relative importance and contribution in terms of fish and wildlife resources. Such information becomes particularly valuable when preconstruction modification of project plans is deemed necessary to reduce or prevent anticipated damage to these resources. A relatively greater mitigation cost, i. e., the cost of modifying project plans or features to benefit fish and wildlife resources, can thereby be justified in situations involving the more valuable habitat in a given estuarine system.

Early studies by the Estuarine Program to determine the relative importance of well-defined areal units comprising the Galveston Bay system in terms of their capacity to sustain fish and shellfish resources during early stages of development, were restricted to two small areas, namely, Offatts Bayou and Clear Lake. A larger area, Trinity Bay, was later included. (See map.) Last year's Annual Report presented



Map of the Galveston Bay system showing Offatts Bayou, Clear Lake, and Trinity Bay.

a brief descriptive comparison of the lightly saline Clear Lake and the higher salinity waters of Offatts Bayou. Although biological sampling with a 10-ft. trawl net showed more species to be present in Offatts Bayou, Clear Lake yielded about four times as many individuals with the same expenditure of effort. Only a small fish, the spot, Leiostomus xanthurus, was consistently more numerous in Offatts Bayou. Further tabulation and analysis of prior data now permit preliminary comparison of biological populations in the limited, protected waters of Clear Lake with those inhabiting the expansive, unprotected waters of Trinity Bay.

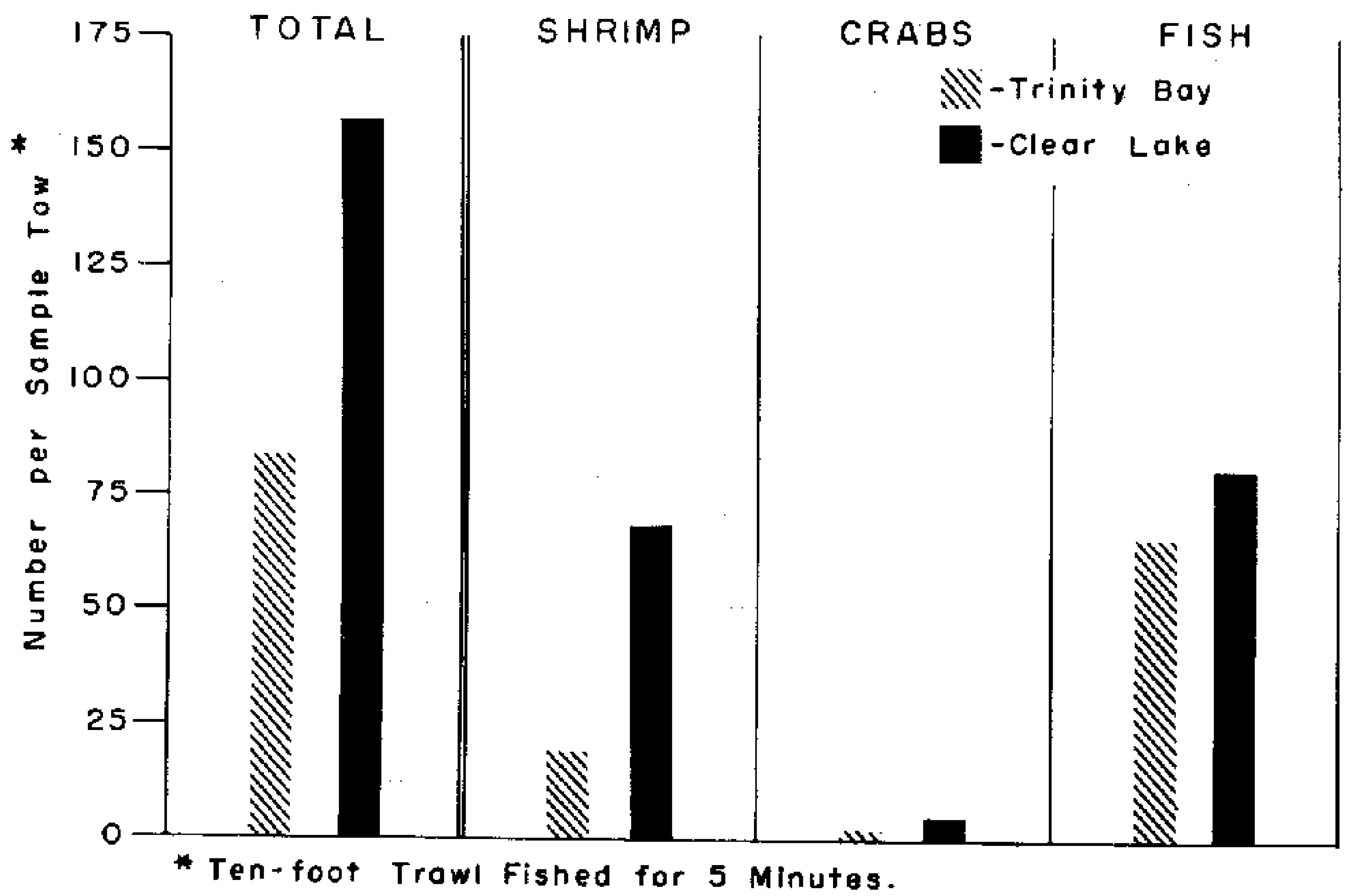
Trinity Bay, covering some 89,000 acres, is about 90 times larger than Clear Lake. In 1961, the average bottom salinity as calculated from monthly values was similar for the two areas (4.7‰ for Clear Lake and 4.0‰ for Trinity Bay), as was the average bottom temperature (less than 1° C. difference). Clear Lake, which is about $2\frac{1}{2}$ miles long, less than 1 mile wide, and 3 to 4 ft. deep, is protected by surrounding woods from strong winds and hence the buildup of heavy wave action. Trinity Bay, on the other hand, is 5 to 8 ft. deep, 14 miles long, and 10 miles wide, and frequently experiences considerable wave action.

Biological sampling during 1961 was conducted biweekly in Clear Lake, whereas sampling in Trinity Bay was carried out semimonthly during February and March, weekly from April through August, once a month from September through November, and three times during December. Sample collections were made with a 10-ft. trawl (3/4-in. stretched-mesh cod-end) towed for 5 min. Salinity and temperature were measured through April by titration and hand thermometer, respectively, and by a direct-reading portable salinometer thereafter. One hundred and seventy-four collections from seven stations in Trinity Bay, and 125 collections from five stations in Clear Lake, during the period February-December yielded the following data.

Sample Catch With 10-ft. Trawl From
Trinity Bay and Clear Lake, 1961

Area	Number of species	Number of animals				No. 5-min. trawl hauls
		Total	Shrimp	Crabs	Fish	
Trinity Bay	45	15,397	3,426	623	11,348	174
Clear Lake	38	19,709	8,592	657	10,460	125

On the basis of catch per unit of sampling effort (5 min. of fishing with a 10-ft. trawl), more shrimp, crabs, and fish were caught in Clear Lake than in Trinity Bay. (See accompanying figure.) Considerable variation also occurred in sample composition between these two areas.



Comparison of abundance indices for common faunal groups in Clear Lake and Trinity Bay, 1961.

Shrimp constituted 44 percent of all animals taken from Clear Lake but only 22 percent from Trinity Bay. Crabs accounted for 3 percent of the total Clear Lake catch, and fish 53 percent. In Trinity Bay, 4 percent of the total catch consisted of crabs and 74 percent of fish. For each 5 min. of sampling effort, $3\frac{1}{2}$ times more shrimp were caught in Clear Lake than in Trinity Bay, $1\frac{1}{2}$ times more crabs, and 1-1/3 times more fish.

Five species of fish, the bay anchovy, Anchoa mitchilli; Atlantic croaker, Micropogon undulatus; sand seatrout, Cynoscion arenarius; largescale menhaden, Brevoortia patronus; and spot, accounted for about 95 percent of all fish caught in both Trinity Bay and Clear Lake. These same species contributed 70 percent of the total sample catch from Trinity Bay but only 51 percent to that from Clear Lake.

Comparison of Relative Composition and Density of Major Species in Clear Lake and Trinity Bay, 1961

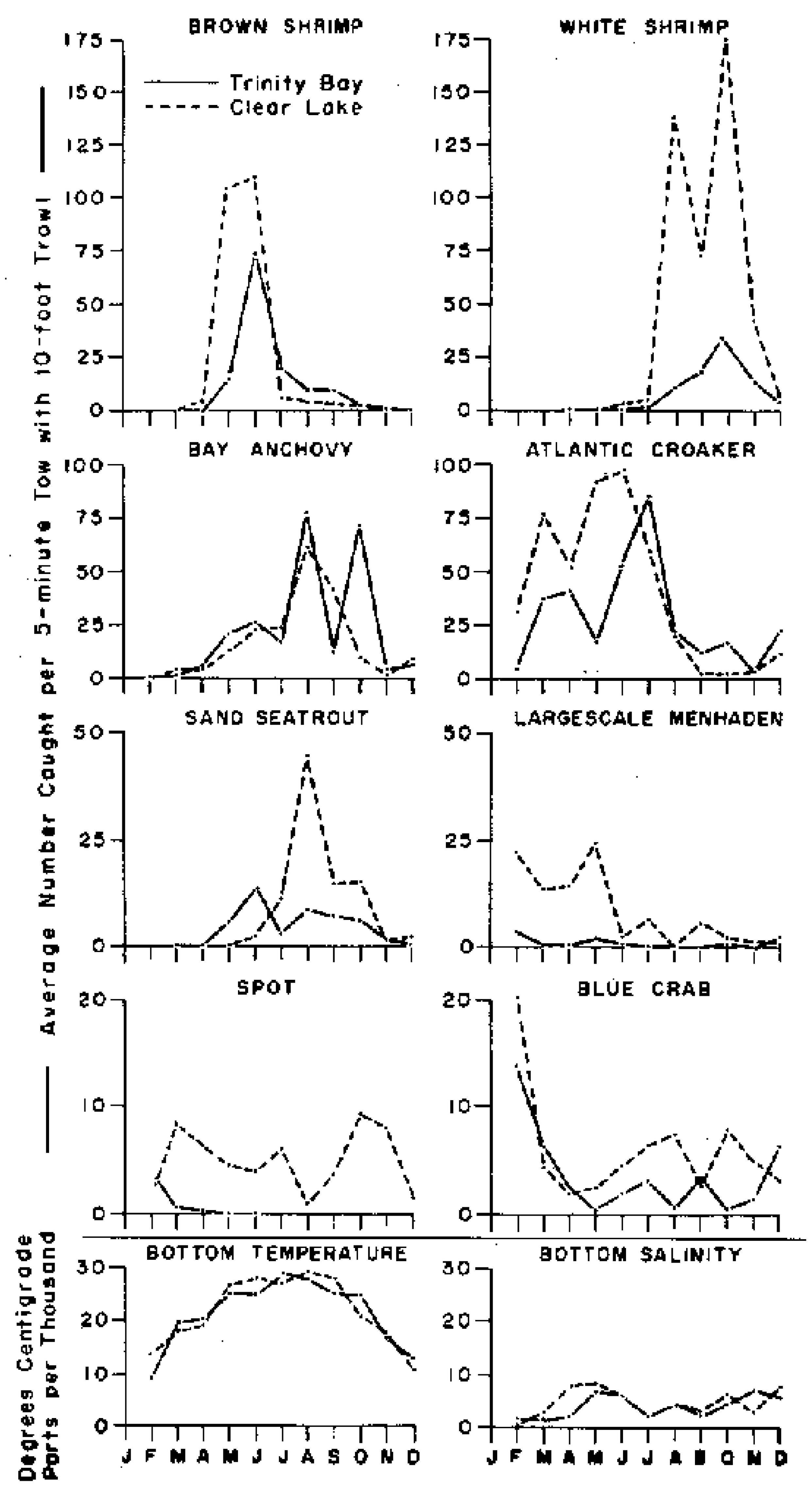
Species	Trinity Bay		Clear Lake	
	No.	C/E[1]	No.	C/E[1]
White shrimp	912	5.2	5,583	44.7
Brown shrimp	2,513	14.4	2,782	22.3
Blue crab	623	3.6	657	5.3
Bay anchovy	4,270	24.5	2,115	16.9
Atlantic croaker	5,464	31.4	4,812	38.5
Sand seatrout	771	4.4	1,070	8.5
Largescale menhaden	170	1.0	1,054	8.4
Spot	63	.4	932	7.5
Other	611	3.5	704	5.6
TOTAL	15,397	88.4	19,709	157.7

1/ Number caught per 5 minutes' sampling with 10-ft. otter trawl.

