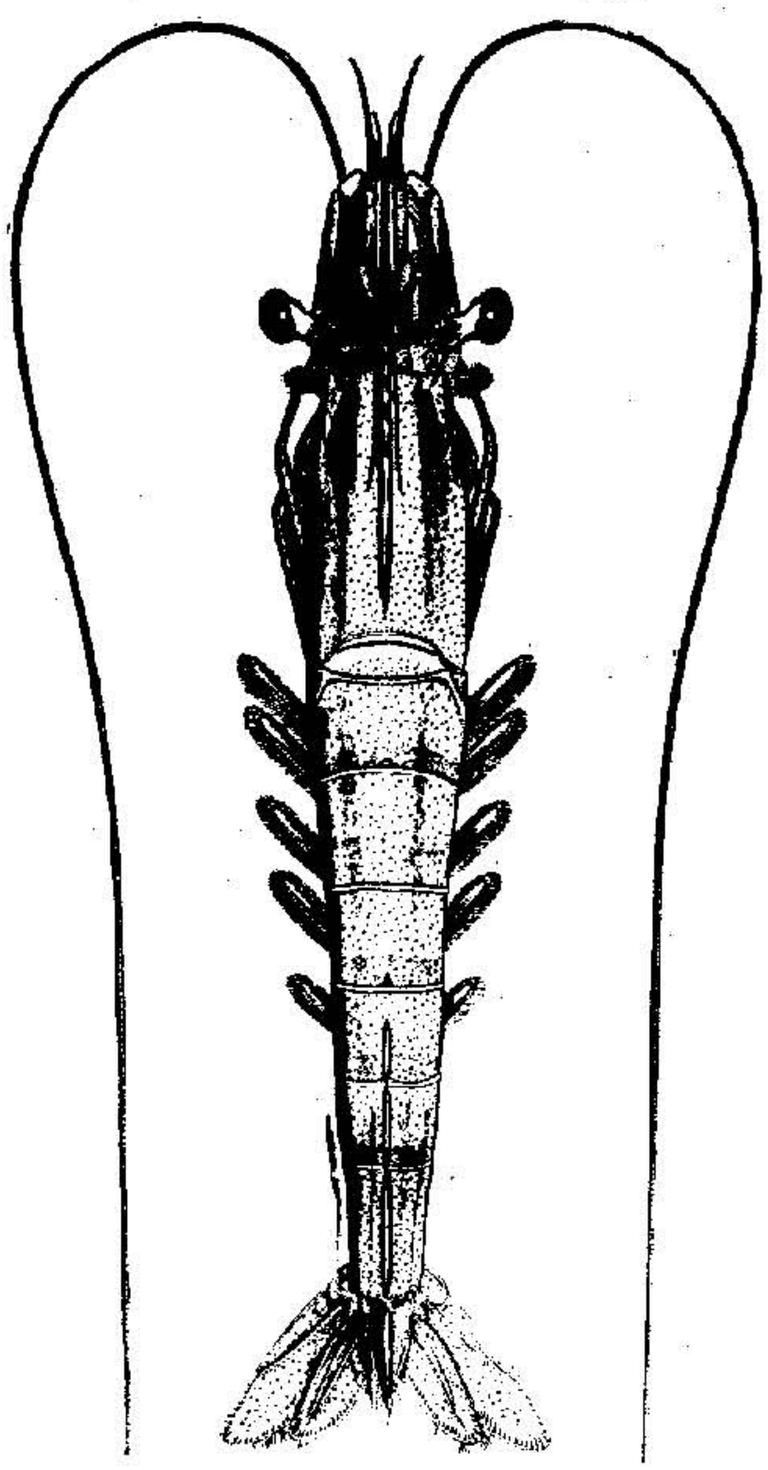
United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner

GALVESTON BIOLOGICAL LABORATORY

FISHERY RESEARCH

for the year ending June 30, 1959

George A. Rounsefell, Director
Bernard E. Skud, Assistant Director
Bureau of Commercial Fisheries



Circular 62

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REPORT OF THE DIRECTOR

George A. Rounsefell

Research highlights of the past year Perhaps first is the successful field use of the newly developed techniques for marking shrimp with vital stains so that they may not only molt without mortality, but also without losing their mark. We may now mark juvenile shrimp on the nursery grounds and follow their growth and their movement into the commercial fishery. Using this new method we have shown that the protected bays of the Everglades National Park are an important nursery area for the Tortugas pink shrimp fishery. Juvenile pink shrimp marked in the Park were recaptured after traveling over 100 miles to the Tortugas grounds. They tripled their weight in four months. A recent marking of young brown shrimp in Galveston Bay has already shown them traveling up to 25 miles in one week.

For the first time we have assessed the extent and value of the industrial fishery. It is expanding with amazing rapidity and holds great promise of aiding the existing fisheries in two ways: (1) by furnishing off-season raw material and employment to the established menhaden fishery, and (2) by providing a means of utilizing the fishing capacity of the shrimp trawlers during periods of the year when shrimp are scarce. The industry is presently fishing chiefly inside the 20-fathom curve in Mississippi Sound and off the Mississippi River delta, taking about 104 species of fish. The products are canned pet food, fishmeal for stock and poultry feed, frozen mink feed, and fish oils.

The intensive ecological study of Tampa Bay and adjacent waters initiated after last year's red tide symposium has already disclosed new facts, (1) the incidence of Gymnodinium breve was higher in off-shore waters than in estuarine situations during the colder months (the organism was located 60 miles off the Florida coast), and (2) phosphorus, which is important to the growth of the red tide organism, accumulated during the winter in the open waters of Tampa Bay in concentrations which exceeded that of the contributing drainage systems.

Gulf States Marine Fisheries Commission As in past years staff members attended the meetings of the Gulf States Marine Fisheries Commission at Biloxi, Mississippi, and New Orleans, Louisiana, participating in discussions on various topics.

As the primary research agency for the Commission, the Bureau reviewed the expanded shrimp research program endorsed by the Commission in 1954 but never fully implemented. It was shown that the need was even more acute now than when the original program was drawn up. A revised program was presented and endorsed by the Commission.

River Basin surveys The Office of River Basin Studies in the Bureau of Sport Fish and Wildlife prepares the final consolidated reports by the Fish and Wildlife Service on engineering projects constructed by federal agencies or under federal license. However, the Bureau of Commercial Fisheries is responsible for research on the commercial fisheries affected. This responsibility is being discharged in three ways:

1. By reviewing reports prepared by the Office of River Basin Studies on marine or tidal waters, or on projects which will affect the volume or seasonal regime of discharges of rivers emptying into marine waters.

2. By short period assignment of scientific personnel to work with River Basin personnel in making short-term surveys of projects.

3. By furnishing supervision and guidance for contract research performed on larger projects.

Under the second item Mr. Arnold made two visits to Florida to work with River Basin personnel on sections of the west coast Intracoastal Waterway--one between Fort Myers and Lemon Bay, the other near Caladesi and Honeymoon Islands.

The Laboratory staff conferred with the Vero Beach Office of River Basin Studies concerning the possible effects on red tide occurrence of certain changes proposed by the Corps of Engineers in the Caloosahatchee project. These would change both the seasonal regime and the maximum possible discharge through the Caloosahatchee of the waters of Lake Okechobee.

The staff held several conferences with the Ft. Worth River Basin staff on the possible effects of the Gulf Basins project under study by the Bureau of Reclamation. The staff also participated in two meetings of the Southwest Field Committee of the Department of Interior in which river basin development was a major topic. The Bureau of Reclamation has furnished the Laboratory with a large compilation of hydrological data on the Gulf Basins project. These need to be studied in relation to their effect on bay and estuarine salinities but no funds are presently available for this purpose.

The Laboratory is currently supervising contract research by the Texas A. and M. Research Foundation on the effects on fisheries of the

Mississippi River-Gulf Outlet project of the Corps of Engineers. A detailed report on progress by Dr. Rae is given elsewhere in this report.

Second annual staff meeting Last year's staff meeting concentrated on the review of 10 years of research on red tide. This was accomplished with the aid of a number of prominent scientists invited by the Director of the Bureau. As a result of this meeting our red tide program was reoriented.

This year the keynote of the annual staff meeting in February was shrimp research. After several days of intense discussion of shrimp migration, nutrition, physiology, and population dynamics, a program was forged which intensified work on growth, mortality, and migration through marking experiments, and which added a study of the identification, movements, and abundance of larval shrimp.

ICA Trainee Program The following individuals visited our laboratory under the auspices of the International Cooperation Administration:

Inocencio A. Ronquillo, Chief, Section of Hydrology and Fisheries Biology, Division of Research, Bureau of Fisheries, Manila, Philippines

Inayot Ullah Kahn, Inspector (Shellfisheries), Central Fisheries Department, Pakistan

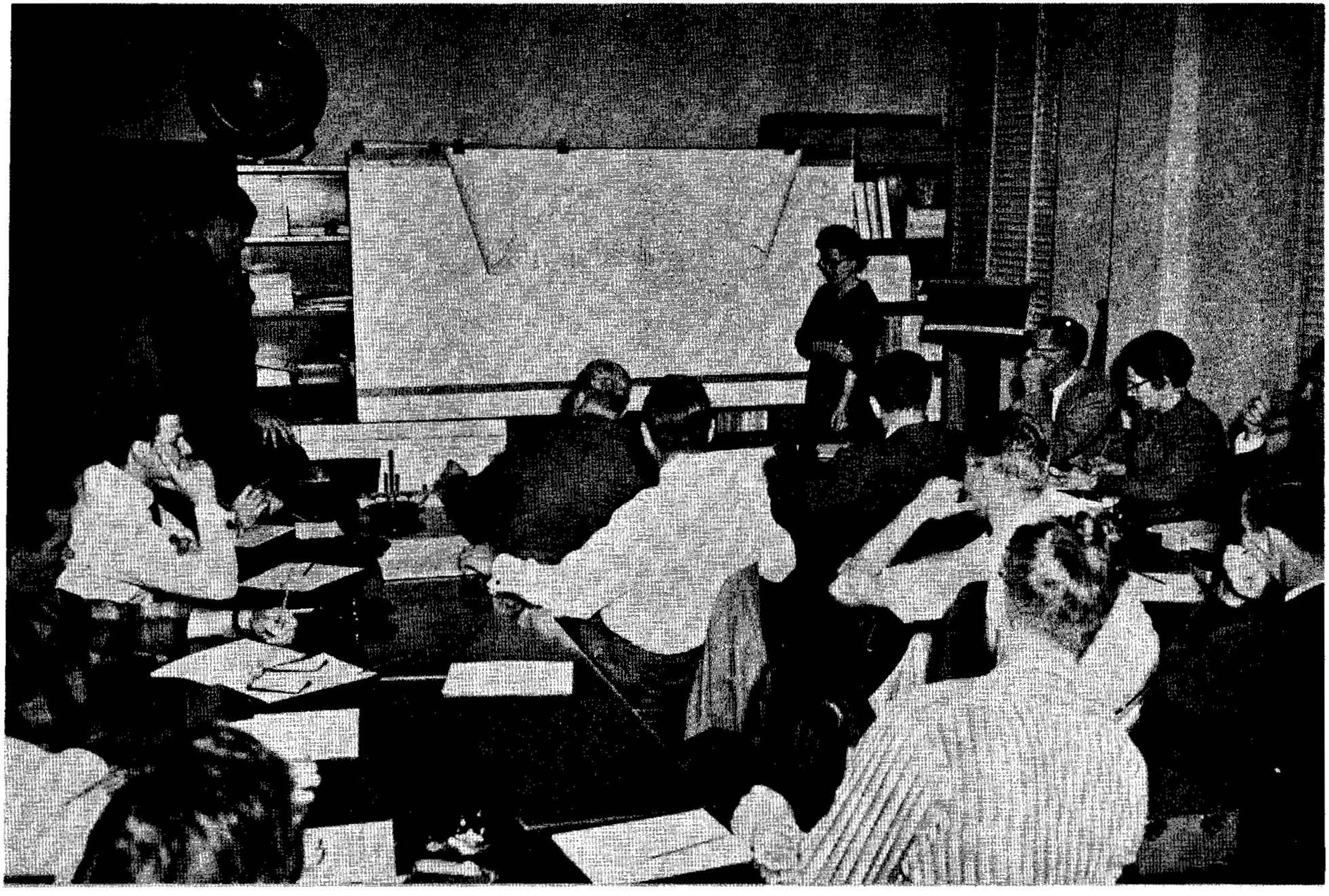
Salam Mohammad Kazmi, Survey and Statistics Officer, Central Fisheries Department, Pakistan

Nazir Husain Bokhari, Secretary, Food and Agricultural Council, Pakistan

Rasso Canly Lamprecht, Civil Engineer, Brazil

Arrangements for training were made at the laboratory to meet the participant's particular area of interest. Mr. W. B. Wilson supervised training concerned with the culture of microscopic marine plants and animals; Mr. E. L. Arnold, the life histories of fishes; Mr. Ed Chin, invertebrate physiology and the shrimp fishery; and Dr. J. H. Kutkuhn, population dynamics and shrimp-catch statistics.

Public relations As in past years, the marine life collection of the Galveston Laboratory was viewed by many appreciative visitors, including several out-of-town science clubs, various scout groups, and the usual complement of school children. Exhibit material from this collection was displayed in the



Second Annual Staff Meeting in the Library

exhibition hall of the Pleasure Pier throughout the 1958 tourist season, and currently is on display at the Texas A. and M. Laboratory, Ft. Crockett.

Material depicting the life history of Gulf shrimp was prepared and sent to the American Museum of Natural History for exhibition.

Edward Chin and Edgar Arnold presented talks on shrimp and sport fishing, respectively, over Galveston's Radio Station KGBC. Mr. Arnold showed and gave a talk on unusual fishes of the Gulf over KPRC-TV, Houston, on a program with the Texas A. and M. Department of Oceanography, under the auspices of the Texas Academy of Science.

Staff members served as judges in the Annual National High School Science Fairs in Galveston, Texas, and Pascagoula, Mississippi.

The Laboratory held open house for interested members of the Texas Shrimp Association during their mid-January annual meeting in Galveston.

LABORATORY FACILITIES

Lawrence E. Wise, Administrative Officer

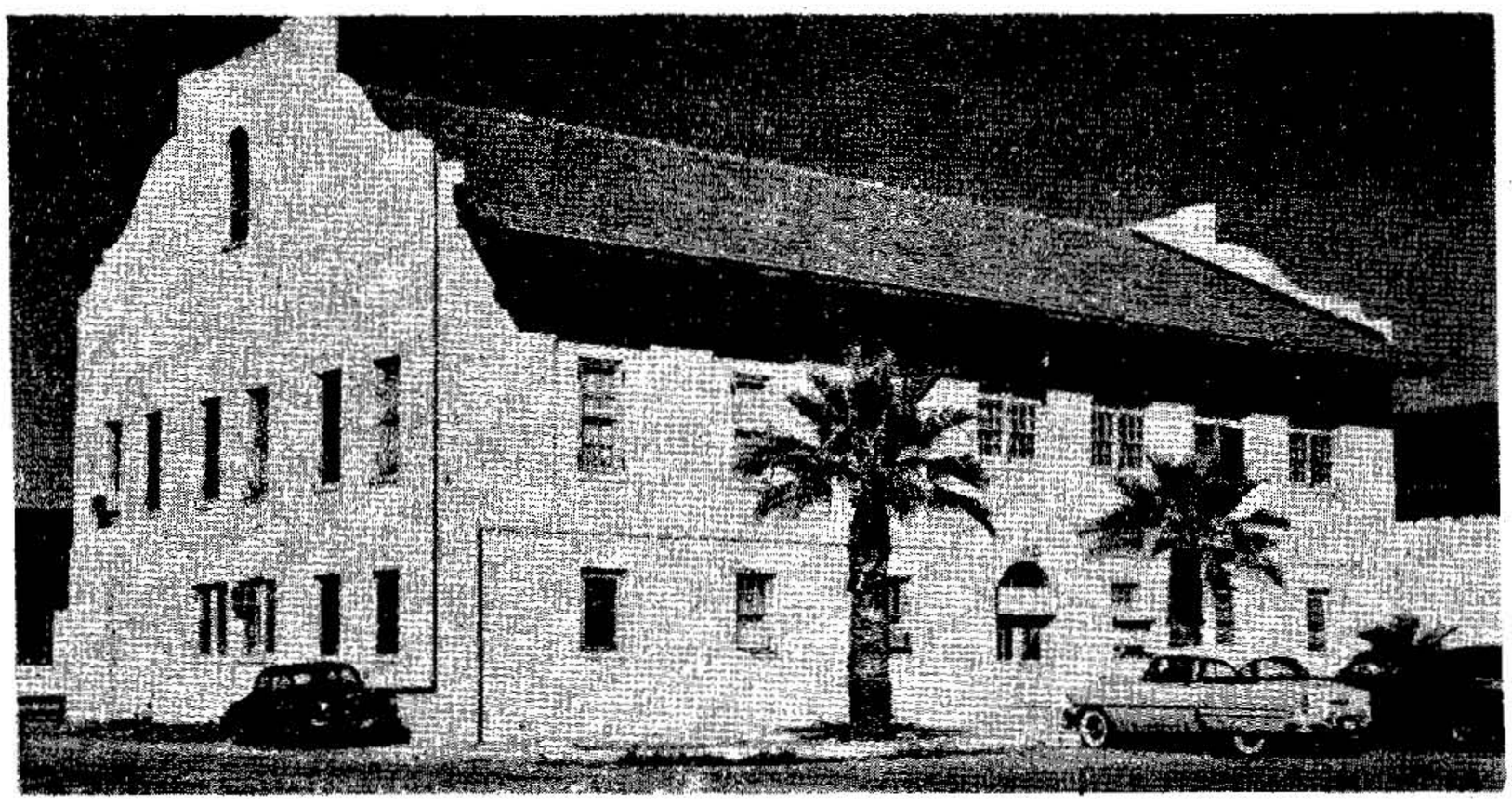
The Galveston Biological Laboratory on the shore of the Gulf occupies seven buildings and covers an area 400 by 200 feet.