The eight most numerous species caught in both areas, including the brown and white shrimp, Penaeus aztecus and P. setiferus, respectively, the blue crab, Callinectes sapidus, and the aforementioned five species of fish, comprised about 96 percent by number of all animals taken in both Clear Lake and Trinity Bay.

A comparison of each species' catch per unit of sampling effort from Trinity Bay and Clear Lake is made in the accompanying figure (next page). Corresponding monthly temperature and salinity curves are also included, with only slight differences in these factors from area to area being evident. Fairly close agreement was noted for time of peak abundance of brown shrimp, white shrimp, bay anchovy, and blue crab, although for shrimp, rapid population increases occurred first in Clear Lake. Largescale menhaden and spot were not taken in sufficient numbers in Trinity Bay to allow comparison of their trends in seasonal abundance. Peak abundance of the Atlantic croaker was noted about a month later in Trinity Bay than in Clear Lake. A sharp decline in abundance during September occurred for several species and might have resulted from the effects of Hurricane "Carla," although evidence is not conclusive. Catch per unit of effort, with the exception of that for the bay anchovy, was usually greater in Clear Lake than in Trinity Bay.

On the basis of numbers of fish and shellfish caught by trawl sampling, Trinity Bay, because of its larger size, could be judged to be roughly 50 times more valuable than Clear Lake from the standpoint of its capacity to produce or maintain estuarine fishery resources. On a unit-area basis, however, an acre in Clear Lake would be about 1.8 times more valuable for the same reason than an acre in Trinity Bay. Furthermore, because of the greater economic value of one type of resource as opposed to another (i.e. shrimp vs. crabs), an acre in Clear Lake could be as much as $3\frac{1}{2}$ times more valuable than an acre in Trinity Bay.



Comparative (seasonal) trends in temperature, salinity, and abundance of common fishes and shellfishes in Clear Lake and Trinity Bay, 1961.

Understandably, these figures are strictly speculative at this time and need considerable refinement and confirmation over a period of several years. Bias resulting from sampling gear and techniques, but particularly from sampling locations, could not be reconciled. Moreover, all stations in Trinity Bay were in open water deeper than 4 ft. pointing up the fact that the "surf" zone was not sampled. The problem of station location has been resolved with the revisions incorporated in the present program, which now provides data from specific locations and areas that are more truly comparable.

Water Chemistry in the Two Sea-Water Laboratories

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

Water circulating through both the Fort Crockett and East Lagoon sea-water systems (laboratories) is checked twice weekly for amounts of some or all of the following constituents: inorganic phosphate-phosphorus, nitrite-nitrogen, nitrate-nitrogen, ammonia-nitrogen, chlorophyll, carbohydrates, and dissolved oxygen. In addition to these checks, the salinity of the water in the recirculating system at Fort Crockett is determined daily by titration, while that in the Lagoon system is recorded continuously by electronic methods.

With the exception of those for nitrite-nitrogen and carbohydrate, the analytical methods employed are as described in the U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 349. The nitrite method described therein was replaced with one better suited to our situation.[1/]

The carbohydrate procedure (method B) described in the above-mentioned Special Scientific Report gives consistently lower values than that upon which it is based (method A). Thus, until such time that the discrepancy between the two methods can be accounted for, carbohydrate estimates will be based on both procedures.

Except for those from which salinity, oxygen, and chlorophyll are determined, samples of water for the analyses mentioned are collected in 200-ml. culture tubes with screw-on polyseal caps. They are immediately stored in a deep-freeze cabinet until analysis. Salinity samples are collected in 4-oz. bottles, oxygen in standard B.O.D. bottles, and chlorophyll in 2,000-ml. flasks.

During the first 7 mo. of the year, rather intensive sampling was undertaken to determine the suitability of the sample containers and also the precision of the various analyses. The number of samples and sample checks per collection period were as follows:

Analysis	Samples collected	Checks per sample
	Number	Number
Phosphate-P	4	2
Nitrate-N	3	2
Nitrite-N	4	2
Ammonia-N	4	1
Carbohydrates (A)	1	2
Carbohydrates (B)	1	2
Chlorophyll	1	2

1/ Bendschneider, K., and R. J. Robinson, 1962. A new spectrophotometric method for the determination of nitrite in sea water. Journal of Marine Research, vol. 11, no. 1, p. 87-96.

The water from which samples were obtained to determine levels of phosphate, nitrate, nitrite, and ammonia was first filtered and then thoroughly mixed before it was dispensed into the sample tubes. Sample tubes were cleaned by boiling them in concentrated sulphuric acid, after which they were rinsed many times with double-distilled water.

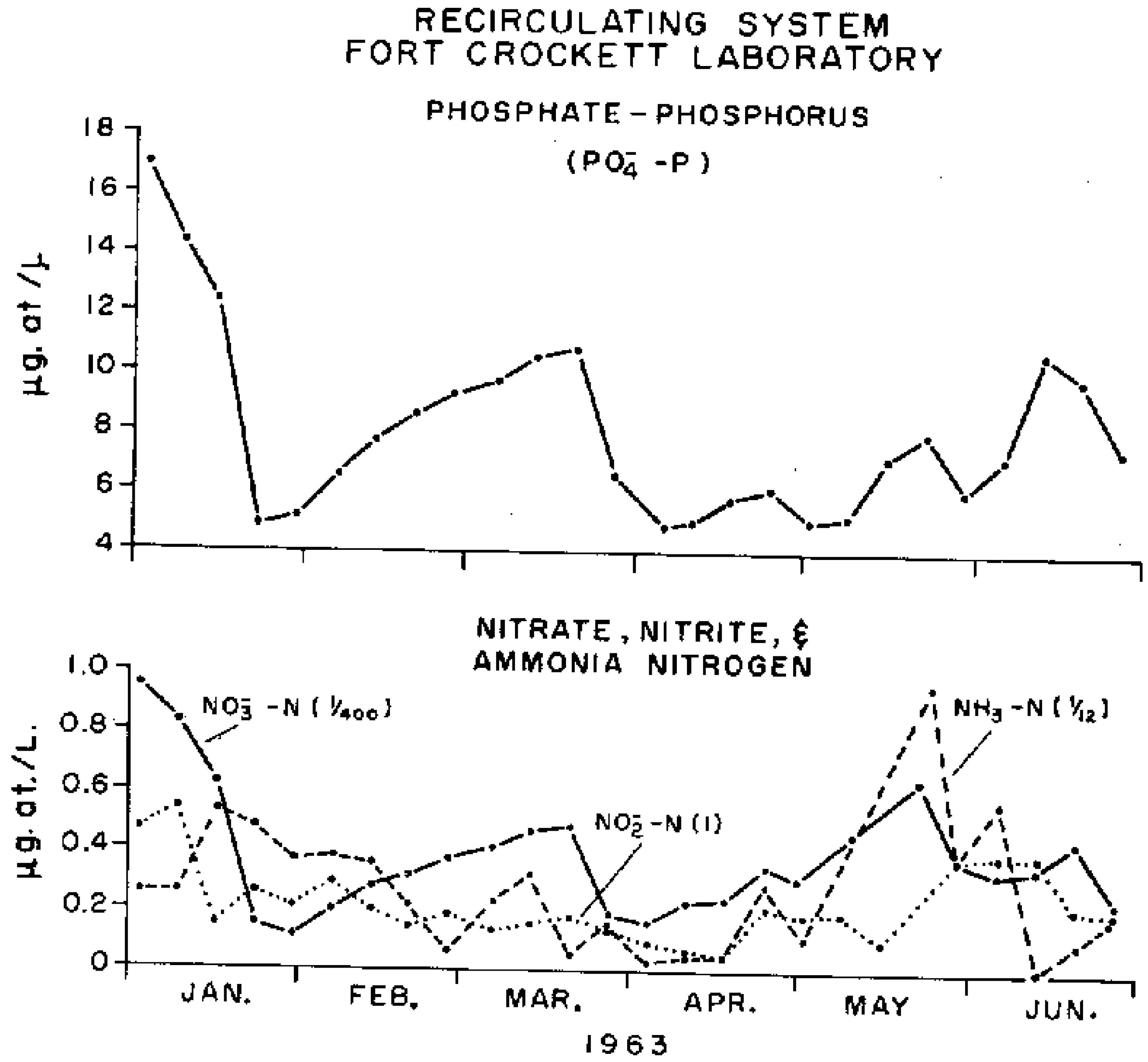
Analyses of variance involving data for nitrite- and nitrate-nitrogen indicated significant differences between sample tubes in the concentrations of these constituents. Whether these results reflect real differences due to nonhomogeneity of the water sampled or experimental bias attributable to contaminated sample tubes is not known. The same analysis employing the phosphate data showed no such difference.

The analysis which tested sample differences in ammonia-nitrogen is based on between-tube data only. Hence, the indicated measure of precision (standard deviation = 0.0265) is possibly biased by significant variation between tubes.

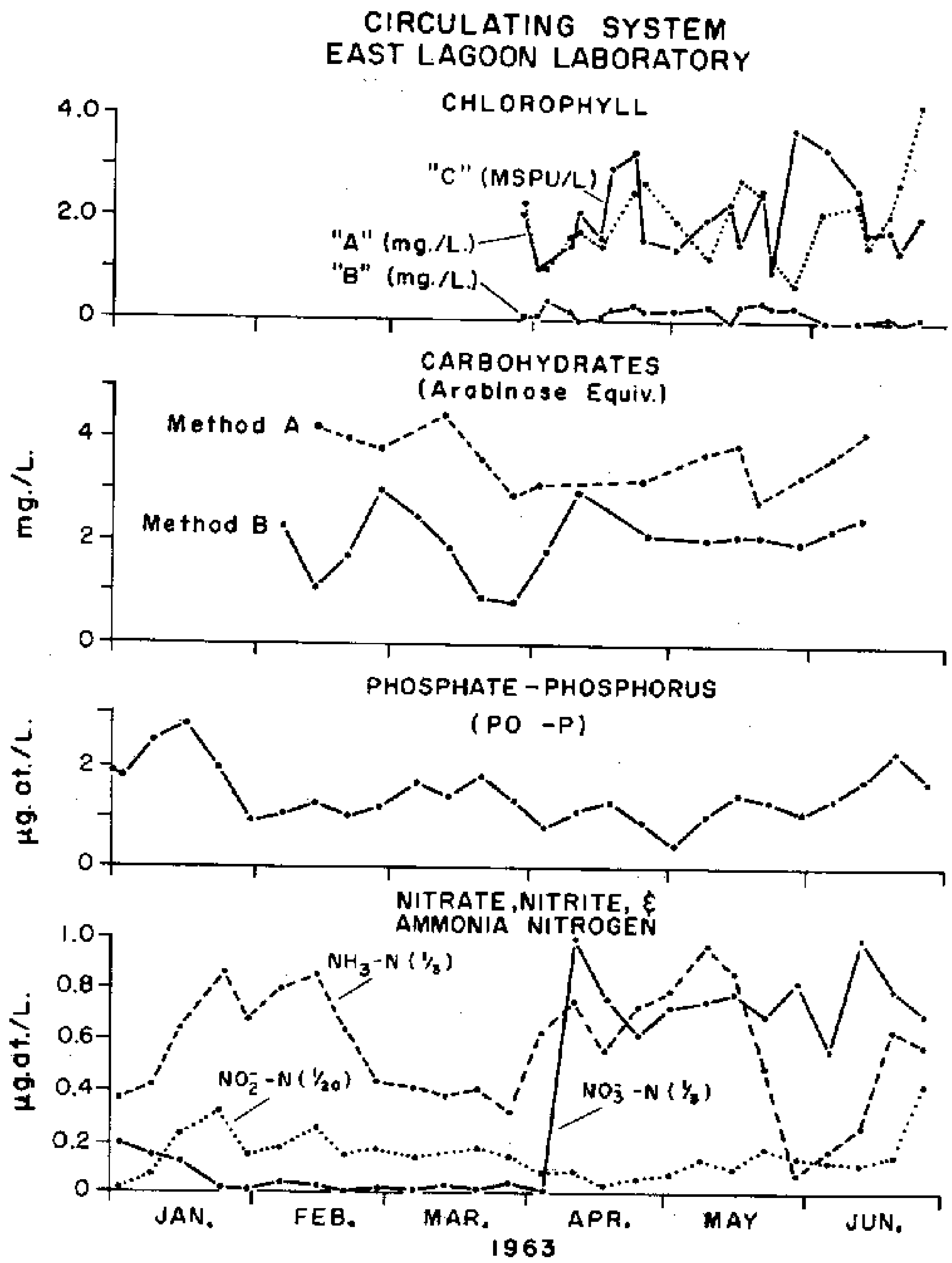
Analyses of the chlorophyll and carbohydrate data were based on within-tube information only and therefore yielded indices of analytical precision that discounted possible between-tube variation.