The scientific facilities were augmented during the year by construction of an ultra-violet room for transferring cultures, a temperature-controlled fluorescent-lighted room for growing cultures, a temperature-controlled room for housing delicate instruments in the Chemistry laboratory and a plankton sorting room including a long hooded table with a vented fume hood.

Laboratory "A", of masonry construction, houses the Director's offices, a fishery library, and the administrative offices on the second floor. The Estuarine Ecology Investigation and Zooplankton Laboratory are on the first floor. The building is heated by a centralized plant. The second floor is air-conditioned by a large single unit. The first floor has window-type air-conditioners.

Laboratory "A" of the Galveston Biological Laboratory housing the library, shrimp and zooplankton laboratories and the Director's office.

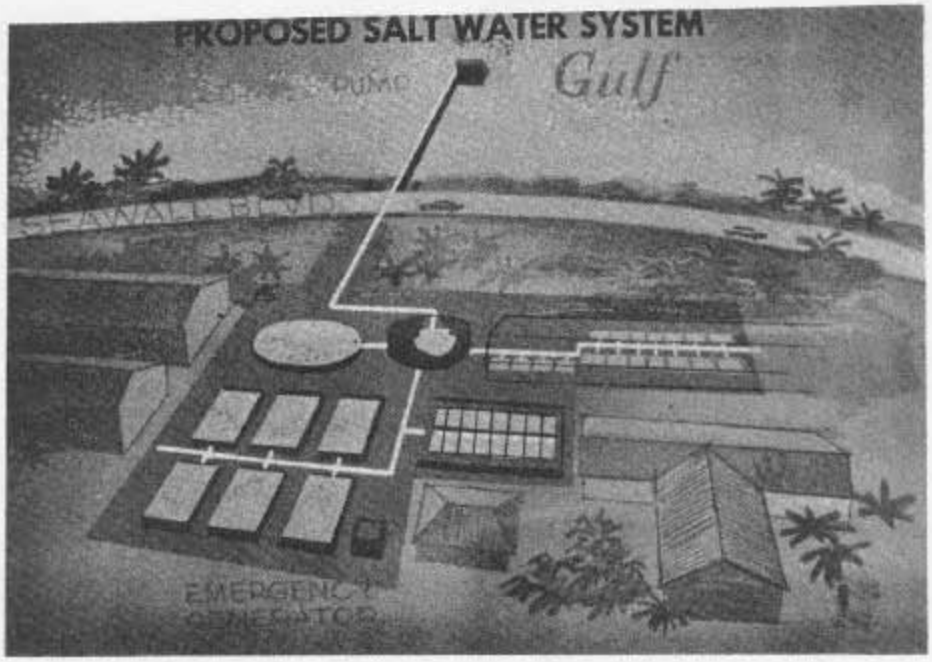
Laboratory "B", a two-story masonry building, houses the Red Tide, Shrimp Fishery and Industrial Fishery Investigations. In addition space has been provided for the Statistical Office presently occupying space in the Post Office building at Galveston. Air-conditioning is accomplished by window-unit air-conditioners. Work is now being done to complete painting on this building and set up additional laboratory space.



Laboratory "B" of the Galveston Biological Laboratory housing the red tide and industrial fishery investigations and the biometrical studies.

Laboratory "C", the Chemistry Laboratory, is a single-story masonry building which has undergone minor repair and been repainted this year. This building has a centralized heating and air-conditioning system. This building also houses the distilled water system for the entire Station. This system was originally set up in two phases; one phase of which was housed in Laboratory "A" and the other phase in Laboratory "C".

Laboratory "D", a single-story masonry building, which will be used for temperature-controlled aquaria and wet laboratory space in connection with the sea-water system to be installed next fiscal year.



Preliminary sketches of the sea-water system to be installed in the Galveston Laboratory.

Building "E", a single-story wooden building, is currently used for storage of equipment and supplies but can be adapted for laboratories when the need arises.

The shop is well equipped with power and hand tools and has adequate space for building equipment for experiments, such as tanks, holding pens, etc.

The garage, a single-story wooden building, is of adequate size to house our motor vehicles which include one sedan, two carry-alls, one pick-up truck, boats and boat trailers.

All of the buildings have been painted by our maintenancemen during this fiscal year with the exception of Laboratory "B" which will be painted by July 31.

Formal transfer of the property from General Services Administration was consummated during the fiscal year as well as transfer of a certain portion of the East Lagoon.

STAFF

George A. Rounsefell, Director
Bernard E. Skud, Assistant Director

Headquarters: Galveston, Texas
Field Stations: Miami, Florida
Pascagoula, Mississippi
St. Petersburg Beach, Florida

Red Tide Investigation

William B. Wilson	Chief	Galveston
David V. Aldrich	Microbiologist	Galveston
Alexander Dragovich	Fishery Research Biologist	St. Petersburg
John H. Finucane	Fishery Research Biologist	St. Petersburg
Billie Z. May	Head, Field Station	St. Petersburg
John E. Watson	Head, Field Station (trfd. 8/58)	St. Petersburg
John D. McCormick	Master, M/V KINGFISH	St. Petersburg
McKinley W. Jambor	Biological Aid	St. Petersburg
Lucius Johnson, Jr.	Physical Science Aid	St. Petersburg
Alice Kitchel	Biological Aid	Galveston
Domingo R. Martinez	Biological Aid	Galveston

Estuarine Ecology Investigation

Edward Chin	Chief	Galveston
Anthony Inglis	Fishery Research Biologist	Galveston
John G. VanDerwalker	Fishery Research Biologist	Galveston
Zoula P. Zein-Eldin	Biochemist	Galveston
Gilbert Zamora, Jr.	Fishery Aid	Galveston
Genevieve B. Adams	Statistical Clerk	Galveston
Imogene A. Sanderson	Physical Science Aid	Galveston
William G. Wilkerson	Fishery Aid	Galveston
Samuel C. Jernigan	Fishery Aid	Galveston

Shrimp Fishery Investigation

Joseph H. Kutkuhn	Chief	Galveston
Donald M. Allen	Fishery Research Biologist	Miami
Thomas J. Costello	Head, Field Station	Miami
Ray S. Wheeler	Fishery Research Biologist	Galveston
Kenneth N. Baxter	Fishery Aid	Galveston
James A. Eiland	Fishery Aid	Galveston
Hanford M. Harris	Fishery Aid	Galveston

Industrial Fishery Investigation

Edgar L. Arnold, Jr.	Chief	Galveston
James P. Cating	Head, Field Station	Pascagoula
Rupert E. Andrews	(Resigned June 1959)	Pascagoula
Lawrence F. Schumacher, III	Fishery Aid	Galveston

Staff Services

Chemistry Laboratory

Kenneth T. Marvin	Chief Chemist	Galveston
Larence M. Lansford	Chemistry Aid	Galveston
Raphael R. Proctor, Jr.	Fishery Aid	Galveston

Zooplankton Laboratory

Abraham Fleminger	Fishery Research Biologist	Galveston

Library

Stella M. Breedlove	Librarian	Galveston

Technical Services

Daniel Patlan	Draftsman	Galveston
Ruth W. Yanch	Secretary	Galveston
Esther E. Sell	Secretary	Galveston
Petronila C. Prado	Scientific Stenographer	Galveston
Mary E. Hipple	Clerk-typist	St. Petersburg

Administration and Maintenance

Lawrence E. Wise	Administrative Officer	Galveston
Tidas C. Alcorn	Maintenanceman	Galveston
Lucille A. Barlow	Clerk-typist	Galveston
Glo S. Baxter	Clerk-stenographer	Galveston
Corinna L. Denbo	Purchasing Clerk	Galveston
Laura M. Hermann	Administrative Assistant	St. Petersburg
Robert L. McMahon	Maintenanceman	Galveston
Sarah M. Robison	App. Accounting Clerk	Galveston
Peter M. Villarreal	Maintenanceman	Galveston

Staff of the Galveston Biological Laboratory

SHRIMP FISHERY INVESTIGATION

Joseph H. Kutkuhn
Chief

This investigation studies abundance trends of the Gulf of Mexico's commercial shrimp resources. Commercial catch data are supplied by the Statistical Branch, Bureau of Commercial Fisheries. The research can be conveniently subdivided on the basis of two components of a single immediate objective - total stock assessment. On the one hand, we are concerned with determining population abundance trends for fished portions of arbitrarily defined penaeid populations on a Gulf-wide basis. On the other, we desire adequate measures not only of spawning stock density, but of the resultant progeny's pre-exploitation abundance as well.

In assessing the stocks, primary consideration has been given the search for a method of estimation that will extract maximum information from the available statistics. Implicit in such a method are the delineation and proper treatment of biases that may be encountered. Involved are the basic quality and general completeness of commercial yield and effort data; and hence their capacity to reflect, for example, actual spatial and temporal distribution of shrimping effort and differential fishing capacity of vessels and gear.

In evaluating parameters of pre-exploitable portions of commercial fish or shellfish populations, required data must necessarily be collected by the research agency itself. This poses problems unlike those associated with acquiring data to assess exploitable portions of the same populations. Factors that had to be considered were (1) selection of an appropriate study area; (2) design of the most efficient sampling schemes and devices, taking into account the amount of available manpower and funds; and (3) regardless of their developmental stage, substantiation of the identity of all species under scrutiny.

Unfortunately, analysis of commercial catches and research vessel samples may not always lead to satisfactory evaluation of parameters describing these populations. Perhaps the most important of these - growth and mortality - can often be independently assessed through marking and recovery experiments. Although initially developed to ascertain shrimp movements in specific Gulf areas, staining experiments may also be a useful tool in anticipated population studies.

Migration and Growth of Pink Shrimp

Thomas J. Costello, Jr. and Donald M. Allen

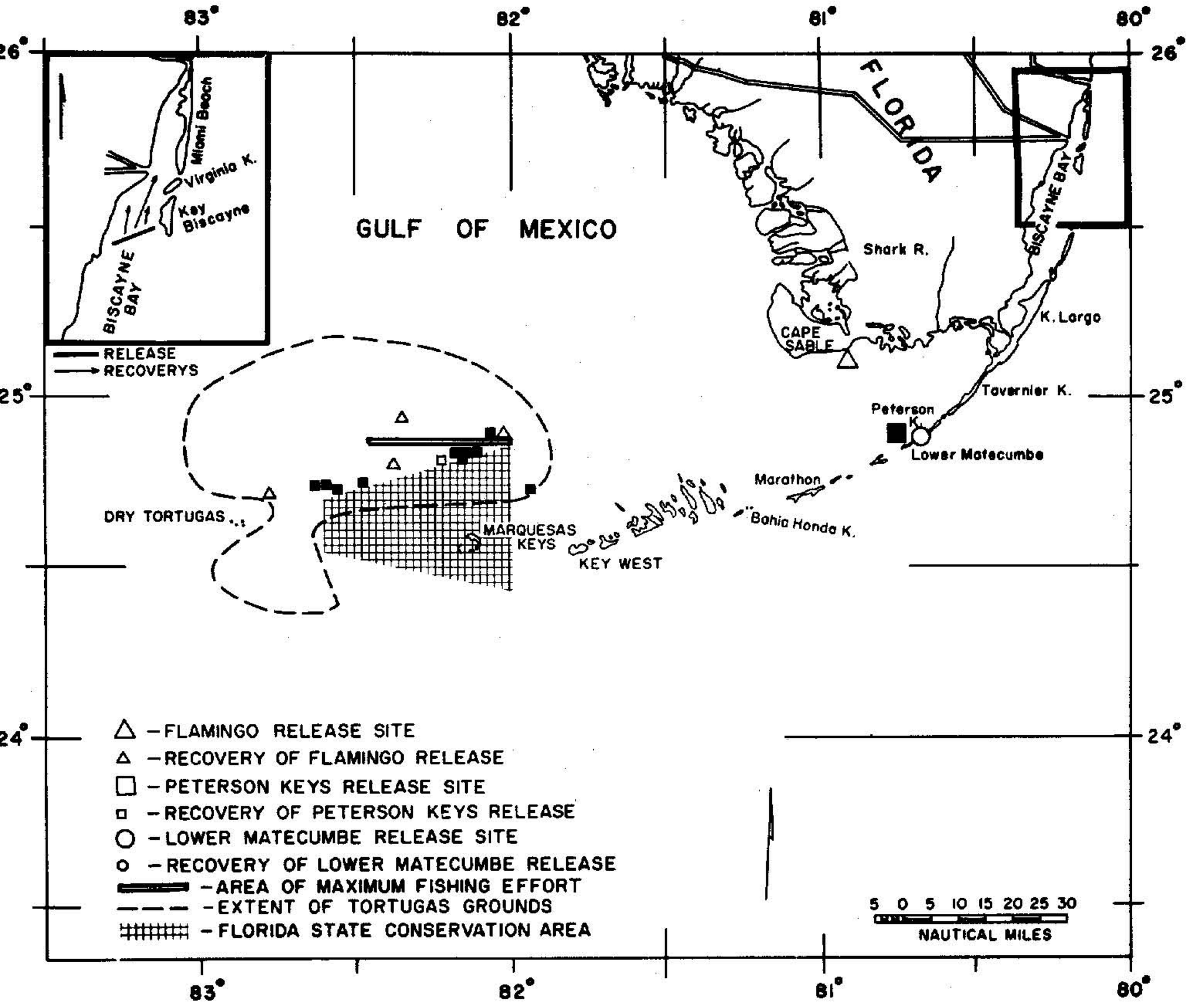
Pink shrimp, Penaeus duorarum, support a well-defined and intensive fishery off Dry Tortugas, Florida. Increasing concern for its projected welfare has dictated attempts to formalize an appropriate management program. Prerequisite to the development of such a program is basic information regarding the environmental requirements during all life history phases of the exploited species.

On the basis of numerous observations, it is generally agreed that an essential requirement for survival and growth of penaeid broods is a so-called inshore "nursery" area. The presumed order of events in penaeid development comprises (1) egg maturation, spawning, and hatching on offshore "grounds"; (2) immediate movement, self-induced or otherwise, of developing meroplanktonic larvae to shallow, inshore areas; (3) metamorphosis and assumption of a benthic existence on the nursery ground; and (4) subsequent migration to offshore habitat.

Mark-Recovery experiments in Florida Bay and adjacent waters The problem is to delineate those inshore areas believed associated with offshore spawning (and hence fishing) grounds, the object being to circumscribe that area containing all segments of the populations upon which the fishery is ultimately based. It should be emphasized that a management program requires an understanding of space-time relationships between parent stock and progeny.

Accordingly, efforts are being made to define nursery areas utilized by individuals comprising what is believed to be a discrete pink shrimp population off the Dry Tortugas. Nursery areas, conceivably representing potential links in the life history of the Tortugas pink shrimp fishery, were selected as arbitrary sites from which the migration paths of juvenile shrimp might be traced. The first staining in the Everglades National Park was at Flamingo where we received both assistance and cooperation from the Park Superintendent, Mr. Warren Hamilton and his staff.

The five mark-recovery experiments thus far carried out have tentatively indicated which inshore waters are the nursery areas for the Tortugas population. Though low in number, stained specimens recovered to date off south Florida furnish a minimal basis for theorizing as to the nursery grounds and migration paths of pink shrimp supporting the Dry Tortugas fishery. Conjecture about the precise route of the migration is



Migration of pink shrimp as shown by marking experiments.

difficult but can be at least partially reconciled by the fact that shrimp most frequently recovered were those released at sites bearing closest proximity to the area defined as the parent population's habitat.

Marked pink shrimp release-recovery information:
Florida Bay and adjacent waters, 1958-1959.

Release			Recovery[1]		
Location and mark	Date	Number	Number	Date	Location
Biscayne Bay (fast green)	4-24 to 5-29-58	19,358	57*	5-1 to 7-5-58	Biscayne Bay, north of release site
			51**		
Flamingo (trypan blue)	10-24 to 10-31-58	7,264	4*	1-28 to 2-26-59	Dry Tortugas
			1**	1-59	Dry Tortugas
			1**	1-59	Atlantic Ocean off Marathon
Peterson Key (fast green)	1-29-59	1,729	11*	3-16 to 5-2-59	Dry Tortugas
Matecumbe Key (trypan blue and red)	3-6-59	1,672	0		
Florida Bay (plastic disc)	1-29 and 3-6-59	400	0		

1/ As of June 1959

* Marks verified - Specimens taken by commercial fishermen and submitted for identification.

** Marks not verified - Specimens not submitted; occurrence reported verbally.

Inadequate distribution of fishing effort precludes formal statements regarding dispersal patterns and ultimate fate of pink shrimp nurtured in Biscayne Bay, though present data suggest their non-association with the heavily exploited stocks existing in and west of Florida Bay.

Growth computations reveal that carapace lengths of four marked (juvenile) pink shrimp released at Flamingo and later captured on the Tortugas grounds increased at an average rate of three mm. per month. Eleven Tortugas' recoveries of specimens marked and released at Peterson Key

showed a two-mm. average monthly growth increment.

Pond experiments In conjunction with the mark-recovery experiments described above, studies of (1) differential survival and growth patterns in stained, tagged, and unmarked pink shrimp, and (2) relative stability of the various stains and tags currently used to mark shrimp, are being conducted in saline ponds adjacent to Biscayne and Florida Bays, and the Atlantic Ocean.

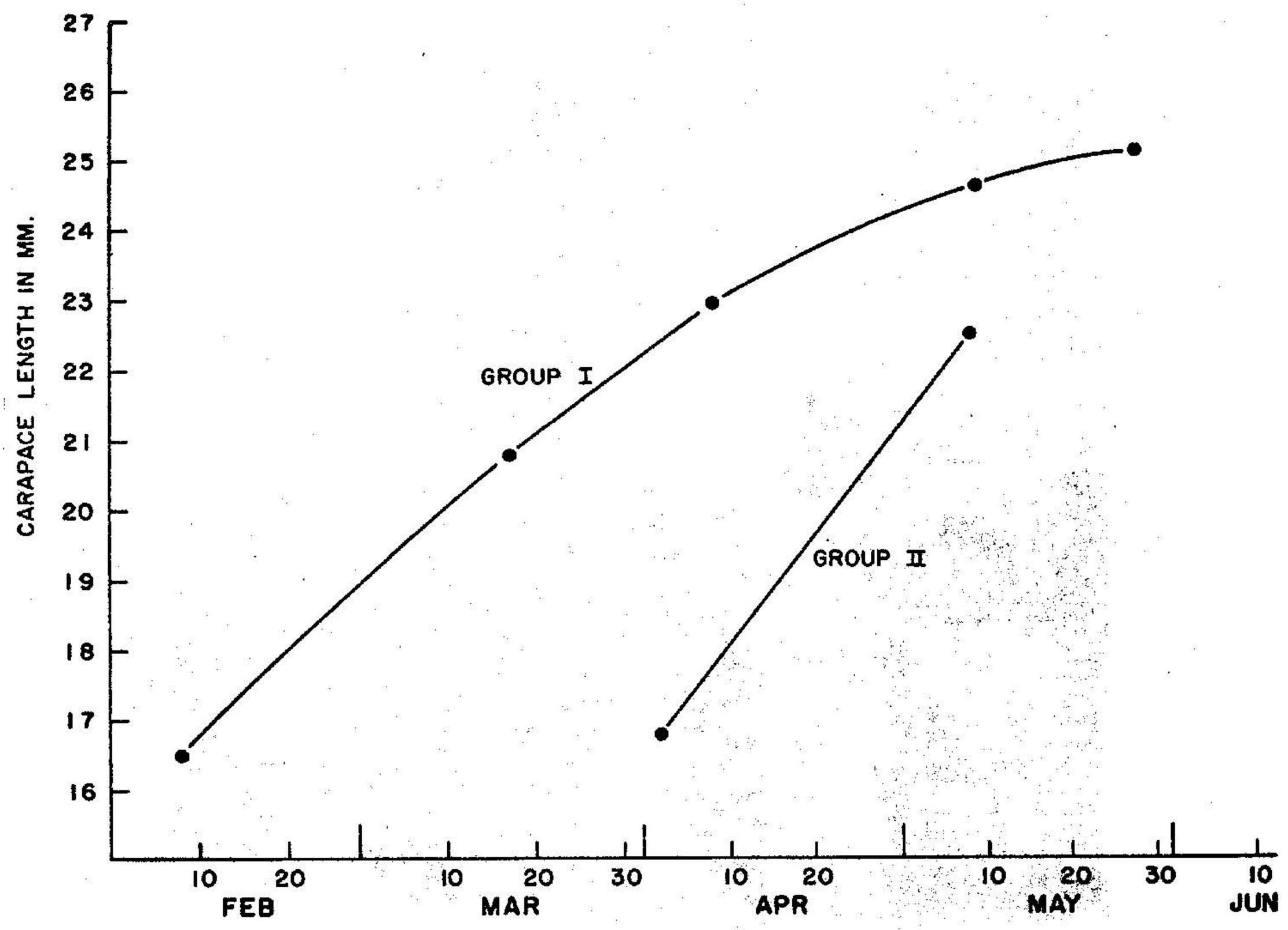
Located at the University of Miami Marine Laboratory, Biscayne Bay, the primary experimental pond has a surface area of about 2,000 square feet and a sand-mud bottom. Treated with "Fish Tox" in late 1958 to destroy potential predators, the pond was planted in early 1959 with varying numbers of stained, tagged, and unmarked, subadult shrimp ("Group I"). The stain employed consisted of a mixture of trypan blue and trypan red; the tags used were small, variously-shaped bits of plastic fastened with fine nylon or wire.

Experimental shrimp trap.

The composition of shrimp collections made systematically throughout the experiment (February 8 to May 27) revealed no significant differential mortality between stained and unmarked individuals. Growth rates of stained and unmarked shrimp were found to be practically identical. Carapace lengths (tagged members discounted) increased an average of 8.7 mm., the mean carapace length at planting was 16.5 mm. and individual lengths ranged from 13.2 to 18.7 mm. In terms of total length, this

represents a growth increment of about 29 mm. The mean corresponding "tail weight" increased from approximately 250 to 65 count per pound.

On April 3 a second planting ("Group II") of shrimp marked with trypan red stain showed an increase of 5.8 mm. in mean carapace length when collected and examined on May 8. Noticeably higher water temperatures and salinities during this period probably engendered the higher growth rate observed.



Growth of pink shrimp in a salt water pond.

Systematic stability comparisons made concurrently under pond (and laboratory) conditions indicated that trypan red stain could be readily distinguished after three months, whereas, a mixture of trypan red and trypan blue was observed to dissipate markedly over periods of similar duration. The relative stabilities of fast green and trypan blue as shrimp marking agents have already been established in field experiments as adequate.

Tagged specimens included in the initial shrimp plant were captured at a much lower rate than the Group I stained and unmarked individuals, and hence provided little data from which comparative growth measurements could be made. Indications were, however, that their average increase in length did not depart appreciably from that observed for the untagged shrimp. The magnitude of mortality attributable to tagging has not been determined.

Projected plans call for the continuation of these studies to aid in establishing the reliability of data obtained from more extensive mark-recovery experiments.

Bridge net for shrimping held in the current just below surface on outgoing night tides.

Gulf Shrimp Abundance Trends

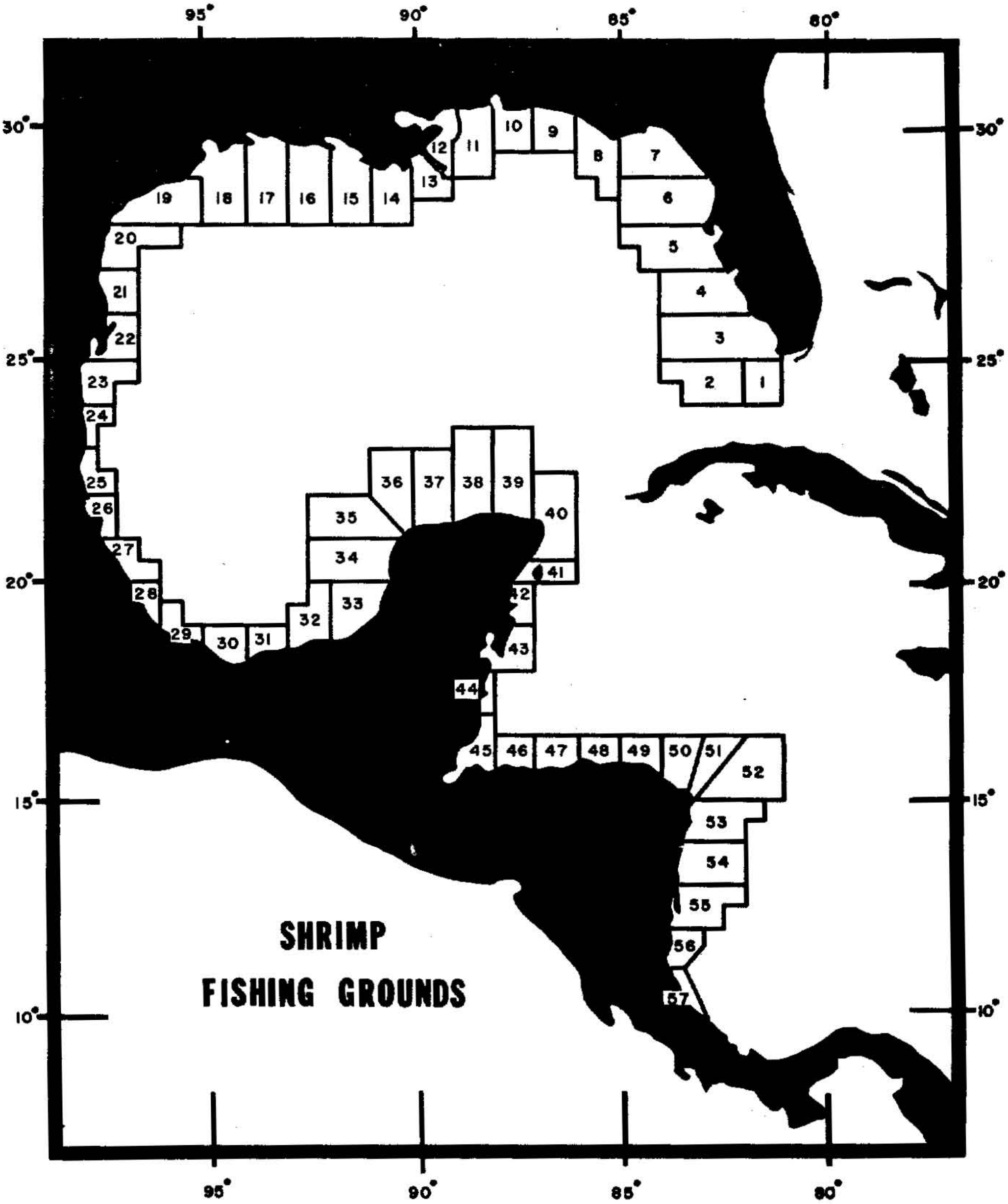
Joseph H. Kutkuhn

Acquisition and systematics of commercial statistics Since January, 1956, the Statistical Branch of the Bureau of Commercial Fisheries has conducted an extensive canvass on the activities of the U. S. shrimp fleet. Attempts to utilize these data have provided total yield by species, size, and spatial origin. However, total effort data, because of the subjective manner recorded, have questionable accuracy and are biased to an unknown degree due to omission of "non-productive" or "zero-catch" effort expenditures. Accordingly, future plans call for increased emphasis upon improvement of these data, especially with regard to those reflecting "searching" or "try-netting" time, which, presently go unaccounted for in the vessel interviews.

In keeping with requisite attributes of a so-called relative abundance estimator, our initial concern was the derivation of an adequate probability-of-capture index and elimination of measurable bias such as differential fishing capacity of shrimp trawlers. It is important to note that a "vessel trip" constitutes the basic statistical unit for which shrimp catch and effort data are being reported by Gulf statistical agents. Complemented with standard operating information, this generally accounts for the necessary details regarding commercial shrimping activity except those that measure haul-to-haul variability.

The present approach utilizes individual vessel catch and effort data consolidated on the basis of space-time distributional criteria. Since each vessel's fishing position(s) and the approximate depth(s) of every trip's catch are known, it is possible to sum all catches and the effort over corresponding areal fishing ground subdivisions, in which it can be assumed that the density of exploitable shrimp remains nearly constant throughout any prescribed period of time. Such a time increment has been conveniently taken to be a calendar month.

Recently adopted for systematizing the statistics was the reporting or "catch-coding" scheme depicted. It employs the 5- or 10-fathom depth zone as the smallest statistical element and divides the offshore trawling grounds coastwise by means of incident meridians and parallels.



Areas used in the collection of shrimp statistics.

Standardization of effort statistics Attempts to eliminate bias in estimating relative population density using commercial statistics, must necessarily consider errors due to non-uniformity of gear. An operating unit's power factor (or fishing power index) is defined simply as the ratio between its catch-effort ratio and that of another, arbitrarily designated a "standard" unit and fishing contemporaneously on the same density of shrimp being exploited. The restrictions of such a definition are at once obvious when one considers all possible situations under which a unit or groups of units might operate. Because of these and the fact that extraction of power factors by any method is a rather tedious process, a logical procedure would be to establish what, if any, functional relationships prevail between its relative power and fixed, measurable size characteristics of the unit itself. Sought here would be the simplest average relationship, necessarily allowing for any differences in gear employed by the units involved.

Trawlers, operating concomitantly in specified areas and assumed to have employed gear rigged to uniform specifications, were selected as collective "standards" against which other "non-standard" trawlers, operating under presumably identical conditions, could be compared and their power factors estimated. Following essentially the same procedure developed by Gulland, power indices were obtained for 70 trawlers catching brown shrimp at depths of 10 to 20 fathoms off Aransas Pass, Texas, during October, 1957. Presumed to bear direct relationship to these indices were specifications as to each trawler's gross tonnage, register length, horsepower, beam, and combinations thereof. For the sake of brevity, only the former two will be considered here.

Each vessel's fishing power index was plotted against its corresponding gross tonnage and register length. Utility of the resulting relationship of the former two variables was deemed negligible because of suspected curvilinearity. In fact, the disposition of points suggested that a satisfactory response curve could be generated by a polynomial expression in some function of gross tonnage, say, log gross tonnage, yielding,

$$\text{fishing power} = a + b \log \text{gross tonnage},$$

which has little physical meaning and would consequently have no usefulness insofar as the objectives set forth above are concerned.