Perhaps the greatest source of error (bias) not isolated by an analysis of variance employing the kind of data available here is that of a systematic nature due to variation in the calibration-conversion process which involves "standard" samples. Attempts are made to minimize this bias by preparing all "standard" (calibration) samples from water which is as similar to that of the samples to be analyzed as possible. The determination of blank values, particularly in the ammonia analysis, is often difficult. The problem is one of ascertaining if a significant blank reading is due to an impurity within a reagent or within the water in which the reagent is mixed. Unless such information is available, the "educated guessing" that follows can introduce appreciable systematic (or constant) error into a set of data.

Temporal distributions of the various chemical indices obtained during the first half of 1963 are shown on the accompanying graphs.



Chemical composition (weekly averages) of water in the recirculating and lagoon sea-water laboratories.



Constituent and unit of measurement	Source of variation	Degrees of freedom	Sum of squares	Mean square	Standard deviation
NO_2-N	Within tubes	164	0.0599	0.000365	0.0190
	Between tubes	123	.1401	.001139	.0338
μg. at. NO_2-N/liter	Total	287	.2000	.000697	.0264

$$F = \frac{0.1139}{0.0365} = 3.12\ (F_{.01} = 1.5)$$

Constituent and unit of measurement	Source of variation	Degrees of freedom	Sum of squares	Mean square	Standard deviation
NO_3-N	Within tubes	130	2.3057	0.0177	0.133
	Between tubes	92	3.3595	.0365	.1911
μg. at. NO_3-N/liter	Total	222	5.6652		.215

$$F = \frac{0.0365}{0.0177} = 2.06\ (F_{.01} = 1.5)$$

Constituent and unit of measurement	Source of variation	Degrees of freedom	Sum of squares	Mean square	Standard deviation
PO_4-P	Within tubes	192	3.1450	0.0164	0.128
	Between tubes	144	2.5788	.0179	.134
μg. at. PO_4-P/liter	Total	336	5.7238	.0170	.130

$$F = \frac{0.0179}{0.0164} = 1.09\ (F_{.01} = 1.4)$$

Constituent and unit of measurement	Source of variation	Degrees of freedom	Sum of squares	Mean square	Standard deviation
NH_3-N					
p.p.m. NH_3-N	Between tubes	147	0.1027	0.0007	0.0265
Chlorophyll					
Method A (mg./liter)	Within 2,000-ml. flasks	38	2.0846	0.0548	0.2341
Do. B (mg./liter)	do.	40	.1941	.0048	.0693
Carbohydrate					
Method A (mg./liter)	Within tubes	23	2.8226	0.1227	0.3503
Do. B (mg./liter)	do.	30	1.9899	.0663	.2575

Abbreviations:

μg. at. /liter - microgram atoms per liter
mg. /liter - milligrams per liter

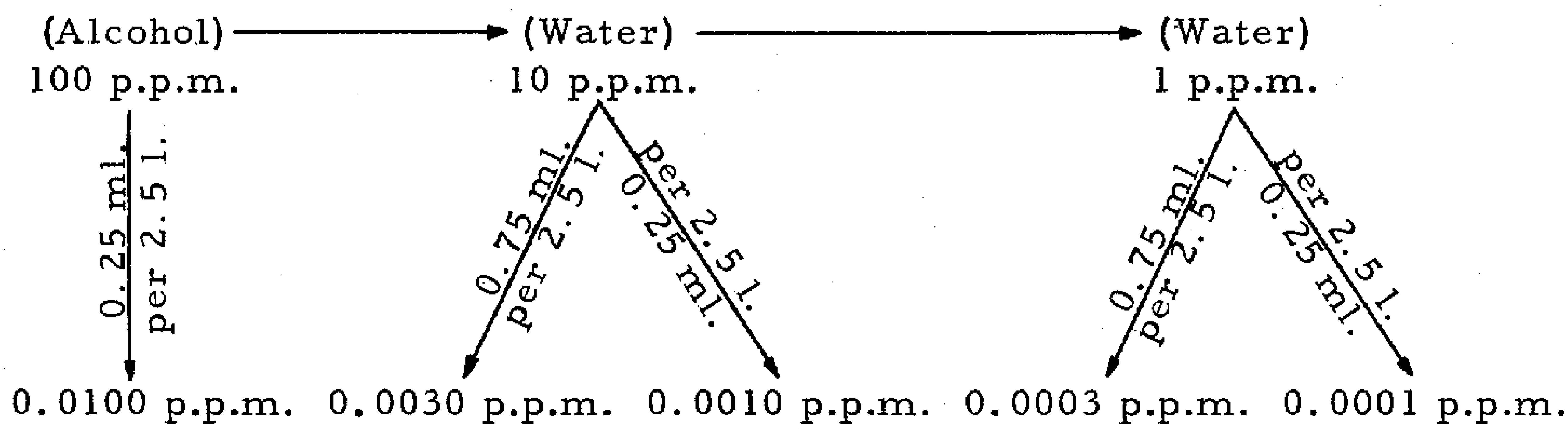
Chemicals Toxic to the Red-Tide Organism

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

This year's activity centered on evaluating seven chemical compounds as possible control agents for the "red-tide" organism, *Gymnodinium breve*. Preliminary research had indicated that these compounds possess the characteristics required of a successful control agent in that they are toxic to *G. breve* at very low concentrations and proved to have little or no adverse effect on several commercially important estuarine and marine organisms against which they were tested.

Tests were conducted in 2.5 liters of *G. breve* culture contained in 10-liter, all-glass aquaria. Experience has shown that to successfully maintain *G. breve* cultures in the laboratory, a high degree of glassware cleanliness is required. For this reason, each aquarium was subjected to a cleaning procedure which involved a scrubbing with detergent, followed by treatments with boiling detergent and nitric acid solutions, and ending with many distilled-water rinses.

Each chemical was tested at five concentrations ranging from 0.0100 to 0.0001 p.p.m. Since the test materials are more soluble in alcohol than in water, they were first placed in 100-p.p.m. alcoholic solutions. These "stock" solutions were then used in the preparation of more dilute "working" solutions. The entire procedure can best be illustrated by the following schematic diagram:



Estimates have been made of the minimum concentrations at which each of the seven chemicals are toxic to *G. breve* in an artificial medium, and in a medium made with water taken from a Florida coastal area where "red-tide" blooms have frequently occurred. These estimates were made by comparing the percent mortality of G. breve in treated cultures with that in nontreated or control cultures.

The experimental results are shown in the accompanying table and generally indicate that the test chemicals had less effect on Florida-water cultures than on artificial sea-water cultures.

The G. breve against which the toxicants were tested had been maintained in the laboratory for approximately 10 yr. Possibly, during this time a less hardy strain of organism had developed. If so, the results of this study would not be indicative of the true effects of the test chemicals on the "red-tide" (or "wild" vs. cultured) variety of G. breve. To minimize this possible source of bias, a "fresh" culture has been started with G. breve samples taken from a recent red-tide outbreak in Florida (spring of 1963). Minimum toxic levels for each of the seven chemicals will be reestimated using the new culture of G. breve as soon as it is ready.

Results of Toxicity Tests in Terms of Percent Mortality of G. breve in Artificial Sea-Water and Florida-Water (underlined) Cultures

Hours exposed	Concentrations (p.p.m.)											
	0.0100		0.0030		0.0010		0.0003		0.0001		Control	
	Artificial	Florida	Artificial	Florida	Artificial	Florida	Artificial	Florida	Artificial	Florida	Artificial	Florida
1. Ferric dimethyldithiocarbamate (fermate)												
24	100	25	100	0	75	0	0	0	0	0	0	0
48	100	50	100	0	100	0	0	0	0	0	0	0
72	100	75	100	0	100	0	0	0	0	0	0	0
2. Tellurium diethyldithio carbamate												
24	100	100	0	0	0	0	0	0	0	0	0	0
48	100	100	75	0	0	0	0	0	0	0	0	0
72	100	100	100	0	0	0	0	0	0	0	0	0
3. Sodium salts of dimethyldithio carbamic acid and 2-mercaptobenzothiazole												
24	0	25	0	0	0	0	0	0	0	0	0	0
48	0	25	0	0	0	0	0	0	0	0	0	0
72	0	25	0	0	0	0	0	0	0	0	0	0

Results of Toxicity Tests in Terms of Percent Mortality of G. breve in Artificial Sea-Water and Florida-Water (underlined) Cultures--Continued

Hours exposed	Concentrations (p. p. m.)											
	0.0100		0.0030		0.0010		0.0003		0.0001		Control	
	4. Tetraethylthiuram disulfide											
24	100	0	0	0	0	0	0	0	0	0	0	0
48	100	50	25	0	0	0	0	0	0	0	0	0
72	100	75	50	0	25	0	0	0	0	0	0	0
	5. Sulfide, bis(2-hydroxy-3-bromo-5-chlorophenyl)-bis-dimethylamino-; Butyne mono salt											
24	100	25	0	0	0	0	0	0	0	0	0	0
48	100	100	100	0	0	0	0	0	0	0	0	0
72	100	100	100	25	50	0	0	0	0	0	0	0
	6. Sulfide, bis(2-hydroxy-3-bromo-5-chlorophenyl)-; Cyclohexylamine mono salt											
24	0	0	0	0	0	0	0	0	0	0	0	0
48	100	100	0	0	0	0	0	0	0	0	0	0
72	100	100	50	75	0	0	0	0	0	0	0	0
	7. 3, 5-hexadienoic acid-2-oxo-6-phenyl-											
24	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0

The Juvenile Phase of the Life History of the Pink Shrimp *Penaeus duorarum* on the Everglades National Park Nursery Grounds

C. P. Idyll
Institute of Marine Science, University of Miami
(Contract No. 14-17-0002-44)

This study on the juvenile phase of the life history of pink shrimp in the shallow coastal waters along the south Florida mainland was begun in October 1962.

Buttonwood Canal near Flamingo, Fla., was selected as the sampling site. It is an important outlet for shrimp utilizing the nursery area in the Coot Bay complex and the southern portion of Whitewater Bay. A highway bridge crossing the canal made a convenient base for operating the sampling gear.

Much of the study's first 9 mo. was devoted to designing and testing sampling gear. A large channel net was constructed and employed to intercept all animals above a certain size moving through the canal at the sampling site during ebb as well as flood tides. Wing nets were also designed, built, and tested. They have an opening of 3 ft. by 6 ft., are fastened to a rectangular frame, and are fished from both sides of a skiff anchored upstream from the channel net. One phase of the study has been to evaluate the wing nets as sampling devices. This is a relatively simple matter since the channel net takes everything the wing nets miss.

The channel net was operated twice monthly (on two consecutive nights each time) beginning in January 1963. The sampling periods were chosen from week days and were representative of all tidal stages and periods as well as weather conditions. Starting in the last half of June, the wing nets were fished simultaneously with the channel net. Observations were also made of current velocity, water height, tidal stages, salinity, and water temperature. Samples were taken during the night as well as the day. Between January 1 and June 15, 216 half-hour shrimp samples were made with the channel net, of which 126 were ebb tide samples and 90 were flood tide samples.

During the first $3\frac{1}{2}$ mos. of the program, all shrimp caught by the channel net were measured and their sex determined. Beginning in mid-April, however, random samples of 100 shrimp of each sex were taken for measurement although the total number of shrimp in each sample continued to be determined.