On the other hand, the empirical relation of fishing power to register length gave promise of possessing practical advantages, a rectilinear relationship with certain desirable attributes being suggested:

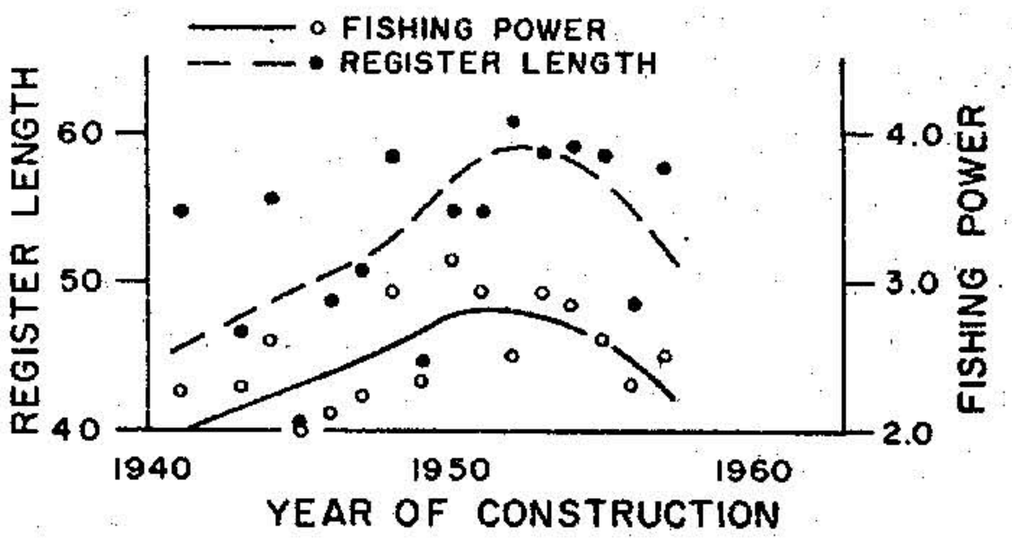
$$\text{fishing power} = a + b \text{ register length}.$$

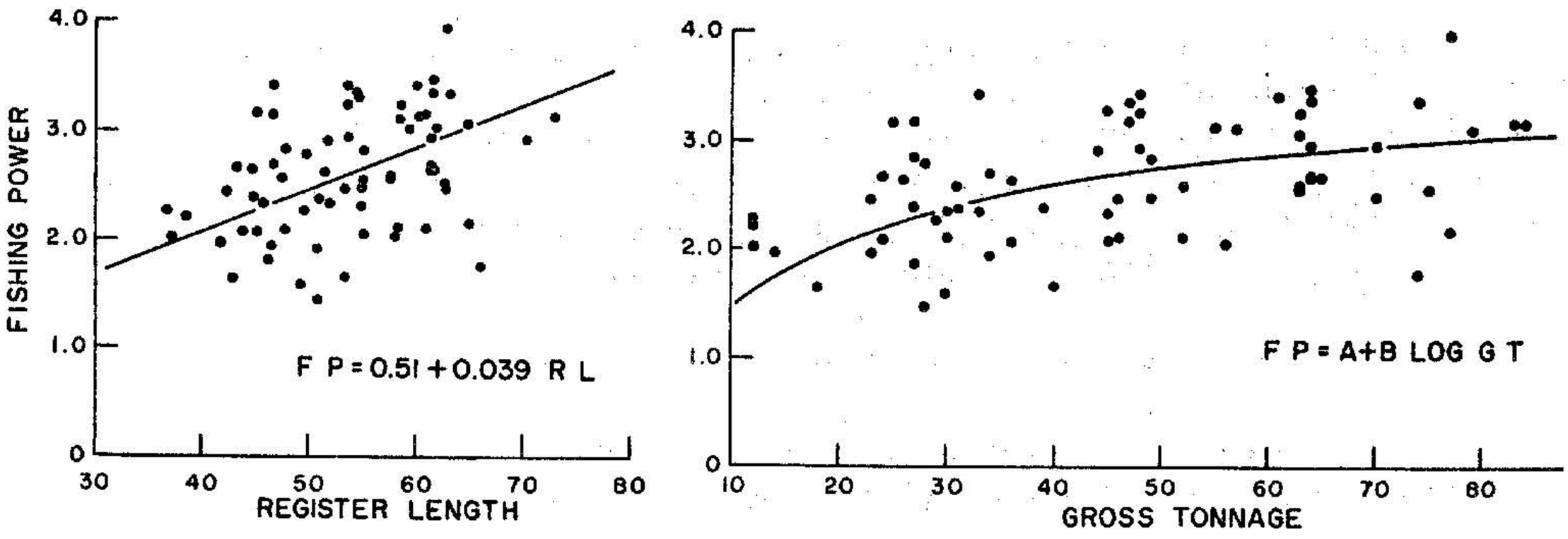
Since the data reasonably satisfied necessary requirements the relationship was tested. Of concern were (1) whether or not a significant regression of fishing power in length existed; (2) whether or not a simple proportional relationship was involved; and (3) the two variables' degree of relationship.

Results of testing the former, i.e., $H_o: \beta = 0$, are given in the following analysis-of-variance table:

Source of Variation	Degree of Freedom	Sum of Squares	Square	"F"
Regression	1	6.85	6.85	33.7
Error	68	13.78	0.20	

The null hypothesis is obviously rejected and high significance attached to the regression coefficient recorded in the figure ($b = 0.039 \pm 0.014$).





Relationships between calculated fishing power, gross tonnage, register length and year of construction for 70 vessels trawling off Aransas Pass in 10-20 fathoms (October 1957).

Usefulness of the observed relationship hinges, of course, upon its relative simplicity. To satisfy practicality here would require that $a = O$. A "t" test of $H_o: \alpha = 0$,

$$"t" = \frac{a - o}{s_a} = \frac{0.510}{0.363} = 1.38 < "t"_{05} \text{ (68 degrees of freedom)}$$

where s_a is the standard error of a, indicated its unqualified acceptance. The estimated coefficient of correlation, $r = 0.574$ (68 degrees of freedom), proved to be highly significant.

Concern subsequently arose over the possible effect of vessel attrition on the stability of the relationship evinced. Curves fitted by eye to plots of mean fishing power and register length of vessels having common age, against year of vessel construction, suggested close correspondence between both variables despite vessel age. This was supported by an analysis of variance of mean power factors calculated for each of five length groupings in each of three age categories.

Mean power factors for 70 shrimp trawlers classified according to length and age criteria. (Figures in parentheses indicate number of vessels falling into the designated categories.)

Period of Construction	Age (years)	Register Length (feet)				
		<45	46-50	51-55	56-60	<60
1953-57	0-4	2.62 (3)	2.39 (4)	2.80 (5)	2.73 (4)	2.85 (13)
1947-52	5-10	2.37 (5)	2.40 (7)	2.80 (7)	2.84 (5)	2.91 (2)
1941-46	11-16	2.01 (5)	2.21 (4)	2.28 (3)	3.18 (1)	2.61 (2)

Since these were based upon unequal numbers of observations, the method of "unweighted means" in lieu of a more appropriate but unnecessarily elaborate method, was used in constructing the following analysis-of-variance table:

Source of Variation	Degree of Freedom	Mean Square	Variance Ratio
Vessel age	2	0.0759	0.74
Vessel length	4	0.2095	2.05
Interaction	8	0.0500	0.49
Error	45	0.1022	

It is sufficient to note without reference to probability tables that for vessels of the same length, fishing power did not vary to any great extent with age. As also noted more rigorously above, a general increase in fishing power was, on the average, associated with increasing length. Age-length interaction was practically non-existent. There appear to be substantial grounds for incorporating vessel length as a sufficient criterion of "shrimping" power in attempts to standardize trawler effort statistics. Moreover, simplicity of the relationship uncovered, legitimately approximated on the average by

$$\text{fishing power} = 0.04 \text{ register length}$$

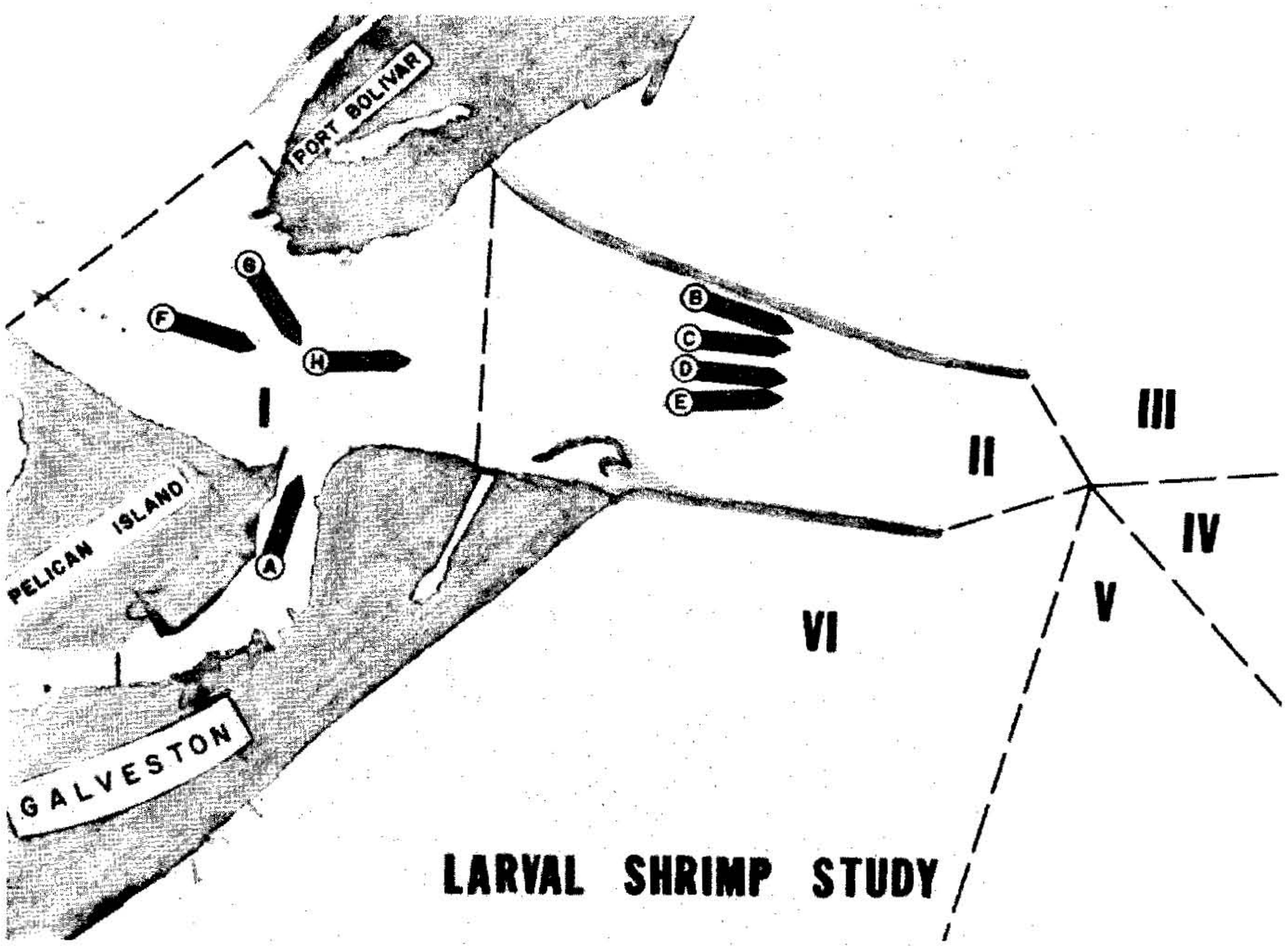
would greatly facilitate their mass adjustment by electronic means, the resultant standard unit of effort being the foot-hour (or foot-day). However, further studies to corroborate this and other usable fishing power-vessel relationships are anticipated before routine adjustment of raw data begins. In this connection, additional plans call for investigating comparative shrimping efficiency of single- and double-rigged trawlers.

Distribution and Density of Larval Shrimp

Joseph H. Kutkuhn

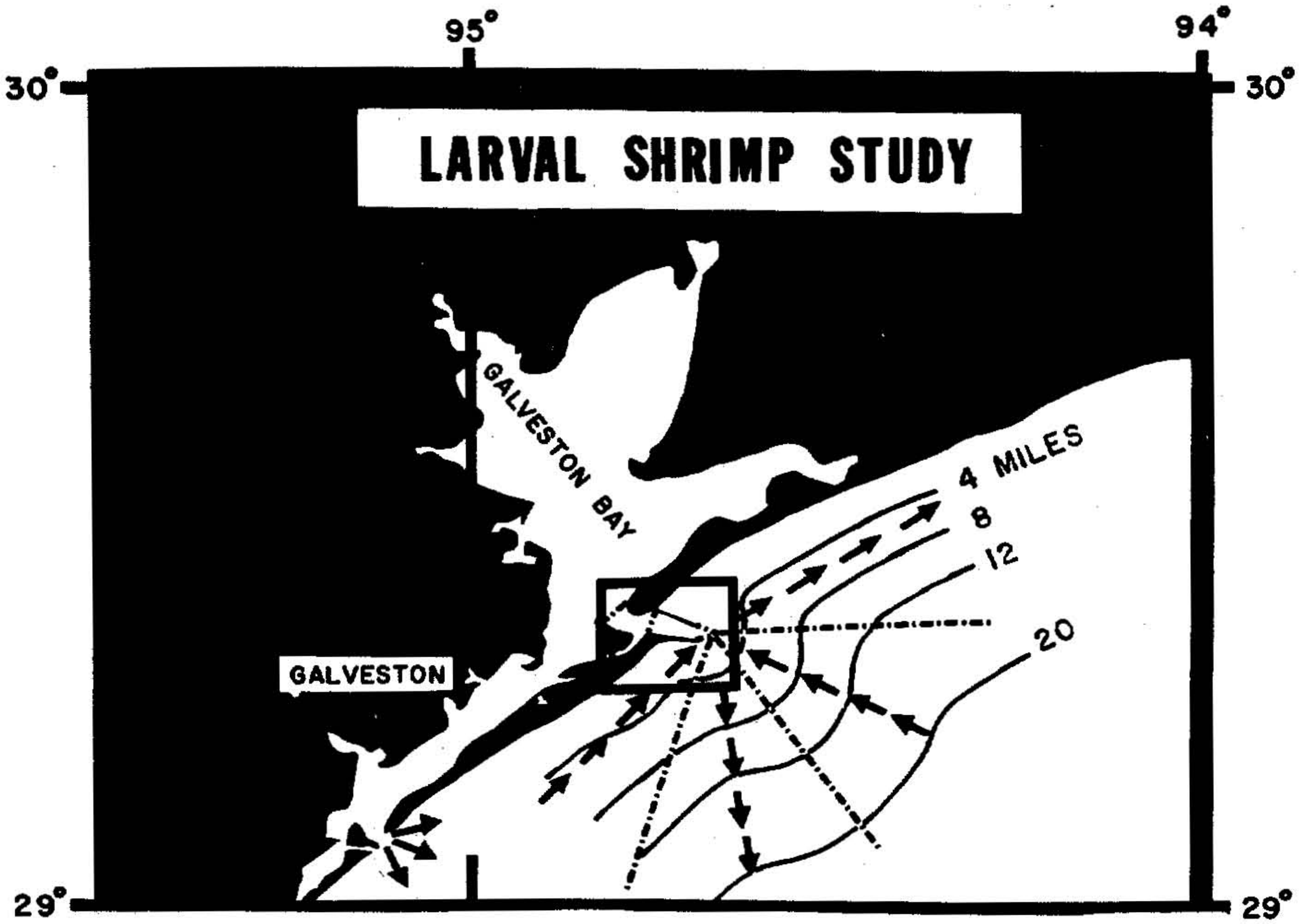
The purpose of this project was to determine movement and distributional patterns of immature penaeid shrimp during planktonic and benthic stages, and to determine the feasibility of securing density indices of pre-exploited shrimp populations.

Anticipated to cover a one-year period, the study involves large-scale, systematic collection of quantitative biological samples utilizing high-speed collecting devices. Plankton elements of the local "microfauna" are being sampled by two, one-half-meter monel samplers towed horizontally at different (but standardized) depths for prescribed time increments. Benthic elements are conveniently collected with a conventional one-half-meter, nylon, Nansen net (No. 1 mesh) fitted over the cod end of a 10-foot otter trawl ("try" net). Serial collections towing all gear simultaneously are being made at specified points along transects in the Bolivar Roads area of Lower Galveston Bay and in Gulf waters off Galveston Entrance and San Luis Pass.



Systematic scheme for sampling planktonic and epibenthic "microfauna": Galveston Entrance-Bolivar Roads.

Portion of Galveston shrimp fleet showing the "Joyce Elaine" chartered from March to June 1959, for the larval shrimp studies.



Systematic scheme for sampling planktonic and epibenthic "microfauna": Gulf of Mexico off Galveston Entrance (20-mile radius) and San Luis Pass.

The resulting data should provide indications of rate, direction, and bathymetric distribution of larval and post-larval shrimp movement shoreward to and through the "passes" monitored. To estimate abundance indices during initial dispersion phases, the project's design will permit elimination of bias due to uneven space (horizontal and vertical) -- time distributional differences, and physical phenomena such as tidal exchange, light intensity, etc., that may affect the observed organisms' behavior. Analytical procedures using routine analysis-of-variance (or stratified sampling) techniques are currently being designed to assist in educing and qualifying the desired density estimates.

Although several hundred samples have been collected and reduced, their detailed examination employing appropriate concentrate-sampling and enumeration techniques has just begun. Statements concerning any findings must therefore await ensuing reports.

Identification of Juvenile Penaeid Shrimp

Abraham Fleminger

Penaeid shrimp reproduction, larval success, migration, and post-larval recruitment in nursery grounds constitute an integral and vital portion of the information needed to understand causes of fluctuation in penaeid shrimp abundance. There is an increasingly urgent need for information at the species level that would answer, among others, the following questions:

Where and under what conditions do shrimp spawn? What is the usual number of eggs and spawning frequency per female? What environmental factors bear, from a quantitative standpoint, most directly on larval success? What are the means of, and time requirements for, migration of developing larvae from spawning to "nursery grounds"? Does each nursery ground consistently serve to nurture the progeny of a fixed stock? Or are some used fortuitously by breeds of several stocks? To resolve these, detailed surveys of coastal and estuarine hydrography; space-time distributional patterns of adult and juvenile shrimp; and controlled studies on general behavior, locomotory powers, and physical, chemical, and biological requirements of penaeid juveniles need to be undertaken.

At this time such an ambitious program would be hampered by difficulties in specifically determining juveniles of penaeid species as well as an inability to identify with certainty the species of any shrimp shorter than 20 mm. Before a penaeid reaches this length, at which "grooved" can be separated from "non-grooved" species, it radically alters its appearance three times. Emerging from the egg as a nauplius, it soon passes through several progressively more developed naupliar stages, metamorphoses into a series of zoeal stages (=protozoea + mysis stages), and subsequently undergoes a final metamorphosis to the pre-adult megalopa (=post-larvae), which in a brief series of moults gradually assumes the adult form. Within each series, the developing juvenile exhibits moderate change at each ecdysis. This general pattern of penaeid development is well documented. Details that would permit specific identification of juveniles at any stage have, however, been largely neglected. Therefore, recalling the urgent need for study of pre-exploitation dynamics prior to entry into the nursery grounds, it is with much concern that we note the local occurrence of at least 10 species of penaeid shrimp, each differing in habits and value as actual or potential fishery products, but all with juvenile stages that are remarkably similar in appearance.