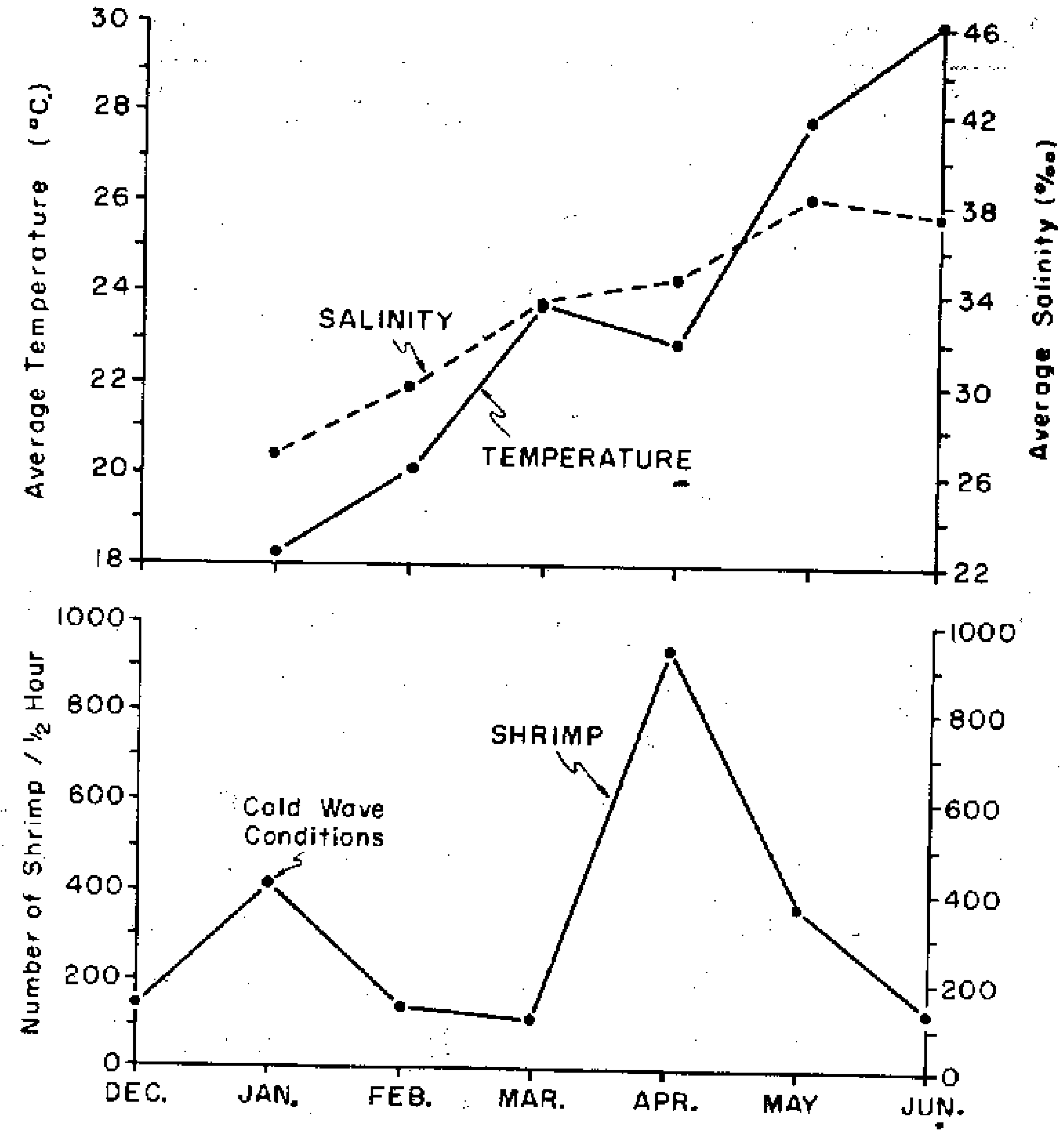
Size frequency data for the 7-mo. period of December 1962 through June 1963 show three features common to the distribution of both sexes. (1) The mode and size range were identical and remained stationary for 5 mo., December through April. (2) There was a marked shift to the right of modal values and range of both male and female distributions beginning in early May and continuing through June, with females being somewhat larger than males. By late June, the large size group had nearly disappeared from the catches. (3) In late June, there was a decrease in average size caused by the disappearance of large shrimp and by the appearance in the catches of a new group of shrimp with a modal length of 13-14 mm. (carapace measurement).

The sample sex ratio approached unity. In a sample of 18,328 shrimp covering a period of 4 mo. (Jan.-Apr.), there were 9,099 males and 9,229 females.

One of the purposes of the study is to determine under what light conditions shrimp are most active, since this will affect sampling procedures which depend upon capture of moving animals by passive gear. During the 7 mo. of sampling in Buttonwood Canal, there have been several periods when the channel net was fished during the late night to early morning hours. In addition, a series of "full-daylight" samples was obtained. Examination of resulting data revealed an abrupt decrease in numbers of shrimp taken just after dawn and that no shrimp were caught during hours of full daylight.

Salinity and temperature at the sampling station changed together (see accompanying figure next page), but there is no strong relationship apparent yet between salinity or temperature and numbers of shrimp. Lowest salinity values were recorded in January, averaging 26.8 p.p.t. (parts per thousand) on the bottom and 26.9 p.p.t. at the surface. Highest salinity values were recorded in May when bottom samples averaged 38.4 and surface samples 28.1 p.p.t. Average surface and bottom temperature ranged between 18.4° and 18.2° C. in January to 29.8° and 30.0° C. in June. Considerable variation in temperature and salinity may be expected in these shallow waters as a result of severe weather fluctuations.

All large shrimp have been examined and found to be pink shrimp, *Penaeus duorarum*. In addition, a small series of samples including medium as well as large individuals was examined, and all the shrimp in these also proved to be *P. duorarum*. Three specimens of *Trachypeneus constrictus* were collected during the period January through June.



Relationship of shrimp abundance with bottom temperature and salinity.

A large number of fishes and invertebrates have been taken incidentally with the shrimp. A few turtles have also been caught. Records of all catches have been made, and material of suitable size has been preserved for future examination. When specimens were too large for preservation, as turtles and large fishes, they were measured and sexed where possible and released unharmed.

Blue crabs exhibited marked seasonal changes in abundance and sex differences on the ebb and flood tides. All blue crabs are sexed at the time of sorting and returned to the water. Females with Sacculina were abundant, particularly during December through February, and notes have been made of the incidence of the parasitized individuals.

Abundance and Distribution of Pink Shrimp Larvae on the Tortugas Shelf of Florida

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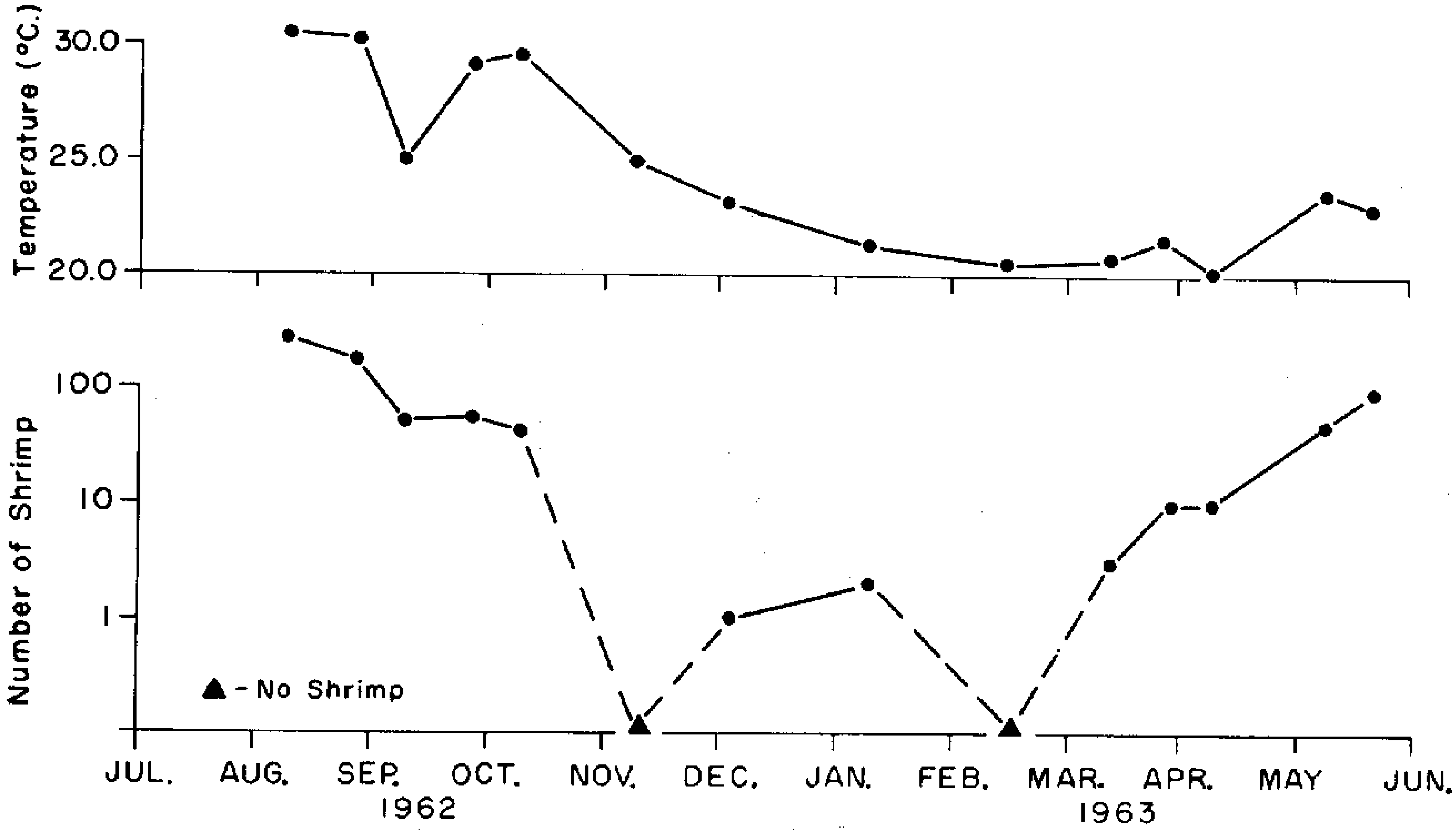
Institute of Marine Science, University of Miami
(Contract No. 14-17-0002-4)

The University of Miami continued its studies of the abundance and distribution of pink shrimp larvae on the Tortugas Shelf in the eastern Gulf of Mexico. During the year, emphasis was on the seasonal and areal abundance of shrimp larvae on the spawning grounds, the seasonal abundance of shrimp postlarvae as they enter an estuary, and the development of techniques to rear shrimp from the egg in captivity.

On two occasions in August 1962, ripe female pink shrimp were brought to and spawned in the laboratory, and the resulting larvae were reared successfully. Some of the problems encountered by previous workers were overcome. The larvae were kept individually in separate compartments of plastic "tackle boxes" after they transformed into first protozoea. Their survival was significantly greater at temperatures of 21° and 25° C. (70° and 77° F.) than at 30° C. (86° F.) and when they were raised in sea water from the Florida Current instead of bay water. A food mixture consisting of unicellular algae, diatoms, dinoflagellates, and marine yeasts was supplied daily.

Spawning surveys were made semimonthly during the summer, fall, and spring, and monthly during the winter. Plankton samples and hydrographic data were collected at 10 stations located on a 10-mile-square grid. Two 30-min., "step-oblique" tows were made at each station with a Gulf-V plankton sampler. A telemetering depth indicator was built, tested, and used to provide for accurate depth control.

The density of pink shrimp larvae on the spawning grounds during the year was generally low. Larvae were most abundant from August to October, averaging more than 40 per tow. (See figure next page.) After October, the larvae were scarce, with the average number per sample tow being below five. In the spring of 1963, the number of larvae per tow did not increase above 40 until May. This event occurred later than in previous years. The annual trend in the density of shrimp larvae was similar to the trend in the temperature of the bottom water.