To obtain information we need concerning spawning and space-time developmental patterns of, and coincident mortality in, the juveniles of commercial shrimp, we must first be able to identify the young of each species. Needed are taxonomic keys which will enable non-specialists to accurately identify penaeid juveniles while reducing the vast number of plankton samples that necessarily constitute the source of data for such a program.

During early 1959, a study of penaeid life histories was begun, its objectives being to describe and compare juvenile stages of local commercial penaeids, and to provide means for distinguishing them from co-existing non-Penaeus crustaceans with which they could be confused during routine analysis of field samples.

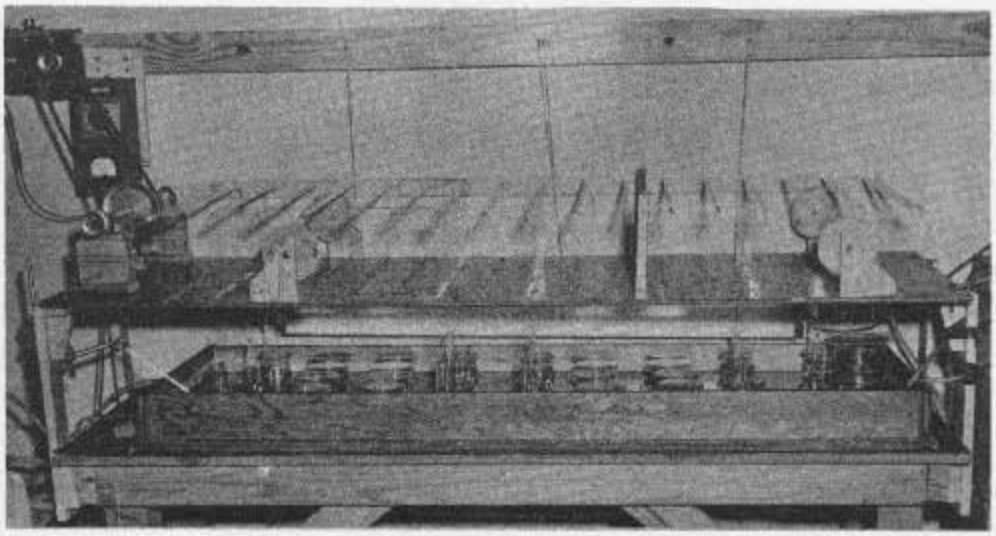
Rearing spawn from known parentage Facilities and equipment for rearing juvenile shrimp from eggs to identifiable (sub)adults as well as culturing plants and animals to serve as food for developing shrimp, are being assembled and tested. However, fully-ripe female shrimp, destined for spawning under laboratory conditions, have not yet been taken in field collections. With regard to specimens procured while in earlier stages of gonad development, we have observed resorption of partially developed ovaries or abortion of inviable eggs in Penaeus aztecus, Solenocera atlantidis and Trachypenaeus similis within three to seven days after capture. Efforts to nurture P. aztecus and P. setiferus to reproductive maturity are in progress. In this connection we have encountered a problem regarding the continued ability of laboratory-held females to spawn fertilized eggs. At the time of collection in the field, the thelycum (seminal receptacle) in adult females is usually filled with seminal fluid and sperm. Laboratory-held individuals that have undergone one or more ecdyses, however, have been found to be devoid of stored sperm. Thus far there has been no evidence of copulation despite the regular occurrence of one or more moulting females in tanks containing ripe males. Limited facilities and relatively short breeding seasons discourage attempts to determine those environmental conditions promoting gonad development, copulation, and spawning. It seems advisable therefore to consider other approaches in addition to continuing efforts to locate ripe adults.

Rearing young penaeids collected in the field to sizes permitting positive identification Small batches of young penaeids are being reared using those facilities mentioned above. Subsamples are withdrawn from the initial batch at regular intervals, examined, measured, and preserved for future reference. Providing that one species was involved, this approach can yield, in the least, a post-larval series for future inter-species comparisons.

In addition to those met in rearing post-larvae, problems of culturing planktonic stages of penaeids, i.e., nauplii and zoea, also require attention. Lacking penaeid larvae, we have been developing equipment and

methods that will permit continued observation of individuals during development on Acartia tonsa, a numerically important constituent of inshore zooplankton along the northern Gulf coast. These tests are designed to provide a basic "set" of environmental conditions that promote growth of the test organism from the youngest nauplius to the sexually mature adult. In the most promising of the experiments conducted to date, early copepodites have been reared through five moults to sexual maturity and the surviving females have spawned.

We can note that environmental stability, adequate supplies of suitable food, and prevention of fouling of test animals by slime-secreting micro-organisms appear to be the most significant factors encountered in our work. Stable conditions have been achieved by maintaining cultures in a controlled-temperature (± 1° C.) water bath kept in a sealed, air-conditioned room



Apparatus designed for constant simultaneous gentle stirring of 100 beakers of sea water in a constant temperature water bath using plastic stirrers.

where it is possible to maintain fairly uniform levels of light intensity and ambient temperature. Food organisms include unialgal and mixed cultures of Skeletonema sp., Nitzschia closterium, Prorocentrum sp., and an unknown chlorophyte. Slime-forming micro-organisms, a significant problem when using small containers with high surface area to volume ratios, have been suppressed by means of anti-biotics in low concentrations. As a base for the sea water medium, filtered sea water heated to 80-85° C., aged sea

water, and artificial sea water have been superior in that order to natural sea water merely filtered through glass wool. Surprisingly, gentle agitation and periodic changing of the medium and container were found to give somewhat poorer results than companion setups in which these changes were not instituted.

Reconstructing life histories from preserved material Developmental series of juvenile penaeids are being assembled for study from plankton and trawl net collections. Dates and locality of collection are taken into account in grouping unidentifiable material. Assumed relationships between stages are based on morphological similarities as well as temporal and spatial proximity. Although preserved material requires the least effort of the three approaches, it is also the least satisfactory from the point of view of obtaining convincing results. Two assumptions are implicit in formulating each comparison: (1) specimens representing each stage belong to the same species, and (2) each stage observed follows the preceding by a single ecdysis. Difficulties and the likelihood of error are enhanced by the three instances of abrupt morphological and ecological changes during development as referred to above, and by the striking similarity between species when sexual structures and color are discounted. The advisability of subsequent pursuit of this method lies in the eventuality that other approaches will prove to be futile.

Pink Shrimp Life History Studies

Edwin S. Iversen
University of Miami Marine Laboratory, Dr. C. P. Idyll

Size-depth relations of pink shrimp (Contract 14-17-008-7 and -23) A study has been completed under the auspices of the Bureau of Commercial Fisheries on the distribution of pink shrimp (Penaeus duorarum) on the Tortugas fishing grounds, particularly in regard to shrimp sizes in relation to the depth of the water. During field work extending over one year, 23 cruises were made and a total of 257 stations were occupied. A technical report on this research is being prepared for publication.

Briefly, this work indicates a general increase in the average size of shrimp with increased water depth. Further, the shrimp appear to move away from land and from very shoal areas as they grow, and occur some distance from these regardless of depth. Finally, there is a considerable variation in the size-depth relationship, smaller shrimp occurring in the spring and again in the fall.

The numbers of shrimp caught in standard try-net tows were counted in samples taken over the grounds. The largest numbers of shrimp, generally occurring in the southeast and southern portions of the grounds, consisted primarily of small shrimp.

Observations made on the intensity and pattern of commercial fishing activity showed a marked seasonal difference in the amount of fishing with the largest concentrations of vessels found on the eastern and southern portions of the grounds during the winter.

Identification and movements of larvae (Contract 14-17-008-78) Analysis of plankton samples containing larval shrimp requires a clear delineation of shrimp larval stages. The study of the larval history of the pink shrimp, Penaeus duorarum, was begun January 1, 1959. Through June 30th, seven cruises had been made of which four were made for the purposes of collecting plankton and hydrographic data, two were made specifically to bring live mature female shrimp back to the laboratory in an attempt to rear any eggs which might be spawned, and the seventh trip was made both to bring back shrimp and collect plankton. About two-thirds of the 150 plankton

samples have been sorted to select the larvae of P. duorarum. It is felt that many are those of the pink shrimp although larvae of the latter have not been found in the abundance originally suspected. The larvae of carideans are in much greater quantity than those of penaeid shrimp.

Plankton tows made on the Tortugas shrimp grounds during the first week in June have produced the largest number of identified P. duorarum larvae. Only a few samples have been completely sorted, but one surface tow has produced 2 third stage protozoea, 28 first mysis, 29 second mysis, and 52 post larvae.

Experiments have been made to rear eggs spawned by female shrimp brought to the laboratory. Eggs were spawned during each of three experiments, and during the first two they hatched and were raised through five nauplius stages and the first protozoeal stage. One second protozoea was also reared. Spawning took place in the third rearing experiment, but the eggs were non-viable. At present an attempt is being made to rear larval shrimp through the critical protozoeal stages.

The current system in Florida Bay and on the fishing grounds is being studied to determine how the larvae reach the nursery grounds. This is being accomplished by the use of drifting buoys tracked by radar, and by analysis of temperature and salinity data. The tidal currents are far stronger--maybe up to 50 times as strong--as the permanent currents. It is difficult to subtract these tidal currents to reveal those we are interested in. It requires, for example, that our research boat take observations over a complete tidal cycle--in fact, we usually make observations for $1\frac{1}{2}$ or 2 plus tide cycles. When completely analyzed, these data should provide measurements of the velocity and direction of the currents.

ESTUARINE ECOLOGY INVESTIGATION

Edward Chin
Chief

The Estuarine Ecology Investigation studies the biology and interrelationships of various species found in estuarine waters. Although the role of the inshore waters in the economy of the seas lacks precise definition, many species of marine fish and shellfish spend at least part of their early life history in these waters. In fact, the brackish streams and bayous that form estuarine waters have commonly been referred to as "nursery areas."

The objectives of our present field studies are to determine the species composition of populations inhabiting the estuaries in the Galveston area, and seasonal changes in the relative abundance and sizes of the various species.

The period spent in inshore waters by commercially important penaeid shrimp is a particularly important phase of their life history. Postlarval shrimp enter the estuaries in great numbers from early spring until fall. By rapid growth they become subject to exploitation within a few months after their arrival. Since pink shrimp (Penaeus duorarum), white shrimp (Penaeus setiferus), and brown shrimp (Penaeus aztecus) currently constitute the most valuable fishery in the United States, emphasis in our field studies has been placed on the occurrence, movements, growth, distribution and abundance of the two species of shrimp found commonly in Galveston Bay, the brown and white shrimps.

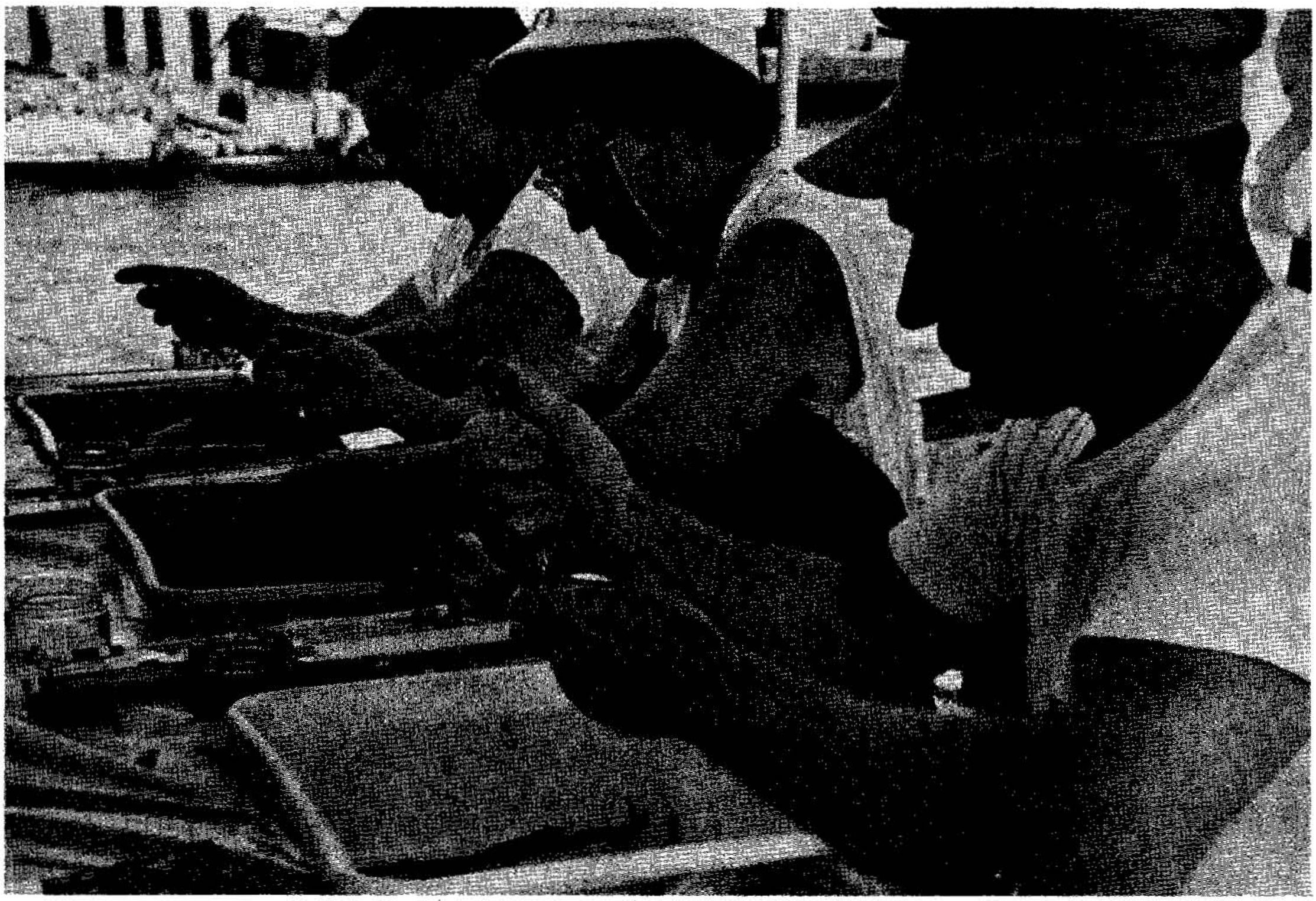
An apparent decline in the numbers of white shrimp over the past twenty years has been accompanied by an apparent increase in the numbers of brown and pink shrimp. Until recently, however, statistics on the commercial shrimp catch were not collected with sufficient detail to permit analysis by species. Thus, it is exceedingly difficult to evaluate the magnitude of the decline in the white shrimp population. Nevertheless it is known that whereas 95 percent of the catch in the 1930's was composed of white shrimp, over one-third of the catch in 1949 was composed of brown and pink shrimp. Since 1949 this proportion has shifted further in favor of brown and pink shrimp. In such a situation, it is of biological and economic interest to determine physiological differences between these species.

Laboratory studies emphasize the comparative physiology of the brown and white shrimps, and presently include differences in nutritional requirements, in degree of tolerance to changes in physical and chemical factors, and in behavior in response to those changes.

Migration of Brown Shrimp

Anthony Inglis

During the spring, a large-scale migration study was undertaken at the Clear Lake field station. The project was designed to supplement the data gained over the past one and one-half years on the growth of shrimp as well as to investigate the relationship of the juvenile shrimp in Clear Lake to the adults contributing to the offshore fishery. Specifically, we hope to follow the movements of shrimp from the brackish waters of Clear Lake through progressively higher salinity waters of Galveston Bay into the Gulf; their rate of movement; and their rate of growth.

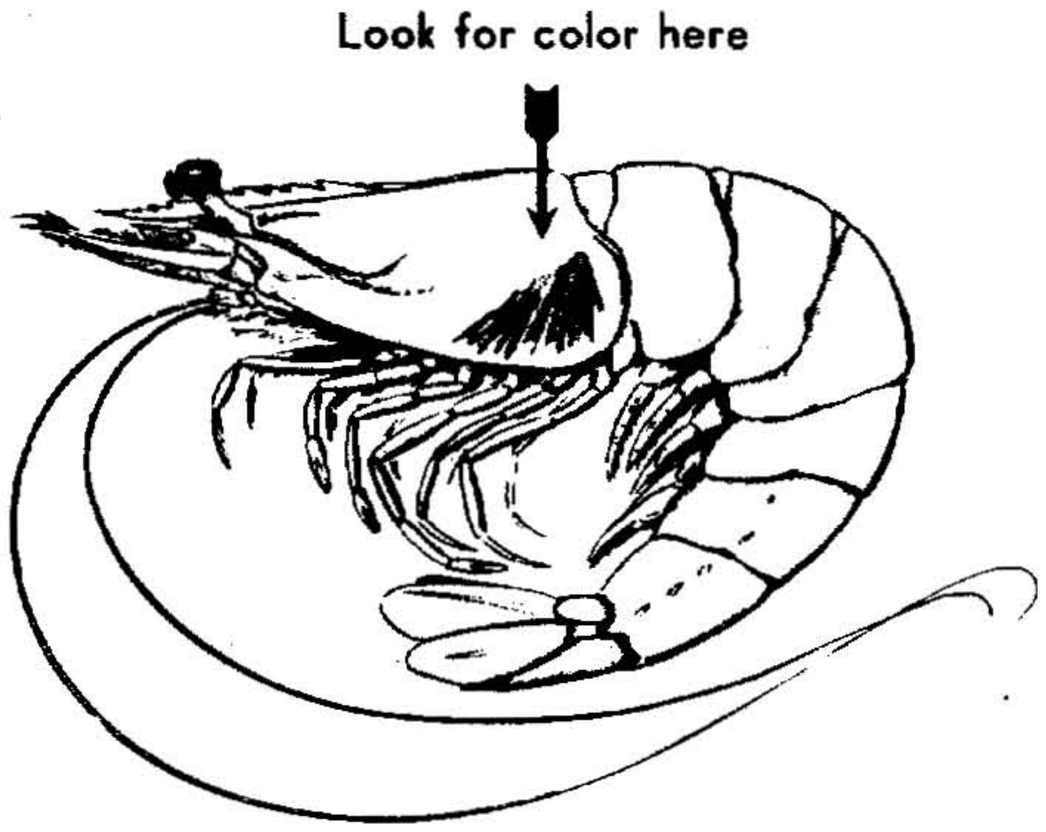


Staining juvenile brown shrimp by hypodermic injection of vital stains, May 1959.

Brown shrimp (Penaeus aztecus) were stained with two dyes, Fast Green and Trypan Blue, using the methods developed by Charles Dawson and modified by T. J. Costello and Donald M. Allen of our Miami Field Station. Shrimp were injected by means of a hypodermic needle with dye at the

STAINED SHRIMP 50¢ REWARD

Shrimp have been marked with blue, green and red biological stains — in order to obtain information on migrations and growth. The color appears only on both sides of the head (in the gills) as shown in the illustration.



A reward of 50¢ will be paid for stained shrimp when returned with the following information:

1. Exact place the shrimp was caught.
2. Date the shrimp was caught.

NOTIFY BY MAIL THE U.S. FISH AND WILDLIFE SERVICE, BIOLOGICAL LABORATORY, P.O. BOX 3098, GALVESTON, TEXAS, OR CONTACT ANY FISH AND WILDLIFE SERVICE AGENT OR REPRESENTATIVE.

Stained shrimp must be verified by Fish and Wildlife Service biologist before payment. The stains used are approved for this use by the Food and Drug Administration.

articulation of the fifth and sixth abdominal segments just ventro-laterally to the intestinal tract. Each shrimp received an injection of approximately 0.02 to 0.05 cc. Shrimp from each day's staining were held overnight and released the following morning--about 16 to 24 hours after injection. Mortalities were removed and counted at the end of each day and just prior to release on the following day. Samples of both dead and live shrimp were preserved for later measurement.

An attempt was made to sort the shrimp into a narrow size range by using two separating tanks similar to those developed by Costello and Allen in Florida, but the shrimp did not separate out fast enough to keep the stainers supplied. The shrimp were therefore sorted by hand. During the sorting it became apparent that about 10 percent would exceed the maximum desired size, consequently, starting on the second day (May 19), the larger shrimp were held separately and marked with Trypan Blue.

Reward posters containing preserved stained shrimp in vials were distributed to bait dealers and commercial fish houses in the Galveston Bay, Freeport, and Port Arthur-Sabine Pass areas. Weekly visits to bait dealers and fish houses in these areas are made by Bureau agents for recovery of stained shrimp.

During the four days from May 18 through May 21, 35,909 shrimp were stained. Of this number, slightly less than a third died. A total of 24,338 shrimp were released, with 21,370 stained green and 2,968 stained blue. The size range for the green shrimp was 11.7 to 20.8 mm. carapace length (52 to 92 total length) with a mean size of 16.5 mm. The blue shrimp ranged from 17.1 to 22.3 carapace length (75 to 98 total length) with a mean of 19.4 mm.

To June 30, we recovered 305 shrimp, including 274 green shrimp and 31 blue shrimp. The greatest percentage of stained shrimp have been taken in the area where releases were made. Eight recoveries have come from lower Galveston Bay in the vicinity of the Bolivar Roads and Galveston ship channel. One unverified recovery of a green shrimp has been reported from the Galveston Causeway at the entrance to West Bay.

On May 29th, one green shrimp, measuring 19.1 mm. carapace length, was recovered by a commercial fisherman 14 miles southeast of the Galveston whistle buoy (Bay entrance) in ten fathoms. This represents a maximum "out time" of ten days figured from the first release on May 19th. The distance traveled is approximately 40 nautical miles, making a minimum speed of four nautical miles per day. The sizes of all shrimp recovered thus far fall within the size range of the original group released. Thus, any estimates of growth would be premature.

Tolerance to Insecticides

Edward Chin

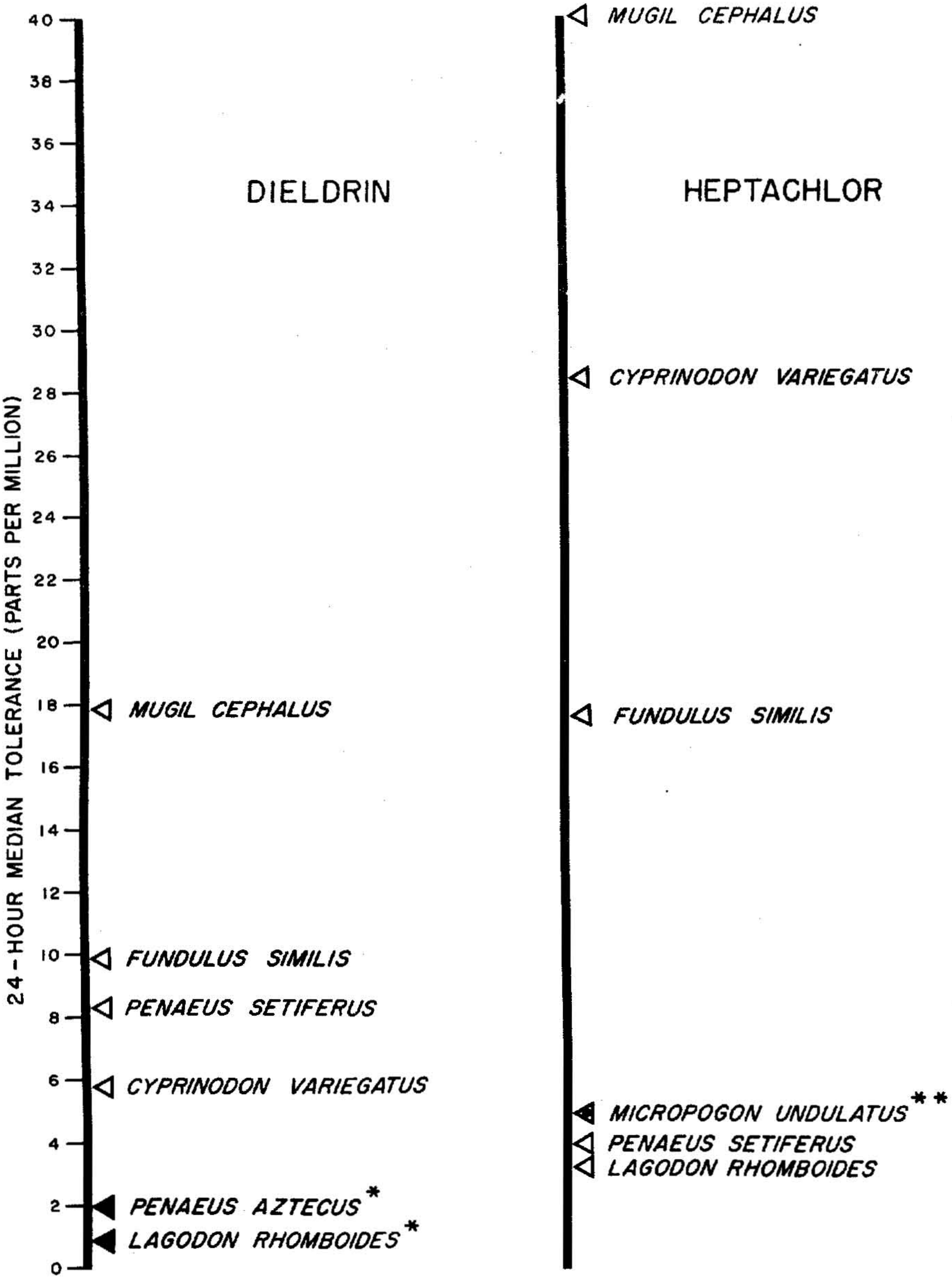
Tolerance tests have been limited mainly to the effects of insecticides on organisms other than the pests for which they were intended. Since most of the previous work in this field has been confined to species of mammals, birds, and freshwater fishes, our studies have been directed towards estuarine and marine species of fish and shellfish.

Dieldrin and heptachlor were tested on a number of species of shrimp and fish found in local waters to determine their relative toxicity to each species. The median tolerance limit (TL_m) or the concentration at which 50 percent of the test animals are able to survive for a specified period of exposure was adopted as a measure of relative toxicity. Derivation of the median tolerance limit is by straight-line graphical interpolation.

Species tested thus far include white shrimp (Penaeus setiferus); brown shrimp (Penaeus aztecus); striped mullet (Mugil cephalus); variegated minnow (Cyprinodon variegatus); pinfish (Lagodon rhomboides); Gulf killifish (Fundulus similis); and golden croaker (Micropogon undulatus).

As shown by the tentative results in the figure, there is a wide range in the relative toxicity of the two chemicals to the various species. In tests with dieldrin, 24-hour TL_m values ranged from less than 1 part per million for pinfish to 18 parts per million for mullet. In tests with heptachlor, 24-hour TL_m values ranged from about 3 parts per million for pinfish to 40 parts per million for mullet. Thus, of all species tested, mullet was the hardiest and pinfish the least resistant to both insecticides. The Gulf killifish, the variegated minnow, the golden croaker, and the two species of shrimp occupy intermediate positions. Of the two insecticides, dieldrin was more toxic to all species of fish except the golden croaker. Tests on the golden croaker are not yet complete.

Of the two species of shrimp tested, white shrimp was more resistant to dieldrin than brown shrimp and also more resistant to dieldrin than to heptachlor. Compared to benzene hexachloride tested last year,



* 100% MORTALITY AT ALL CONCENTRATIONS UP TO VALUE DENOTED

** NO EFFECT AT CONCENTRATIONS UP TO VALUE DENOTED

dieldrin and heptachlor are considerably less toxic to shrimp. Ironically, benzene hexachloride which yielded 24-hour TL_m values of 3 and 32 parts per billion for white and brown shrimp, respectively, is used in many areas because of its relatively low toxicity to fish.

Due to the lack of knowledge of the effects of various factors on the relative toxicity of the chemical tested, conclusions are necessarily tentative. Among factors that may affect bio-assay results, some of which have been cited by other investigators, are:

1. Temperature. Toxicity varies according to temperature, but there is seldom a way to predict the direction or the magnitude of the change.

2. Volume of test solution. Several investigators have noted that at equal concentrations, larger volumes of test solutions were more toxic to fish.

3. Captivity time. There is conflicting evidence that increased captivity time affects bio-assay results.

4. Age of test solutions. This factor is vital in any consideration of the stability of toxic ingredients. Test solutions of rotenone reportedly become less toxic with age.

5. Size and age of test animal. It is of obvious importance to elicit differences in resistance to a particular chemical between different size groups of the same species.

6. Nature and toxicity of diluent or absorbent. It is quite easy to overlook the effects of "inert ingredients" which make up the bulk of most commercial preparations. Inconsistencies in results could conceivably be due to testing different commercial preparations of a particular insecticide.

7. Feeding vs. starving. With some organisms such as shrimp, cannibalism is a problem in the analysis of results that include figures on mortality. In such instances, feeding is a necessity, but creates the further problem of introducing food saturated with test chemical directly into the digestive system.

Nutritional Studies of Shrimp

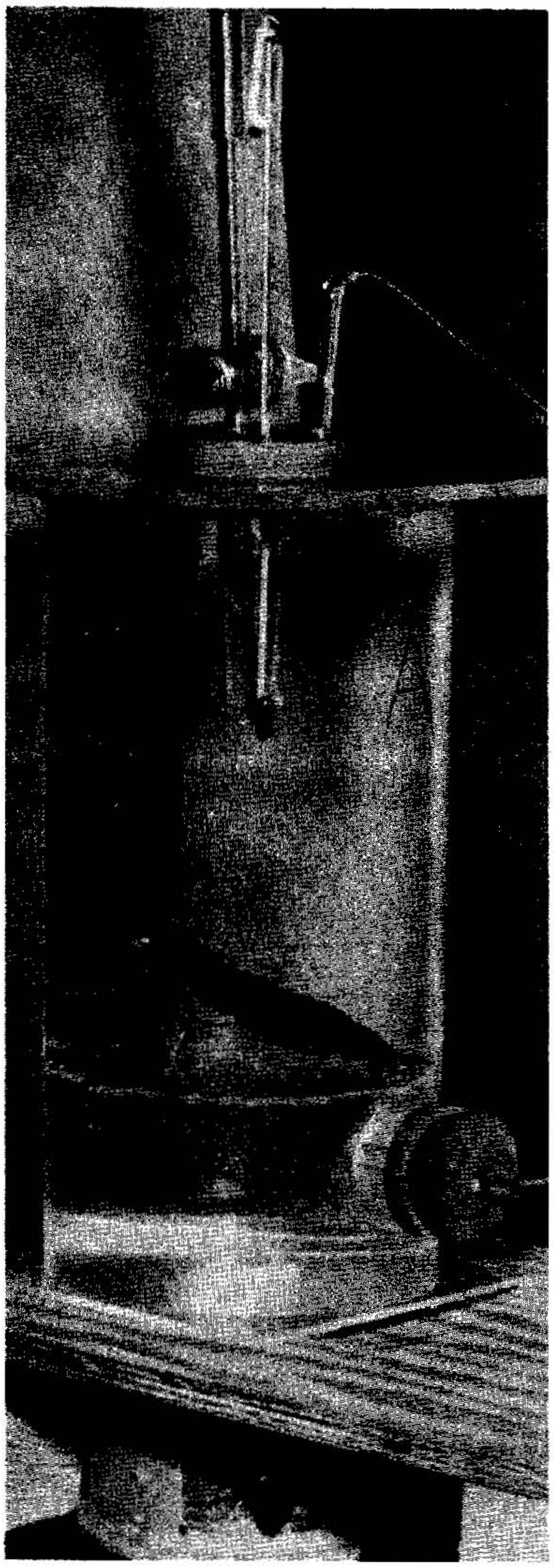
Zoula P. Zein-Eldin

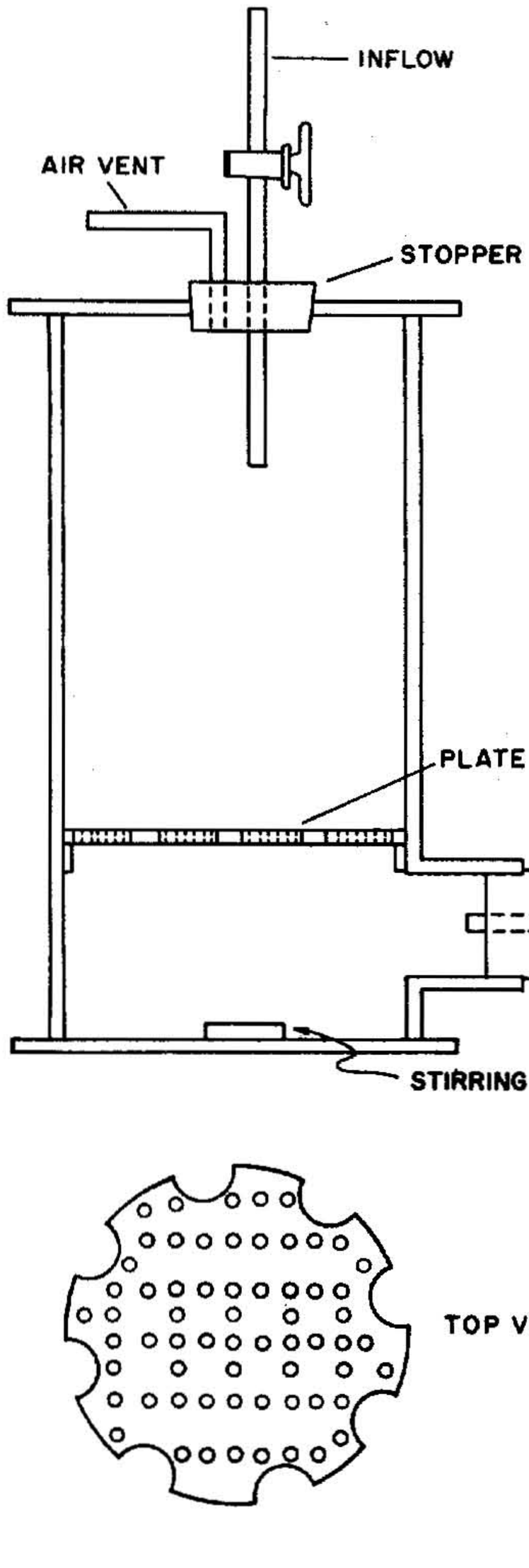
The nutritional studies of shrimp have been divided into two phases: studies of nutritional requirements and determination of metabolic activity.