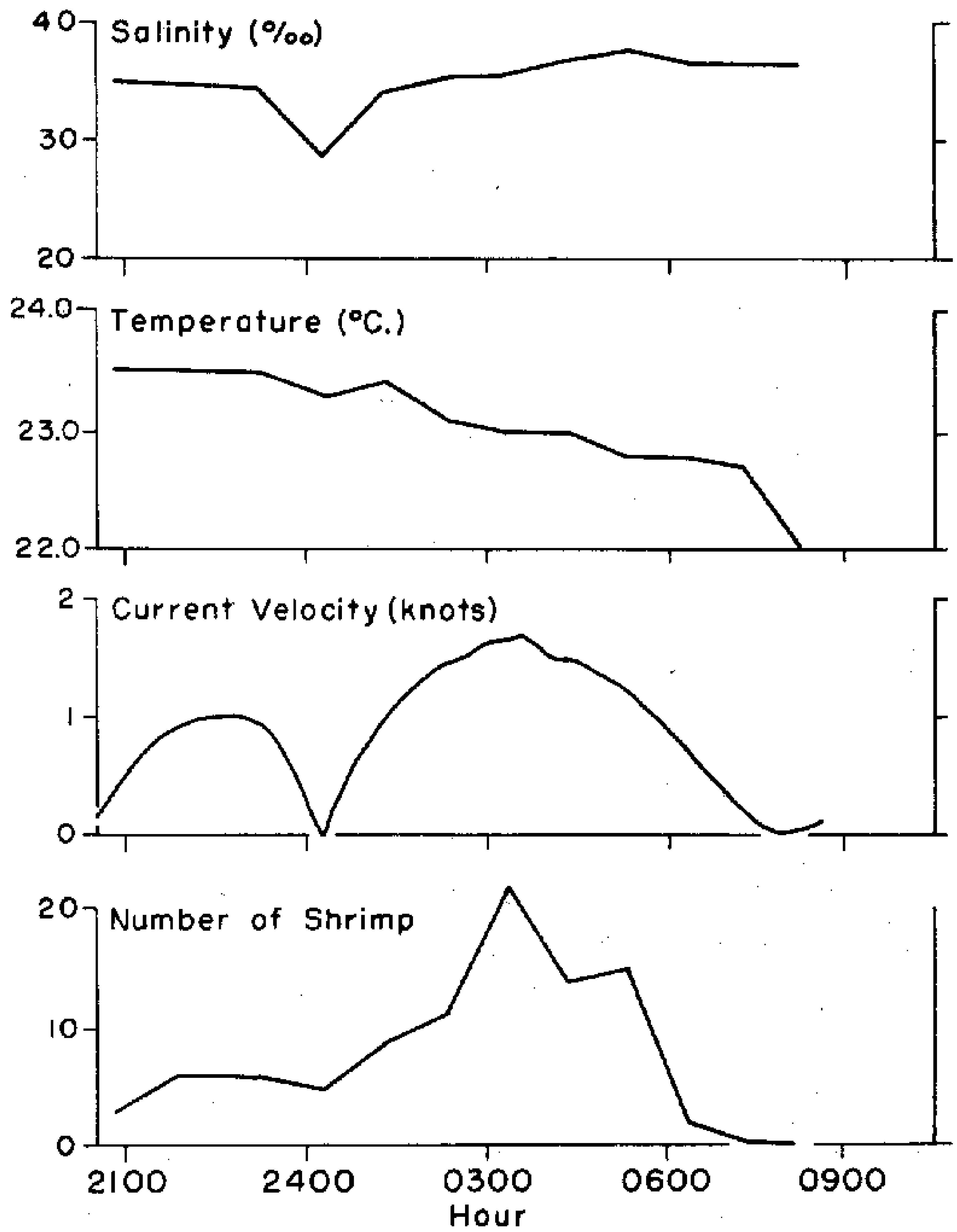


Bottom temperature and average number of pink shrimp larvae collected at a station on the Tortugas Shelf.

Spawning occurred in all periods of collection so that exact temperature limits for spawning cannot be established. The observations do, however, extend both the minimum and maximum temperatures for spawning of pink shrimp which have been previously reported. The minimum temperature at which spawning was observed was 19.6° C. (67.3° F.), and the maximum was 30.6° C. (87.1° F.).

The pattern of abundance of pink shrimp postlarvae at the entrance to an estuary is being studied in relation to the abundance of larvae on the offshore spawning grounds and to the time of migration of juveniles out of the estuarine nursery areas. Also, the abundance of larvae in relation to the speed and direction of the tidal currents is expected to shed some light on the method of movement of the older larvae from the offshore spawning grounds to the coastal nursery areas.

Plankton samples were collected from Buttonwood Canal, an entrance to the Whitewater Bay estuarine complex in Everglades National Park, with a 3-in. centrifugal pump having a rated capacity of 300 g.p.m. The water is sampled through an adjustable intake so that the depth of sampling may be varied, pumped into a 30-gal. drum where it is filtered of its plankton, and then discharged. Over 200 samples were collected by this method during the year. Beginning in October 1962, these samples were taken generally from dusk to dawn at full- and new-moon periods each month. Numbers of postlarvae were greatest during peaks of flood tides although some postlarvae were collected in nearly all samples. More postlarvae were collected during flood tides than during ebb tides, indicating that they are possibly able to control their movement in relation to the direction of the tide.



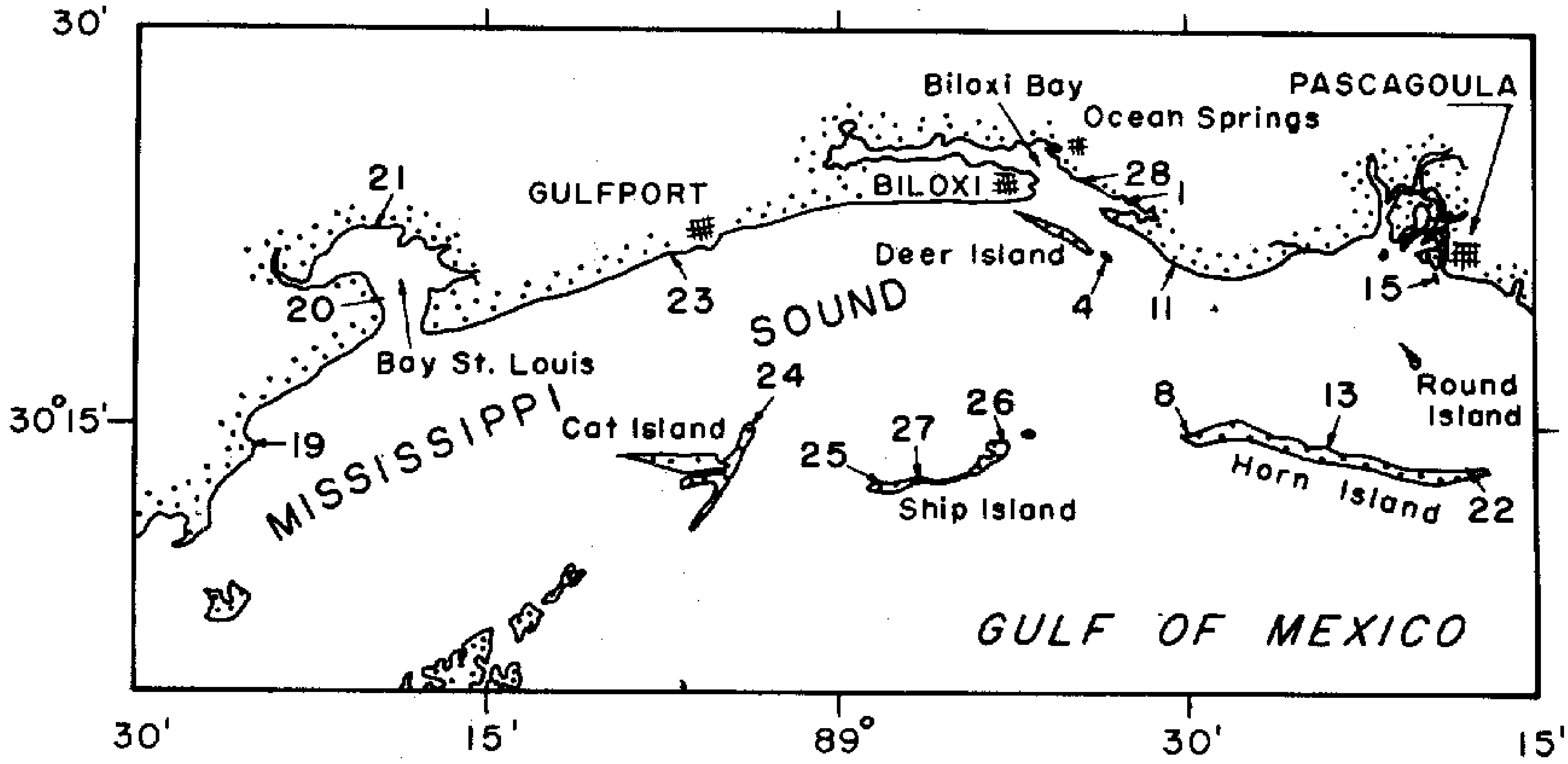
Number of pink shrimp per plankton-pump sample from Buttonwood Canal on October 29, 1962, together with salinity, water temperature, and current velocity.

Abundance of Postlarval Shrimp in Mississippi Sound and Adjacent Waters

J. Y. Christmas
Gulf Coast Research Laboratory
(Contract No. 14-17-0002-43)

This study to determine the feasibility of measuring postlarval shrimp abundance to forecast commercial shrimp production in the Mississippi area was begun in November 1962.

The sampling method employed is essentially the same as that being used by Bureau biologists at the entrance to Galveston Bay, Tex. In addition to the biological sample, observations are made of water and air temperature, salinity, tide stage, water depth, bottom type, and weather. Twenty-eight stations were initially established.



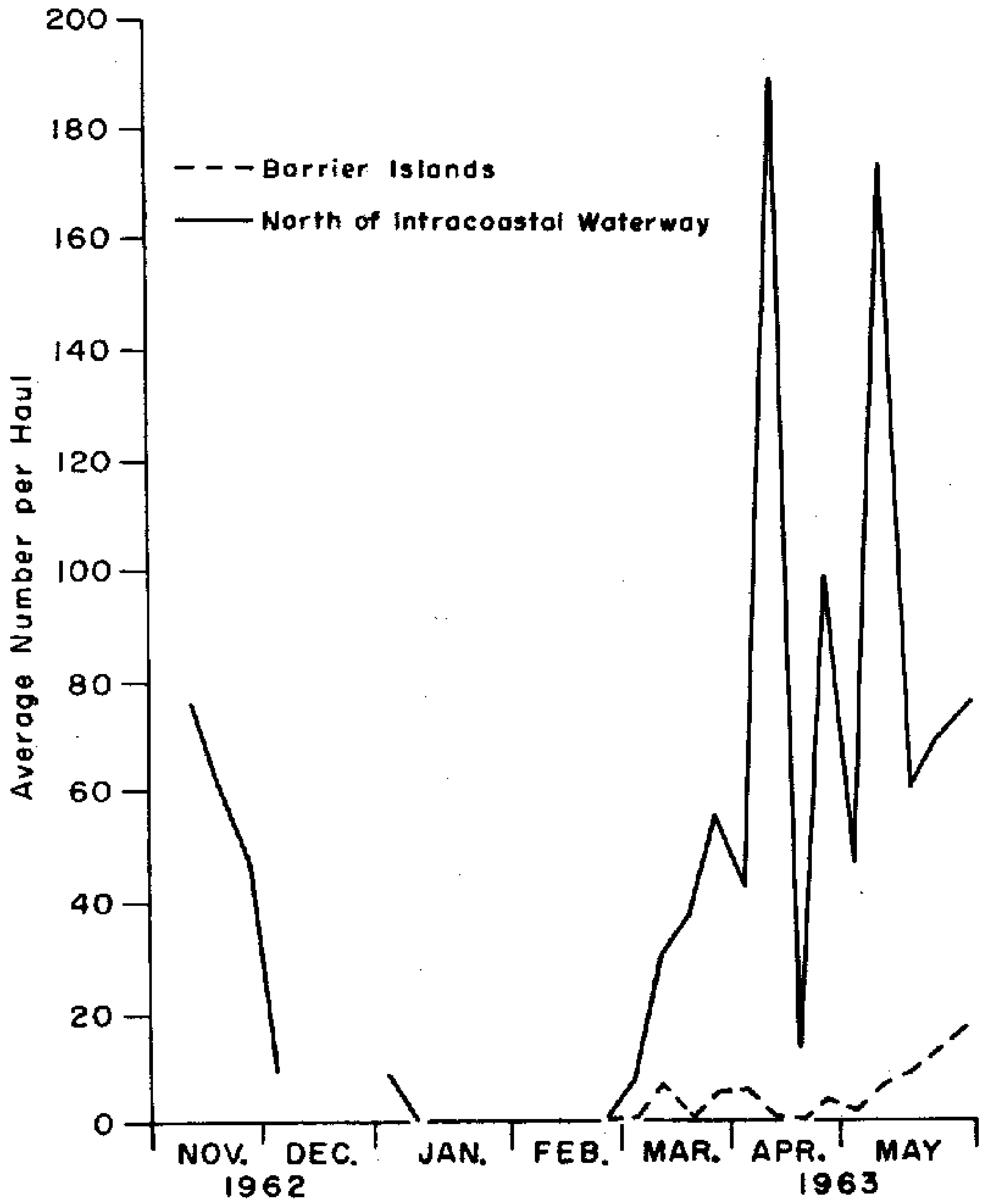
Stations at which postlarval shrimp are sampled in Mississippi Sound.

All of the stations where the 6-ft. beam net could not be towed by wading were eliminated in March 1963, leaving 18 stations at which samples are now being taken once weekly. (See accompanying figure.)

Postlarval shrimp were collected in relatively small numbers in November and early December. After the first "freeze" in

December, they virtually disappeared. They were again taken in February and increased in number during March, April, and May. Pink shrimp predominated in the fall catches. Brown shrimp appeared in February and were the primary species until white shrimp appeared in mid-May.

There was considerable variation in catches between stations on the same day. The numbers of postlarvae collected at the barrier island stations were consistently less than those taken at stations located along the mainland or north of the Intracoastal Waterway.



Comparative numbers of postlarval shrimp (all species) collected at barrier island stations and stations north of the Intracoastal Waterway.