At present the determination of nutritional requirements is limited to studying the effects of three artificial sea waters on shrimp. The control medium contains only NaCl, KCl, $MgSO_4$, $MgCl_2$, in ratios normal for sea water, a small amount of inorganic phosphate with EDTA and Tris as buffering agents. The salinity is adjusted to approximate that of the water from which the animals are taken. Of the other two media, one lacks phosphate, the second lacks calcium. Animals in all groups are fed the standard laboratory diet of shrimp and liver. Length and survival and growth of the animals in these solutions will be compared with each other and with available data on laboratory survival of animals in natural sea waters. Preliminary results indicate that animals in solutions lacking calcium do not survive as long as animals in other artificial media; this may be related to the known requirement for calcium in molting. Following this initial project giving information on the survival in artificial media, animals will be fed various test diets enriched with vitamins and minerals for growth studies.

Supplementing the nutritional studies are metabolic or respiratory determinations which will permit an evaluation of the physiological effects of the artificial diets. Currently, the metabolic studies are limited to determinations of the oxygen consumption of shrimp obtained from local bait dealers and maintained in the laboratory until tested.

A five-liter plastic respiration vessel has been designed and constructed for these studies (see diagram). The jar is divided into two compartments by a perforated plastic plate immediately above the lower opening. The experimental animal is placed in the upper compartment and a magnetic stirring bar in the lower one to insure homogeneity of the sample. The respiration vessels are connected to two 150 gallon reservoirs of natural sea water. The inflow in each comes from the upper reservoir, while the water which has circulated through the jars drains into the lower one. At the end of each test period, water from the lower reservoir is pumped back into the upper tank, thus aerating and mixing the water supply.





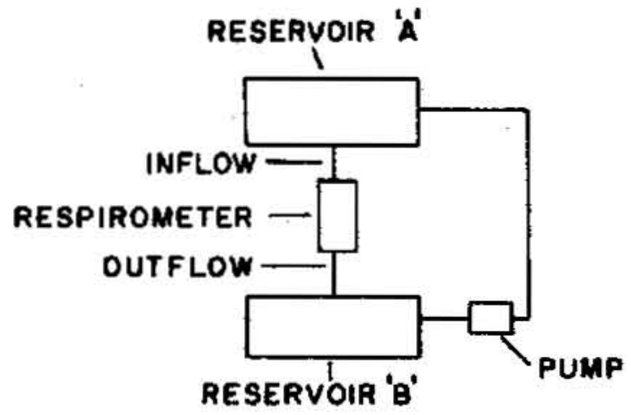
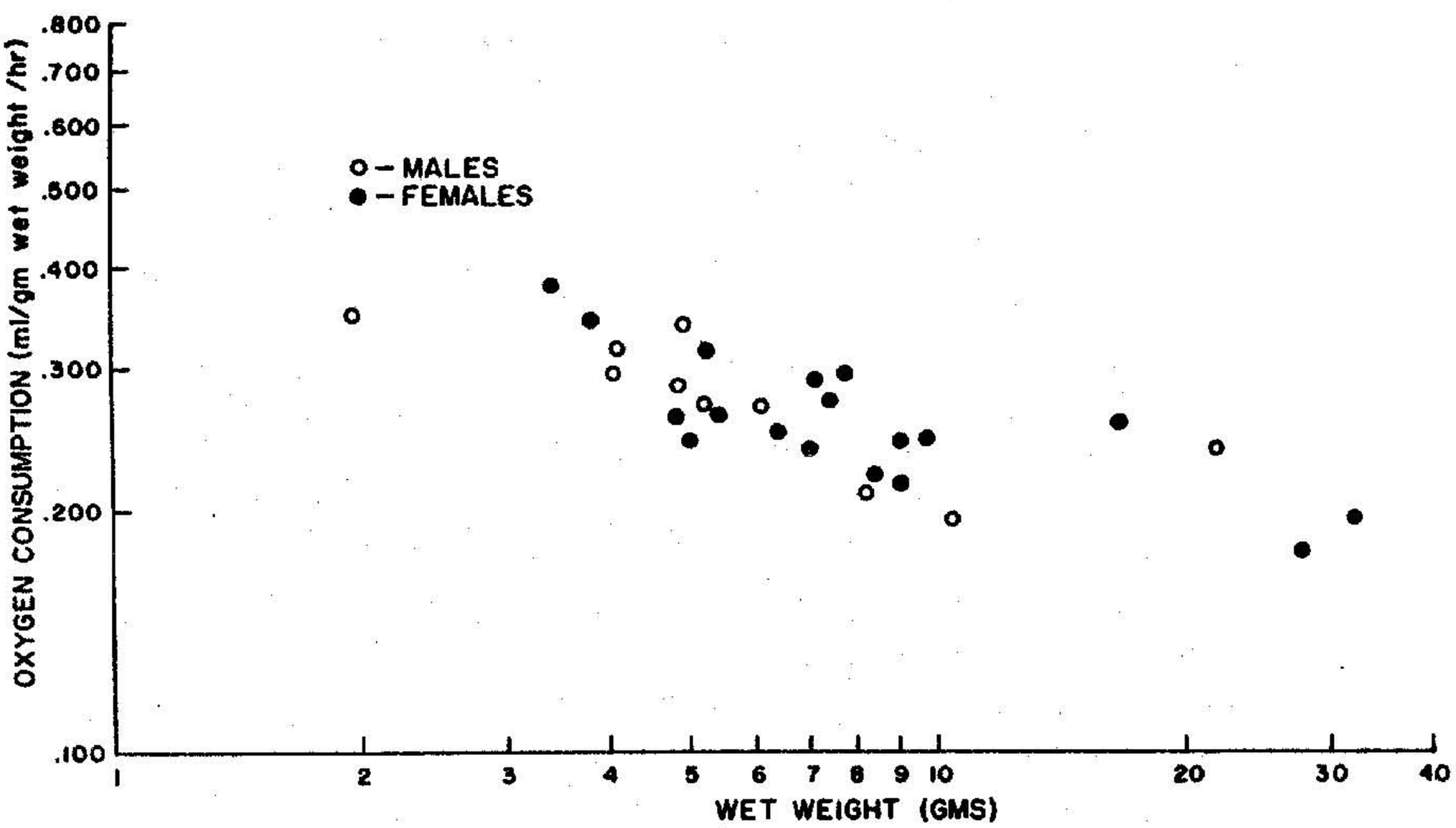


Diagram and picture of apparatus used in respiration studies.

At the beginning of an experiment the main outflow is closed and the vessel is almost filled with sea water. The inflow is then stopped and the animal is introduced. Animals are placed in the vessels at least 16 hours prior to testing to permit acclimation to the experimental vessel. Sea water is allowed to circulate continuously during the acclimation period. A water sample is drawn from the outflow, the inflow is stopped, and the main outflow is clamped. At the end of the test period (one or two hours) the stirrer is turned off, the air vent is opened and a sample is drawn through the main outflow. The remaining water is allowed to drain, the apparatus is refilled, and sea water is again allowed to flow for twenty minutes before the next test. Four tests are usually made on a given animal during a day--three of one-hour and one of two-hour duration.

Oxygen determinations are made by the Winkler method as described by Strickland, using the alkaline iodide of Pomeroy and Kirschmann. The logarithmic graph shows the relation between size and mean oxygen consumption (expressed as milliliters of oxygen per gram wet weight of shrimp per hour) of 30 white shrimp (Penaeus setiferus). Mean values range from 0.178 ml./gm./hr. for a 27.6 gm. female to 0.379 ml./gm./hr. for a 3.4 gm. female, showing the typical tendency for the oxygen consumption to decrease as the weight increases. There is, however, considerable individual variation between hourly tests, in part due to differences in activity under the same test conditions. Results of two types have been omitted from



Relation of weight to mean oxygen consumption in white shrimp.

the graph, (1) experiments either preceded or succeeded in 24 hours by a molt, and (2) experiments in which the water temperature varied more than 2° C. from the test temperature of 23°-25° C. This was necessary since the mean oxygen consumption in three animals was significantly greater, 0.062 ml./gm./hr., during pre-molt than during inter-molt. Significant differences were also found in four post-molt animals. Further, in three of four animals tested at 19°-21° C., the oxygen consumption was 0.066-0.132 ml./gm./hr. lower than the results obtained from tests conducted on the same animals at 23°-25° C.

Preliminary studies on the brown shrimp (P. aztecus) indicate that the respiration may be greater than that of the white shrimp under identical conditions. Two tests on the rock shrimp (Sicyonia brevirostris) indicated a much decreased respiratory rate on a ml. oxygen per gm. wet weight per hour basis. This decrease may be due to the great weight of the shell (about 4 gm. in an 18 gm. animal), which is presumably an inactive tissue in respiration.

The work to date has not permitted the determination of a true continuous rate of oxygen consumption. Future work will include the use of the Scholander apparatus to give a rate, which may be compared with values obtained by the Winkler method. Study of tissue respiration will also be continued; preliminary tests using the Warburg respirometer have indicated that gill and midgut gland (hepato-pancreas) are more active metabolically than tail muscle.

Estuarine Field Studies

Edward Chin

Estuarine studies have been conducted at Clear Lake, a shallow, brackish body of water about $2\frac{1}{2}$ miles long and one mile wide, connected to Galveston Bay by a narrow opening. The average depth is about 3 feet; the channel is 10 to 12 feet deep. Six stations in the lake were sampled intensively with a ten-foot shrimp try net with mesh sizes of $1\frac{1}{4}$-inch stretched measure in the cod end. Temperature and salinity of the water were recorded at each station at the beginning of each haul. Supplementary salinity and temperature data, recorded continuously by equipment established and maintained by personnel of the Houston Light and Power Company at Webster, Texas, have been made available to us.

At the head of the lake, the Houston Light and Power Company maintains four pumps capable of pumping 45,000 gallons of water a minute. Water is withdrawn for cooling purposes and returned to the lake about three miles away. Rotating screens at the point of intake prevent animals, including shrimp, crabs, and fish; vegetation, and debris from clogging the pumps. Periodically these screens are flushed into a concrete well. As a result, an unusual sampling technique which can yield an almost continuous picture of faunal changes throughout the year is available to us. Samples were obtained from the pumping station twice a week during the period from late spring through early fall, and once a week during the rest of the year.

The following check-list of species found in samples obtained with the trawl at the six stations and from the pumping station include almost 70 species of which over 90 percent consisted of fish. In numbers, however, brown and white shrimp were by far the dominant species.

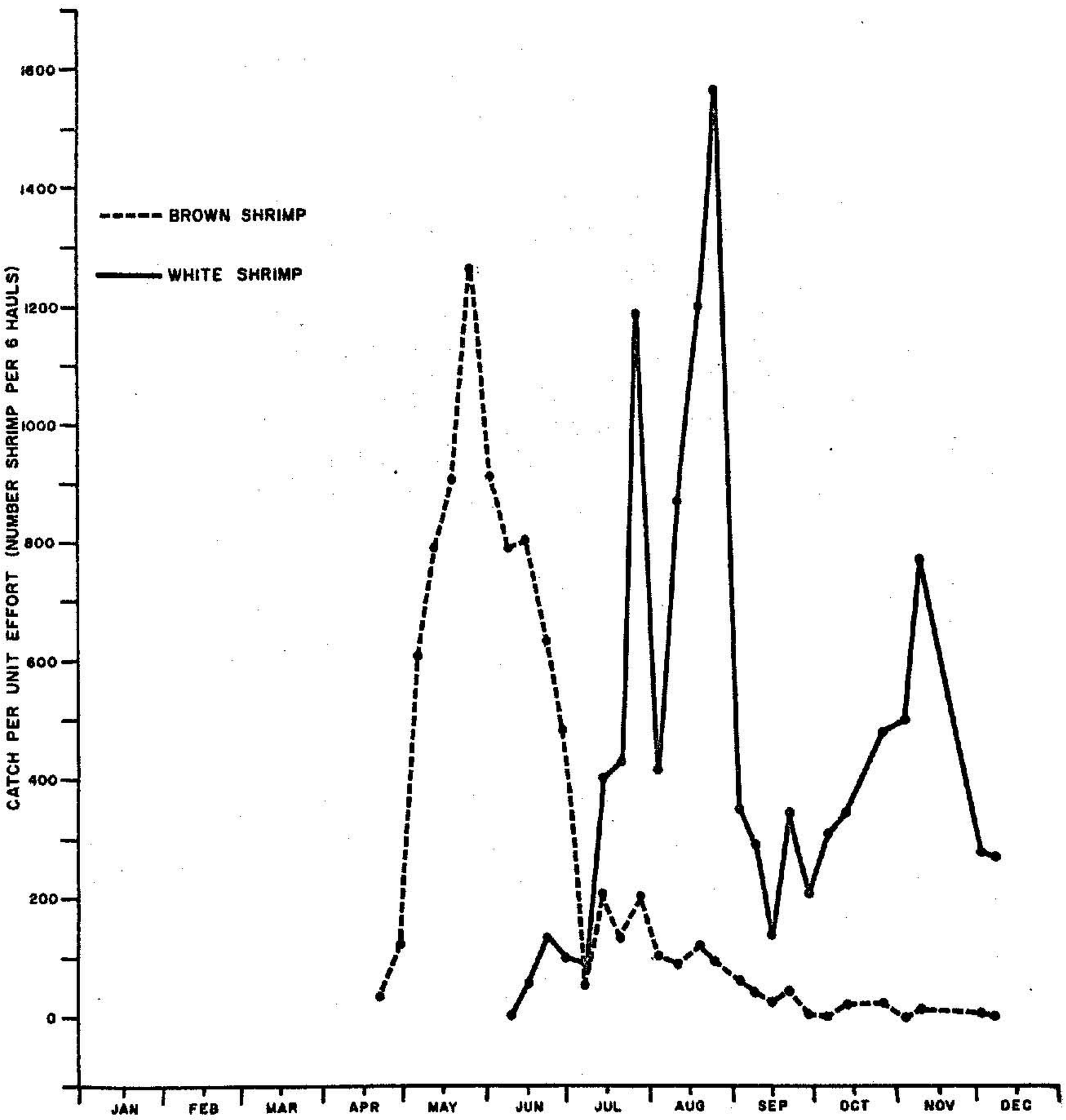
Lepisosteus spatula	Alligator gar
Megalops atlanticus	Tarpon
Brevoortia patronus	Menhaden
Dorosoma cepedianum	Gizzard shad
Opisthonema oglinum	Thread herring
Anchoa mitchilli	Anchovy
Synodus foetens	Lizard fish
Notropis spp.	Shiners
Bagre marina	Gafftopsail catfish
Galeichthys felis	Hardhead catfish
Ameirus melas	Black bullhead
Myrophis punctatus	Speckled worm eel
Urophycis floridanus	Southern hake

Typical sample of fauna flushed from the rotating screens at the pumping station.