Rainfall was abnormally low during the sampling period. Consequently, the salinity was unusually high, particularly at stations north of the Intracoastal Waterway. Temperatures ranged from freezing, with surface ice present during the winter, to a late spring high of 35° C. (95° F.).

Distribution of Postlarval Shrimp in Vermilion Bay, La.

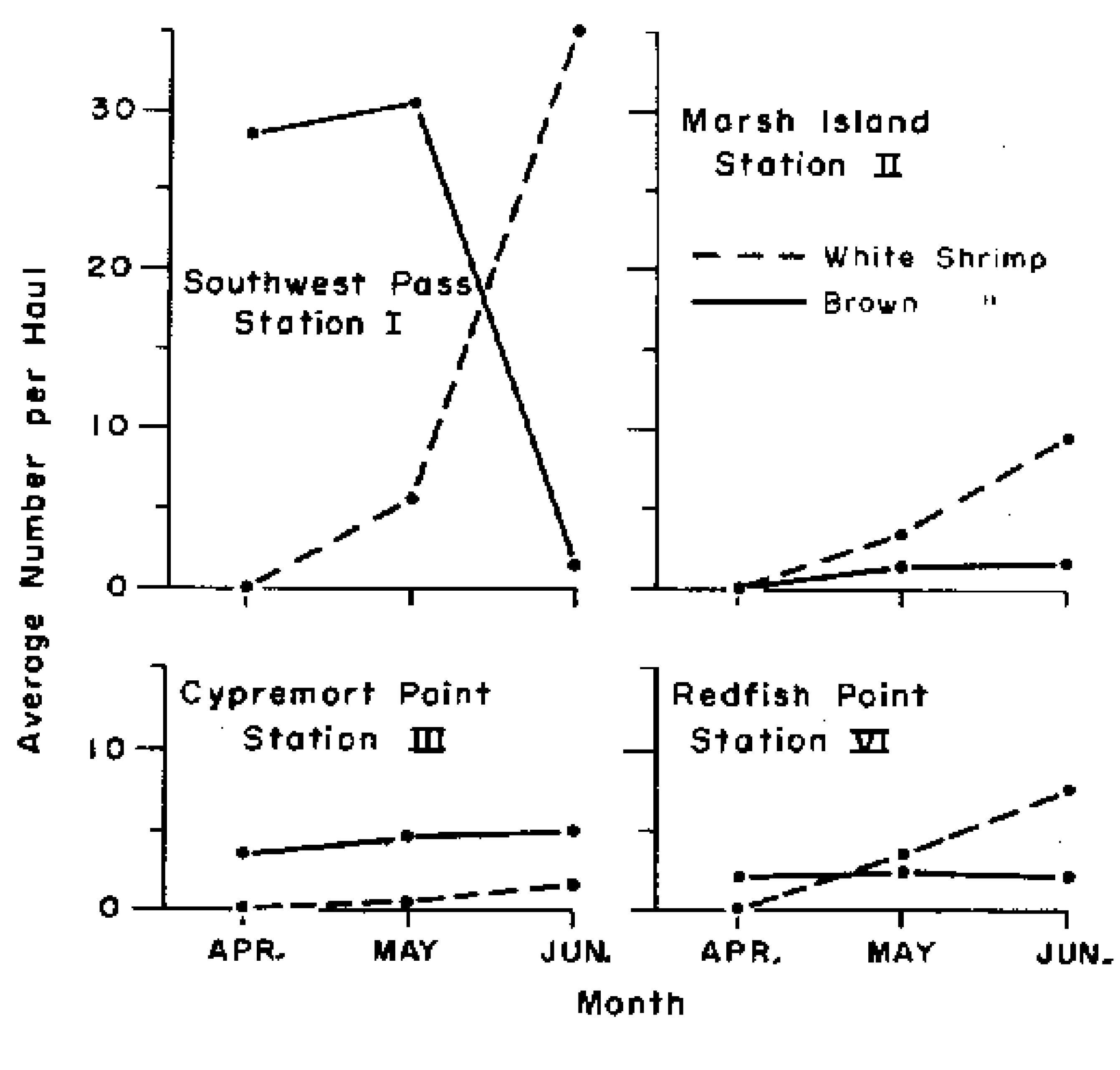
Carroll R. Norden
University of Southwestern Louisiana
(Contract No. 14-17-0002-48)

This study of the distribution and movements of postlarval shrimp in Vermilion Bay, La., began in February 1963.

Eight sampling stations have since been established, four of which are occupied biweekly and the remainder on a weekly basis. The 6-ft. beam trawl developed by Bureau personnel at Galveston, Tex., constitutes the standard sampling gear. Because sampling efficiency was often reduced due to the soft mud and abundant organic debris on the bottom, the net was towed in a semicircle with a 100-ft. radius rather than with the usual 150-ft. radius.

Brown shrimp postlarvae were most abundant in April and at most stations decreased markedly in June. Beginning in the latter part of May, juvenile brown shrimp occurred in samples more frequently than did postlarvae. White shrimp postlarvae appeared in samples at Southwest Pass on May 14 and at the inside stations between May 21 and 25.

Greatest concentrations of postlarvae were observed at the Southwest Pass entrance to Vermilion Bay. On June 12, over 3,000 white shrimp postlarvae were taken there. This entrance to Vermilion Bay was apparently used more than either East or West Cote Blanche Bays although such an observation may be biased by a tendency of the postlarvae to become more concentrated in the pass than in the bays.



Numbers of shrimp postlarvae taken at four stations in Vermilion Bay, La., 1963.

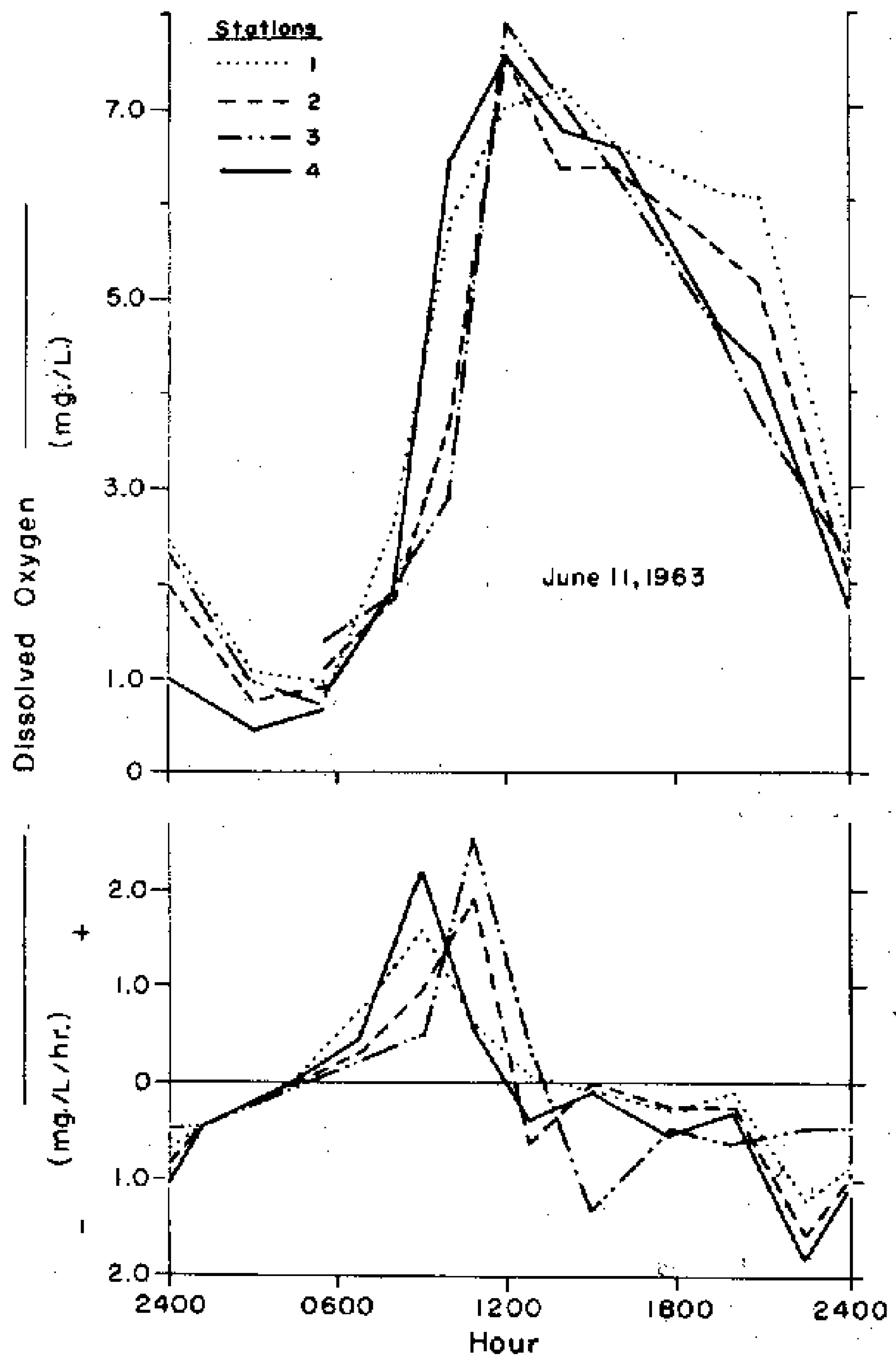
Hydrological observations were also made at the time each biological sample was taken. The salinity throughout the study area was generally very low. The highest salinity, 14.6‰ was recorded at Southwest Pass on June 11. The average low salinity for all stations was 1.7‰ and the average high 6.0‰. During the period of study, Vermilion Bay was virtually a body of fresh water. The lowest temperature of 21° C. (70° F.) was recorded on April 6. The highest temperature of about 33° C. (91° F.) occurred on June 15. The pH varied from 7.3 to 8.3.

Seasonal Distribution of Adult and Larval Shrimp in Aransas Pass (Texas) Inlet

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

Beginning in April 1962, semimonthly sampling for plankton in 24-hr. sequences was undertaken in the Aransas Pass Inlet. During these sequences, samples are being taken just below the surface and off the bottom.

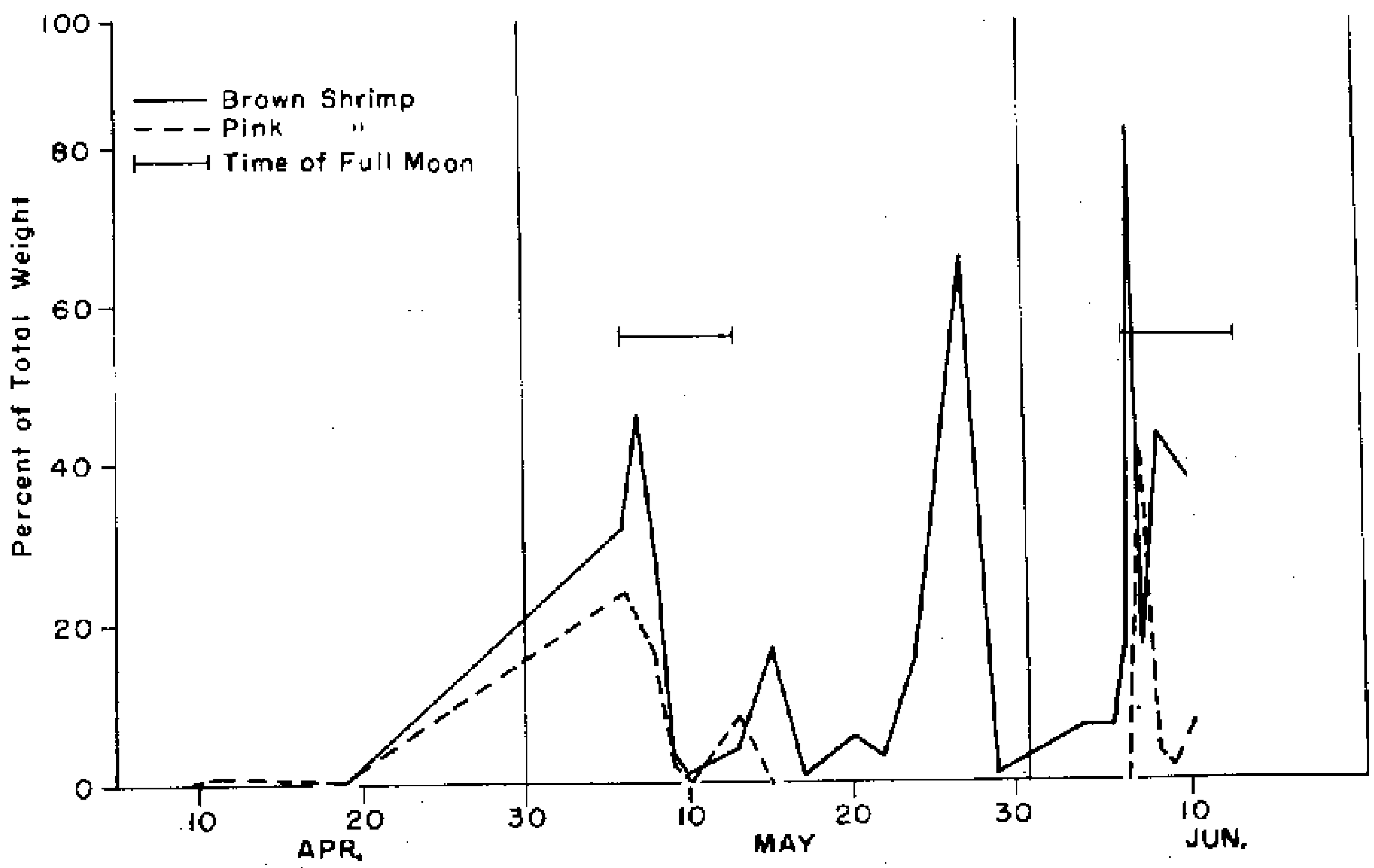
In March, a small concrete pond was sodded with mud and turtle grass from Redfish Bay and flooded with about 2 ft. of sea water diluted to 25‰ salinity. Representatives of the fauna of Redfish Bay were then transferred to the pond. Diurnal curves for both oxygen and carbon dioxide metabolism were determined on two occasions at four stations in the pond, although no measurements were made of either the weight or the metabolic role of the introduced fauna. Oxygen concentrations varied from less than 1 mg. /liter just before dawn to 7.8 mg. /liter at noon. Variation between stations was greatest at night. Maximum photosynthesis occurred during the morning hours, and maximum respiration



Diurnal oxygen curves at four points in an experimental pond sodded with vegetation from Redfish Bay.

occurred during the late evening hours. These diurnal variations were similar to those observed in Redfish Bay.

A "tide trap" is being operated in Aransas Inlet during the maximum ebb and flood currents three times a week. Generally speaking, fewer shrimp have been captured per volume of water filtered during flood tides than during ebb tides. The apparent conclusion is that juvenile and adult shrimp were migrating out of the bays. In May and June, during two periods coinciding with large movements of juveniles and adults through the pass, samples were collected daily. Between May 6 and 9, 1,129 brown shrimp and 216 pink shrimp were caught. Most of the brown shrimp ranged in total length from 70 mm. to 80 mm. No pattern in the distribution of their lengths was evident for the pink shrimp. Between June 7 and 10, 283 brown shrimp and 305 pink shrimp



Catch of brown and pink shrimp made with the "tide trap" in Aransas Pass, Tex.

were sampled. Two peaks of abundance were noted for the brown shrimp, one of small amplitude at 50-60 mm. total length and a larger one at 70-85 mm. In the case of the pink shrimp, a peak was observed at the 70-75 mm. length class. It is interesting to note that peak migrations of both species occurred at the time of full moon.

Life History Stages of Gulf of Mexico Brown Shrimp

William C. Renfro

With research on the biology and dynamics of all stages of shrimp expanding rapidly along the Gulf coast, there has arisen a need to standardize criteria used to classify shrimp according to their life history stage. The purpose of this report is to propose a set of standard terms for the life stages of the brown shrimp, Penaeus aztecus (Penaeidae), in the Gulf of Mexico. It was necessary to be quite arbitrary in defining some of these terms which will be of value only when they are generally accepted and used. Total length (tip of rostrum to end of tail) was selected as the criterion for separating stages more advanced than the postlarval. This is a common field measurement, and graphs and formulae are available for its conversion to carapace length or to weight.

In developmental sequence, life history stages of the brown shrimp are as follows:

Embryo - Includes stages contained within the egg from fertilization to the moment of hatching.

Larva - Includes the following stages:

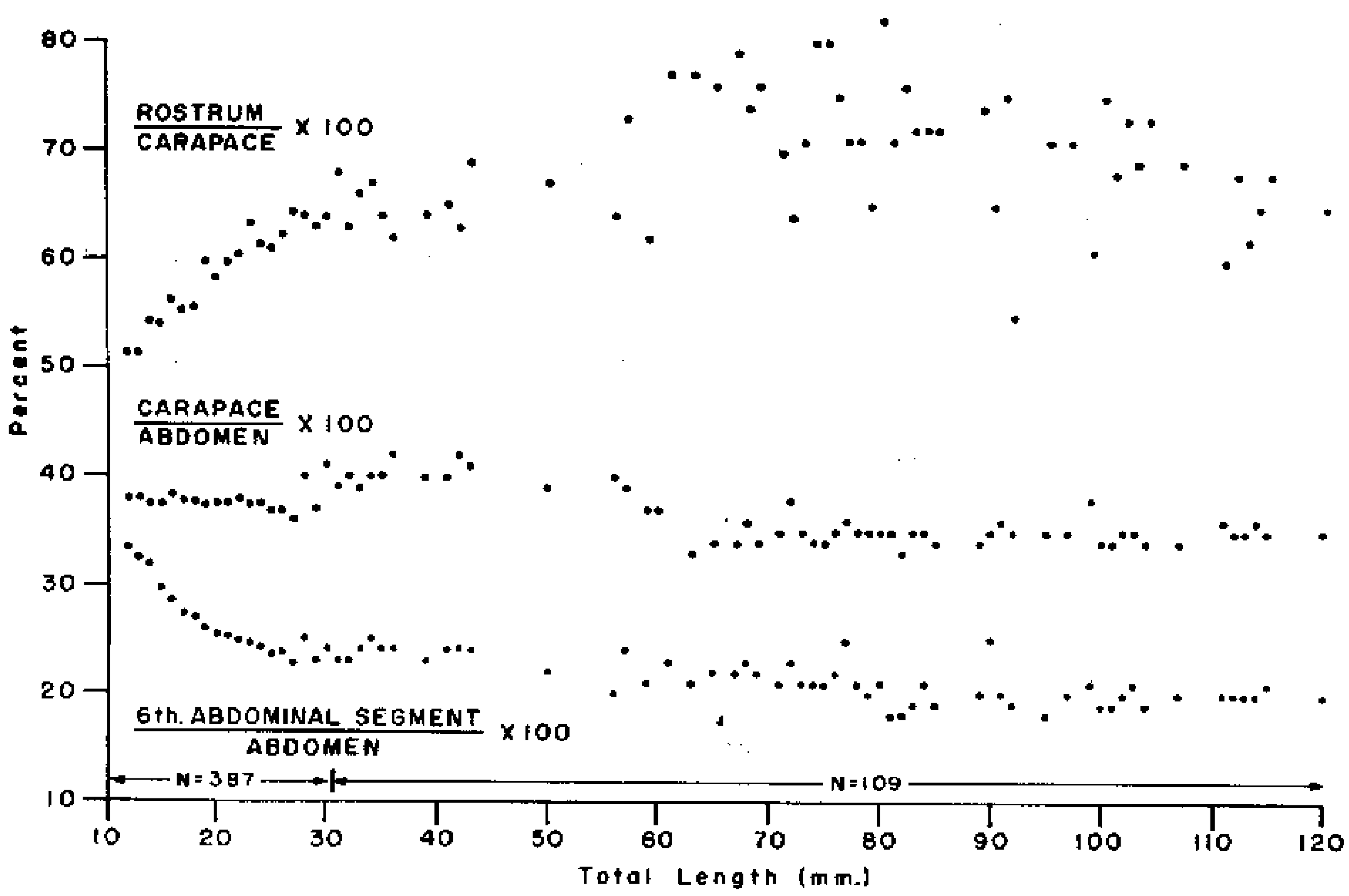
1. Nauplius
2. Protozoea
3. Mysis

These stages have been described in detail for other penaeid species by Pearson (1939), Hudinaga (1942), Dobkin (1961), and others.

Postlarva - The postlarval stage begins with the molt of the last mysis stage. The first postlarva differs from the last mysis stage in the loss of exopods from its pereiopods (walking legs). It is during the postlarval stage that young shrimp generally enter estuarine nursery grounds and make the transition from a pelagic to a benthic, shallow-water existence.

The most striking morphological characteristic of the early postlarva is the relatively great length of its sixth abdominal segment. As the postlarva grows, this segment becomes proportionately shorter although it remains the longest abdominal segment throughout the shrimp's life.

The accompanying figure shows the ratios of the lengths of several body parts in a series of brown shrimp caught as postlarvae in Galveston Entrance and reared under laboratory conditions. Note the definite change in the slope of the curve depicting the ratio of sixth abdominal segment to abdomen length as a function of total length. Clearly, the young shrimp approaches juvenile body configuration on reaching a total length of between 20 and 30 mm. For convenience, we may arbitrarily define the postlarval stage as ending at a total length of 24.9 mm. This definition is in general agreement with the results of others who have studied young Penaeus shrimp. Working with P. japonicus, Hudinaga (1942, p. 351) presented a graph of the proportions of a number of body parts for specimens ranging from Postlarva 1 (5 mm.) to Postlarva 22 (42 mm.). His graph showed that the ratios of lengths of most body components fluctuated widely until the Postlarva 16 stage (about 21 mm.) was reached, when the proportions became fairly constant. Eldred (1958) observed that the external genitalia of pink shrimp, P. duorarum, were first discernible at lengths around 22 to 30 mm. Williams (1953) showed that white (P. setiferus), brown, and pink shrimp first attained fairly distinctive uropod pigmentation and rostrum shape at about 20 mm.



Juvenile - As arbitrarily defined above, the juvenile stage begins when the young shrimp reaches a length of 25 mm.

Subadult - Field studies have shown that young brown shrimp generally grow rapidly to lengths of about 80 to 100 mm. before leaving the estuarine nursery grounds. On reaching oceanic waters, they are usually found near shore for a while and are distinguished by their relatively small size and, in the case of the females, by their immature ovaries. Studies of shrimp spawning populations now in progress in the northwestern Gulf of Mexico are providing some insight into the degree of ovary maturity of these recruits to the offshore populations.

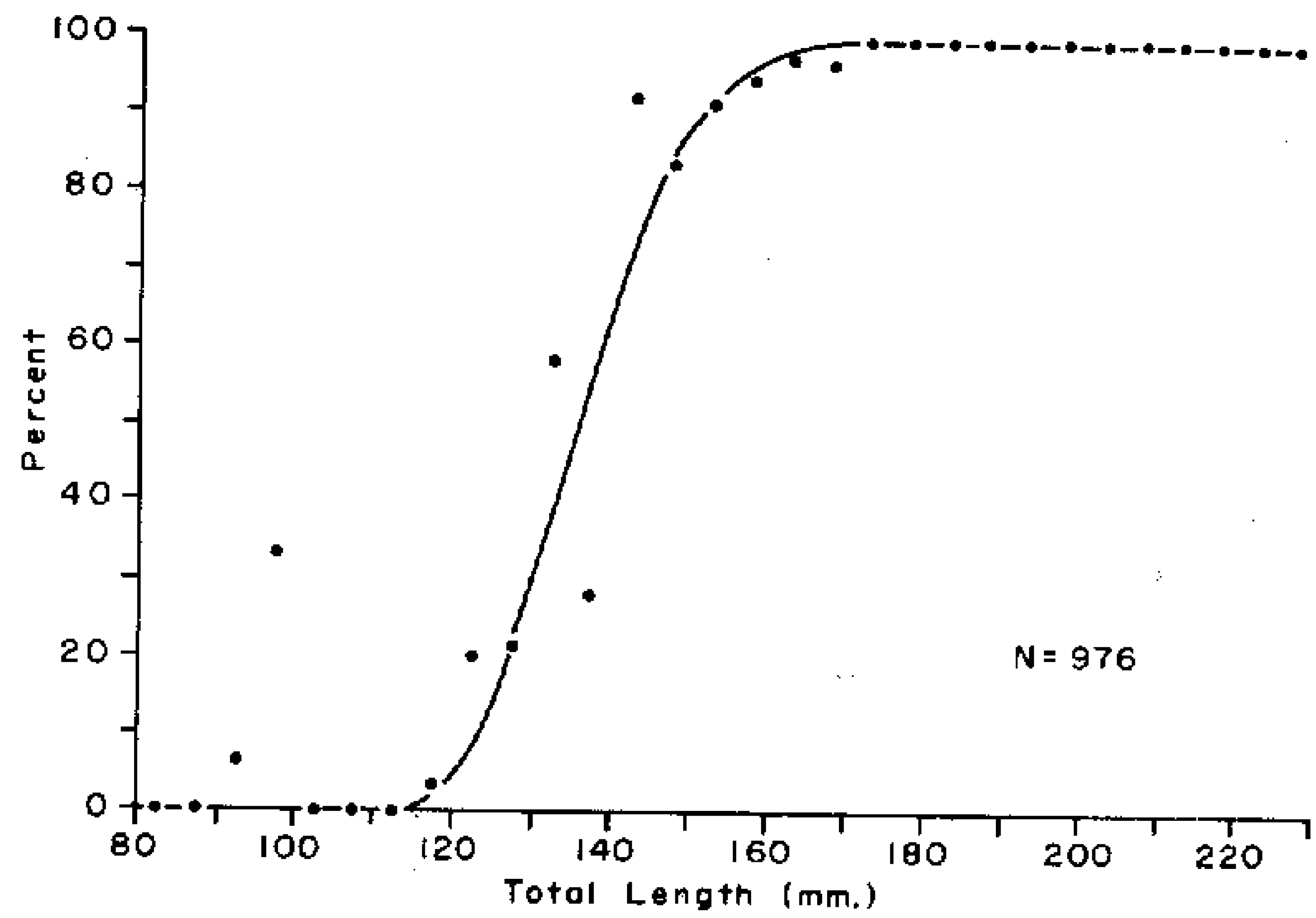
The following table gives results of the examination of brown shrimp ovaries obtained in the Gulf of Mexico between Freeport, Tex., and Cameron, La., during 1961.

Total length	U	ED	D	LD	R	SP	Total
mm.							
80-84	1	3					4
85	2	5					7
90	4	10	1				15
95	1	5	3				9
100		15					15
105	1	20					21
110		24					24
115		26	1				27
120		20	5				25
125	2	20	4	2			28
130		13	10	5	1	2	31
135		18	4	3			25
140		2	10	9	2	3	26
145		5	20	3	1	2	31
150		2	6	9	2	5	24
155		2	8	17	7	2	36
160		1	9	14	12	8	44
165		2	9	46	6	4	67
170			4	27	9	5	45
175			6	30	10	1	47
180			7	25	11	3	46
185			5	47	10	9	71
190			2	46	12	6	66
195			1	35	11	6	53
200			5	36	13	8	62
205			5	30	10	4	49
210				22	10	8	40
215			3	16	4	2	25
220			1	2	2	3	8
225-229				1	2	2	5
Totals	11	193	129	425	135	83	976

Note: 363 females with "D" or "LD" ovaries showing evidence of prior spawning have been excluded - 11 of these measured less than 140 mm.

Stages of ovary development were determined by histological examination of stained slide mounts and included: "Undeveloped" (U), "Early Developing" (ED), "Developing" (D), "Late Developing" (LD), "Ripe" (R), and "Spent" (SP). Since most of the recently immigrated females (those below 140 mm.) possessed "Undeveloped" or "Early Developing" ovaries, they were not sufficiently mature to be considered part of the spawning population. It is proposed that such shrimp be termed subadults and that the subadult stage be arbitrarily defined as beginning at a length of 90 mm.

Adult - The adult stage begins at sexual maturity, i.e., the point at which females are first capable of spawning. The accompanying figure,



Length frequency distribution of brown shrimp females with developing, late developing, ripe, and recently spent ovaries.

which presents graphically the data in the foregoing table, indicates that females attain sexual maturity at lengths of about 140 mm. or longer. Because little information is at present available regarding the length at which males become sexually mature, it is proposed that both sexes be considered adult at total lengths of 140 mm. or greater.

In summary, criteria for classifying Gulf of Mexico brown shrimp according to their life history stage are proposed as follows:

Life stage	Begins at:
Embryo	Fertilization
Larva	Hatching
Postlarva	Loss of exopods from pereiopods
Juvenile	25 mm. total length
Subadult	90 mm. total length
Adult	140 mm. total length

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Library

Stella Breedlove

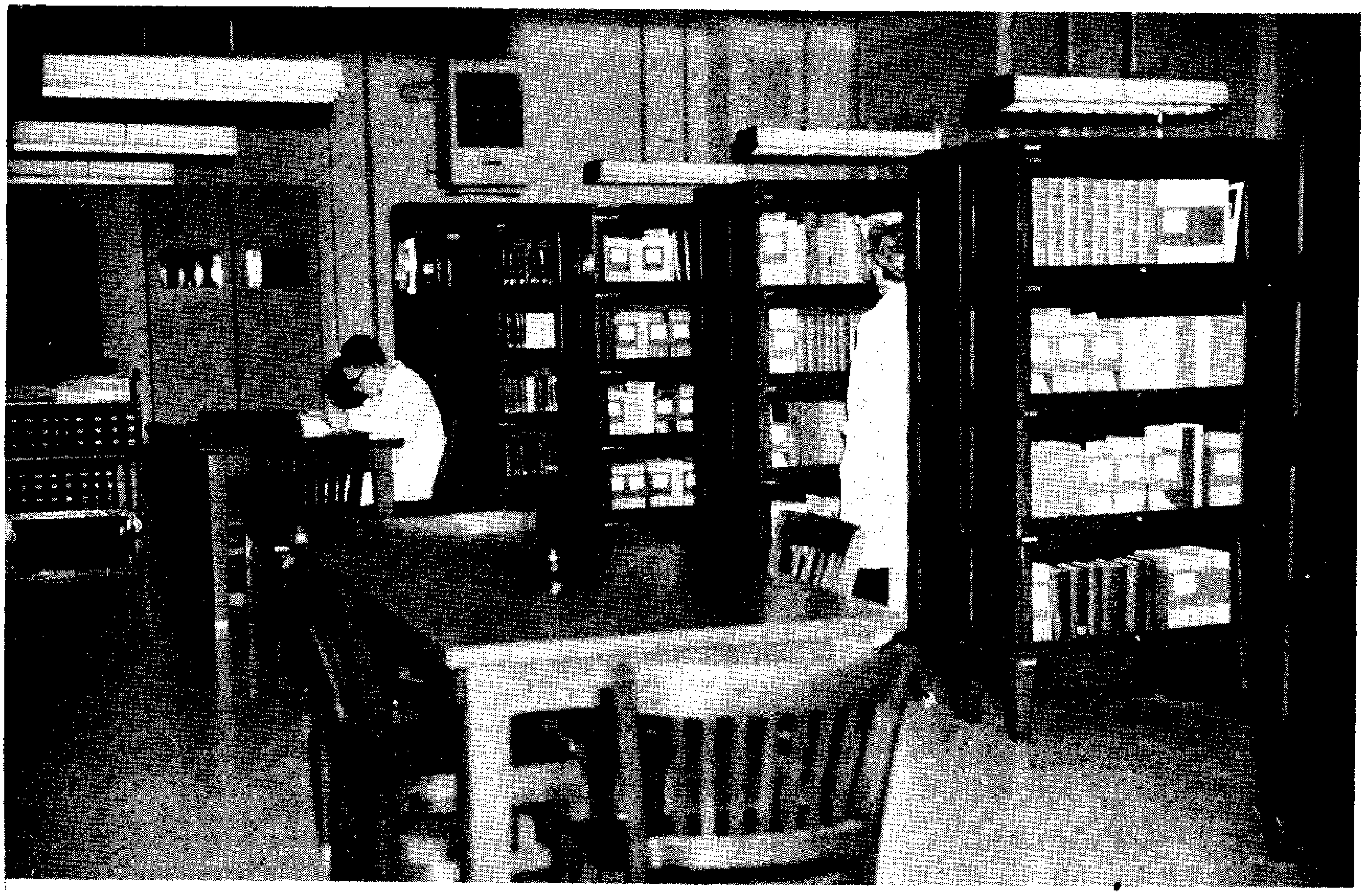
Included in library acquisitions during the year were 452 volumes of books and journals and 2,861 reprints and miscellaneous items. All materials have been processed and are available for use.

In October 1962, 103 volumes were withdrawn from the library collection and transferred to the library of the Biological Station, East Gulf Estuarine Investigations, St. Petersburg Beach, Fla. These items, mostly duplicates, had been on indefinite loan to the St. Petersburg Field Station for use by its personnel.

Fifty-eight volumes, including a number of theses, were borrowed by the staff through the interlibrary loan service, while 85 volumes were loaned to other libraries and institutions, including the Library of the School of Medicine, University of Texas, and the Texas A. and M. Marine Laboratory.

The library handled approximately 1,250 reference questions during the year, and an estimated 3,000 items were circulated to the staff. Many inquiries were received from other libraries and individuals in the area concerning information about our collection. As our own library has acquired needed materials, there has been a progressive decrease in the use by the Laboratory staff of other libraries in this region.

The biennial inventory of the library collection was completed in the spring of 1963. A total of 116 volumes of journals was bound or prepared for binding during the year. The library contacted over 60 other laboratories and Government offices for official publications on fishery science and related fields and received satisfactory responses in each case. Preparation of the weekly list of library acquisitions was continued for distribution to the staff and to other laboratories, four of which are outside the United States Fish and Wildlife Service. The library also continued to prepare the quarterly list of "Recent Publications" for the Transactions of the American Fisheries Society.



View showing new accommodations for expanding library.

MEETINGS ATTENDED*

Third Seminar on Biological Problems in Water Pollution, U. S. Public Health Service, Cincinnati, Ohio, August (3)

International Congress of Limnology, Madison, Wis., August (1)

American Society of Limnology and Oceanography (with American Institute of Biological Sciences), Corvallis, Ore., August (1)

American Fisheries Society, Jackson Hole, Wyo., September (3)

International Council for the Exploration of the Sea (Symposium and Statutory Meeting), Copenhagen, Denmark, September-October (1)

Gulf States Marine Fisheries Commission, Dauphin Island, Ala., October (3)

Gulf and Caribbean Fisheries Institute, Galveston, Tex., November (8)

American Geological Society, Houston, Tex., November (1)

Joint meeting of Southern Interstate Nuclear Board, Texas Committee on Atomic Energy, and Harris County-Houston Ship Channel Navigation District, on "The Handling of Nuclear Shipments in Port Communities," Houston, Tex., November (1)

Texas Shrimp Association, Corpus Christi, Tex., January (2)

Louisiana Shrimp Association, Houma, La., February (2)

Gulf States Marine Fisheries Commission, Clearwater, Fla., March (5)

1963 World Fishing Exhibition, Earls Court, London, England, May (1)

Bureau of Commercial Fisheries, Third Annual Laboratory Director's Conference, Ann Arbor, Mich., May (1)

*Attendance shown in parentheses.

Gulf States Marine Fisheries Commission, Shrimp Research Committee, meeting with State biologists, New Orleans, La., September (2)

Meeting with personnel of East Gulf Estuarine Investigations to assist in organizing the station's new library, St. Petersburg Beach, Fla., October (1)

Meeting with spokesmen for Galveston area shrimp producers to advise on biological matters arising in connection with newly proposed legislation for regulating the Texas shrimp fishery, Galveston, Tex., December (2)

Texas Water Pollution Control Board, Austin, Tex., January (1)

Meeting to plan for the Bureau-sponsored "Symposium on Estuarine Research" scheduled for April 1964, St. Petersburg Beach, Fla., January (1)

Meeting of Representatives of the Bureau of Commercial Fisheries, Public Health Service, Office of River Basin Studies, and State of South Carolina to discuss the Proposed Copper River Rediversion Project and other engineering projects planned for the Gulf coast area, Atlanta, Ga., February (1)

Conference with Corps of Engineers personnel on the Hurricane Protection Project for the Texas coast, Galveston, Tex., February (1)

Meeting to discuss plans for coordinated research on long-range effects of electrical stimuli on shrimp with personnel of the Bureau's Exploratory Fishing and Gear Research Station, Galveston, Tex., February (1)

Fish and Wildlife Service coordination meeting relative to the Texas Basins Project, Austin, Tex., February (1)

Conference with Branch of River Basin Studies personnel relative to hurricane protection projects along the Texas coast, Fort Worth, Tex., February (1)

Coordination meeting with Bureau of Sport Fisheries and Wildlife relative to status of engineering projects potentially affecting fishery resources along the Texas coast, Fort Worth, Tex., April (1)

Public meeting called by Texas Water Pollution Control Board, Webster, Tex., April (1)

Bureau of Sport Fisheries and Wildlife, Regional Conference, Athens, Ga., April (1)

Hurricane Conference, U. S. Weather Bureau, Galveston, Tex. May (1)

Conference to assist in the selection of sampling stations for proposed interim study of the Mississippi River-Gulf Outlet Project, Vicksburg, Miss., June (2)

Preliminary meeting of Texas Water Pollution Control Board to discuss preliminary survey plans and arrange for exchange of hydrological data, Galveston, Tex., June (1)

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*Contract Research

MS #1358