Syngnathus scovelli	Scovell's pipefish
Syngnathus affine	Gulf pipefish
Cyprinodon variegatus	Variegated minnow
Fundulus heteroclitus grandis	Mummichog
Mollienisia latipinna	Sailfin molly
Mugil cephalus	Striped mullet
Mugil curema	White mullet
Menidia beryllina	Tidewater silverside
Polydactylus octonemus	Eight-fingered threadfin
Morone americana	White perch
Caranx latus	Horse-eye jack
Selene vomer	Lookdown
Trachinotus carolinus	Pompano
Lobotes surinamensis	Tripletail
Ulaema lefroyi	Florida mojarra
Ortoopristis chrysopterus	Pigfish
Cynoscion arenarius	Sand squeteague
Cynoscion nebulosus	Spotted squeteague
Bairdiella chrysura	Silver perch
Leiostomus xanthurus	Spot
Menticirrhus americanus	Southern king-whiting
Menticirrhus littoralis	Gulf king-whiting
Micropogon undulatus	Golden croaker
Pogonias cromis	Black drum
Sciaenops ocellata	Redfish
Stellifer lanceolatus	Star drum
Archosargus probatocephalus	Sheepshead
Lagodon rhomboides	Pinfish
Chaetodipterus faber	Spade fish
Astrascopus y-graecum	Southern stargazer
Scomber scombrus	Mackerel
Gobiosoma bosci	Naked goby
Gobiodes broussonnetii	Violet goby
Gobius shufeldti	Shufield's goby
Eleotris pisonis	Fresh-water goby
Dormitator maculatus	Fat sleeper
Prionotus tribulus	Southern sea robin
Citharichthys macrops	Large eyed whiff
Citharichthys spilopterus	Spot-fin whiff
Paralichthys lethostigmus	Southern flounder
Symphurus plagiusa	Tonguefish
Trinectes maculatus	Hogchoker
Spheroides marmoratus	Marbled swellfish
Spheroides spengleri	Southern swellfish
Gobiesox strumosus	Clingfish

Opsanus beta	Oyster dog
Porichthys porosissimus	Midshipman
Astacidae	Crayfish
Palaemonetes spp.	Grass shrimp
Callinectes sapidus	Blue crab
Penaeus aztecus	Brown shrimp
Penaeus setiferus	White shrimp

Seasonal changes in relative abundance denoted by catch per unit of effort and changes in size composition were determined for each species. The following figure shows seasonal fluctuations based on trawl samples



Fluctuations in relative abundance of brown and white shrimp in Clear Lake.

in the relative abundance of the two species of shrimp. Both species apparently have an extensive spawning season. Brown shrimp first appeared in our samples in late April, and reached a sharp peak in abundance in late May. Indications of a secondary peak can be seen in July. White shrimp did not appear in the samples until the first part of June. Major peaks of abundance are evident in late July, late August, and early November.

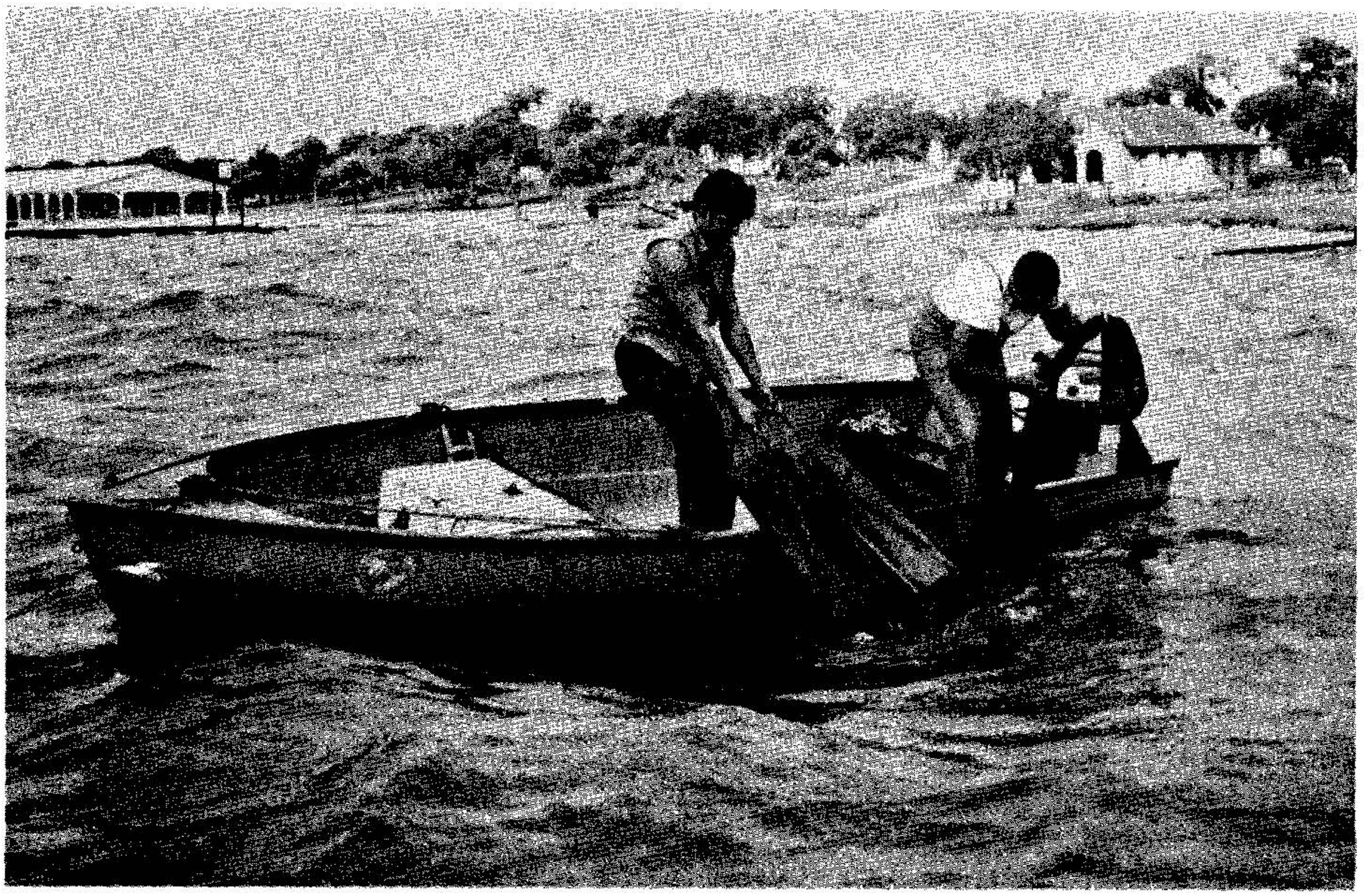
As we noted in last year's study of the bait shrimp fishery, brown shrimp not only enter the bay sooner, but do not stay in the inshore waters as long as white shrimp. The maximum size of brown shrimp taken in our trawl samples was 12 grams (114 millimeters total length). In contrast the maximum size of white shrimp was 17.5 grams (135 millimeters total length).

Predation on Shrimp

Anthony Inglis

Many marine fishes spend a portion of their early life histories in the inshore areas at the same time as commercially important penaeid shrimps. This project was undertaken to investigate the role of juvenile fishes as predators on post-larval and juvenile shrimps.

Fish taken from weekly samples from Clear Lake have been examined for the period January 1958 through June 1958. All fish were frozen as soon after collection as possible, usually within six hours. Sex and standard length (catfish measurements are given in fork length) were recorded for all species examined.



Collecting fish for predation studies with small otter trawl.

Species	Number examined	Number with food	Percent empty	Size range	Mean Size
				mm.	mm.
Golden Croaker	868	788	9.2	12-106	40
Sand Trout	216	193	10.7	23-105	46
Speckled Trout	26	17	34.6	81-125	102
Redfish	52	46	11.5	30-101	60
Gafftopsail Catfish	32	29	9.4	52-91	71
Hardhead Catfish	13	13	0	48-210	107
Spot Croaker	35	28	20.0	18-143	58
Spotfin Whiff	71	23	67.6*	53-83	64
Southern Flounder**	14	11	21.4	18-160	114
Pinfish	11	11	0	87-115	107
Hogchoker	10	5	50.0	34-48	41
Naked Gobie	9	9	0	29-51	41
Black Drum	6	6	0	131-158	141
Oyster Dog (Toadfish)	6	0***	100.0	117-162	146
Silver Perch	5	4	20.0	46-90	57

*Empty stomachs and empty intestines

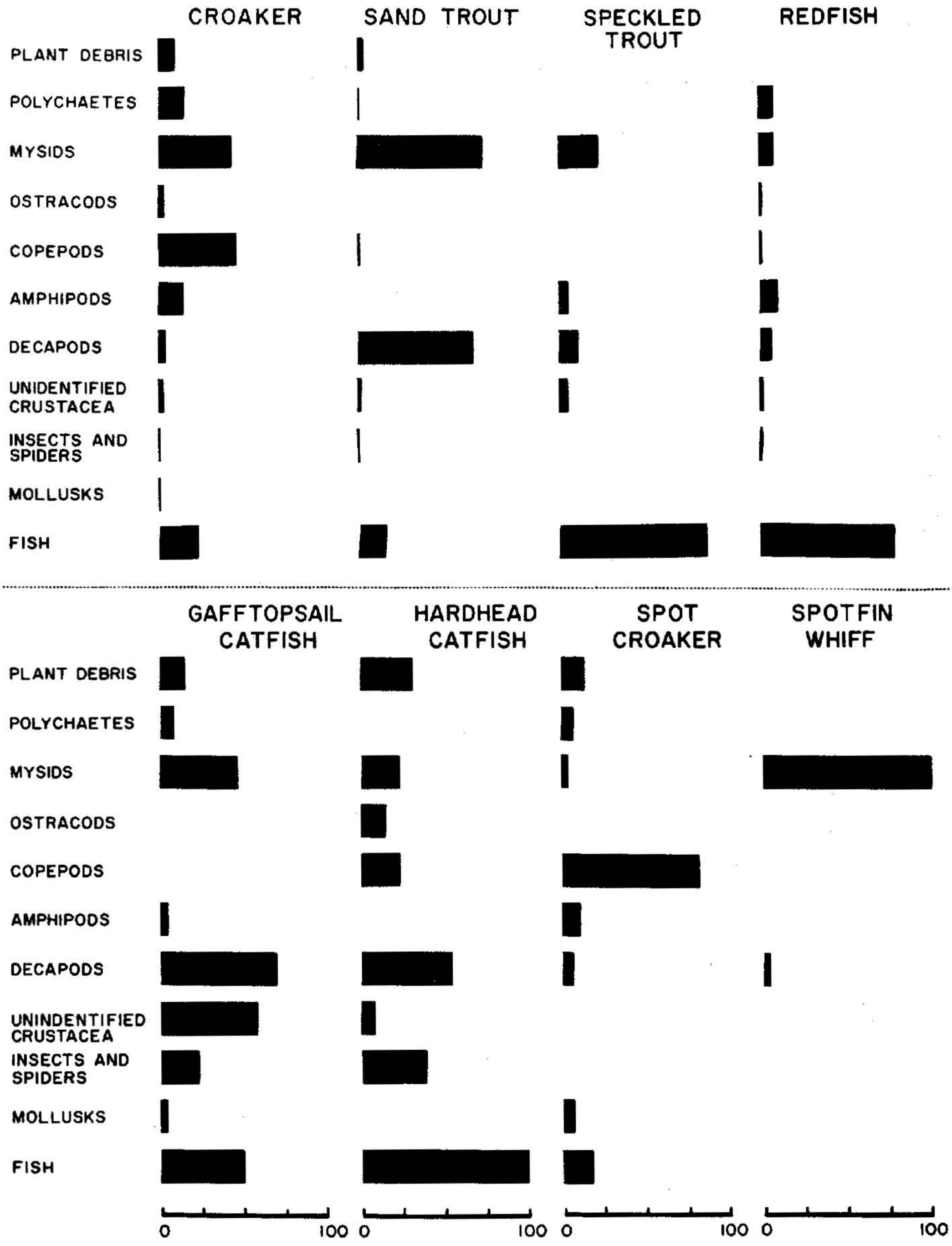
**Examination of Flounder stomachs incomplete

***Intestines of Oyster Dog all contained remains of a species of mud crab.

Analyses were made of the stomach contents; for some species, intestinal contents were noted when the frequency of empty stomachs was high. Identification of food items was to the lowest taxonomic unit possible, but later grouped into higher units. Representative material was periodically preserved for future reference.

Several species of fish were represented by too few specimens to determine utilization of food items with any degree of accuracy. Only those species represented by twenty or more specimens, with the exception of the hardhead catfish, (Galeichthys felis), are included in the following figure. The results are recorded as percent frequency of occurrence of the food item in those stomachs containing food.

Mysids appear to be the most important invertebrate food item, varying from 3.6 percent in spot croakers, (Leiostomus xanthurus) to nearly 80 percent in sand trout, (Cynoscion arenarius), and 100 percent in the spotfin whiff, (Citharichthys spilopterus). Copepods occurred most often in the bottom feeding fishes such as golden croaker, (Micropogon undulatus), spot croaker and hardhead catfish. Acartia tonsa; Canuella sp.;



Percentage occurrence of particular food items in those stomachs containing food.

Eurytemora hirundoides; and Diaptomus moorei made up the bulk of the copepod group. Penaeid shrimps, grass shrimps, and crabs were grouped together under the heading decapods. This group was represented by only 4 percent in golden croakers and about 70 percent in gafftopsail catfish, (Bagre maria). Larval grass shrimp, (Palaemonetes spp.), blue crabs, (Callinectes sapidus), and mud crabs (Neopenopeus texana) composed the bulk of the decapod group. Penaeid shrimps occurred in less than 4 percent of all species of fish examined, in spite of the fact that, from April through June, these shrimp were very abundant in Clear Lake. The low frequency occurrence of penaeid shrimps in the stomachs of speckled trout, (Cynoscion nebulosus) and redfish, (Sciaenops ocellatus) probably occurs because the period of abundance of these shrimps in the lake occurred later than that of the fish. Fish, mainly menhaden (Brevoortia patronus), and golden croaker, occurred in the stomachs of most fish examined, varying from none in spotfin whiffs to 15.5 percent in sand trout and 88 percent in speckled trout.

INDUSTRIAL FISHERY INVESTIGATION

Edgar L. Arnold, Jr., Chief

The Industrial Fishery Investigation of the Galveston Laboratory includes research work on two important fisheries of the Gulf of Mexico, based on two primary objectives.

1. The menhaden (and other clupeoids)
2. The demersal fishery for industrial fishes.

With the increase in commercial landings of the Gulf menhaden, Brevoortia patronus, from 10 million pounds in 1937 to approximately 450 million pounds in 1951 and subsequent years, justifiable concern was felt as to whether the menhaden population could maintain itself indefinitely. Knowledge of the year class composition of the commercial catch from year to year would aid in solving the problem, and since April 1956, catches have been sampled from two areas (Sabine Pass, Texas, and Moss Point, Miss.) to determine age and growth of the species by scale reading. Additional data have been obtained through collections of pre-exploitable sizes of menhaden in local waters.

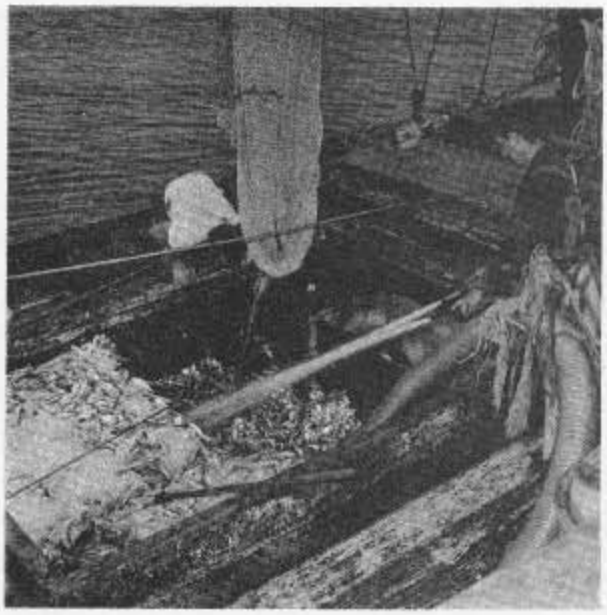
The manufacture of animal food products from demersal fish landings in Florida, Alabama, Mississippi and Louisiana, has grown from a pilot plant operation, started in 1953 at Pascagoula, Mississippi, to a firmly established industry processing landings approaching 100 million pounds annually. The Pascagoula-Moss Point area is the center for the plants engaged in this activity. Processing plants are also located in the Gulfport-Biloxi area, Mississippi; in Empire, Cameron, and Morgan City, Louisiana; Apalachicola, Florida; and Sabine Pass, Texas; with expansion either presently occurring or contemplated.

Pioneer processors believed they could obtain enough fish for their products from those caught incidentally by the shrimping fleet. In support of this opinion, previous investigations had shown that millions of pounds of scrap or trash fish were discarded annually by the shrimp fleet. However, the rapid expansion of the market for industrial fish products has since forced the processors to equip boats specifically for their needs, and such vessels are now in operation.

Trawl-caught Industrial Fishes

James P. Cating and Rupert E. Andrews

Since October 1958, biologists at the Pascagoula field office have been engaged in a study of the industrial fishery of the northern Gulf. The long-range objective is to observe and measure the effects of this fishery on the exploited populations of fish and other marine forms in or near the fished areas.



Pumping fish into a processing plant from a trawler.

Several cruises were made aboard research vessels of the Pascagoula Laboratory during exploratory fishing. Because of the nature of the catches it was decided that the most productive data could be obtained by concentrating on fish landed at the processing plants. These fish are almost exclusively demersal or bottom species. Current activities, therefore, have been directed towards acquiring information on the following:

1. Statistics of landings by months
2. Identification of fishes entering the catch
3. Species composition of the catch by weight and number

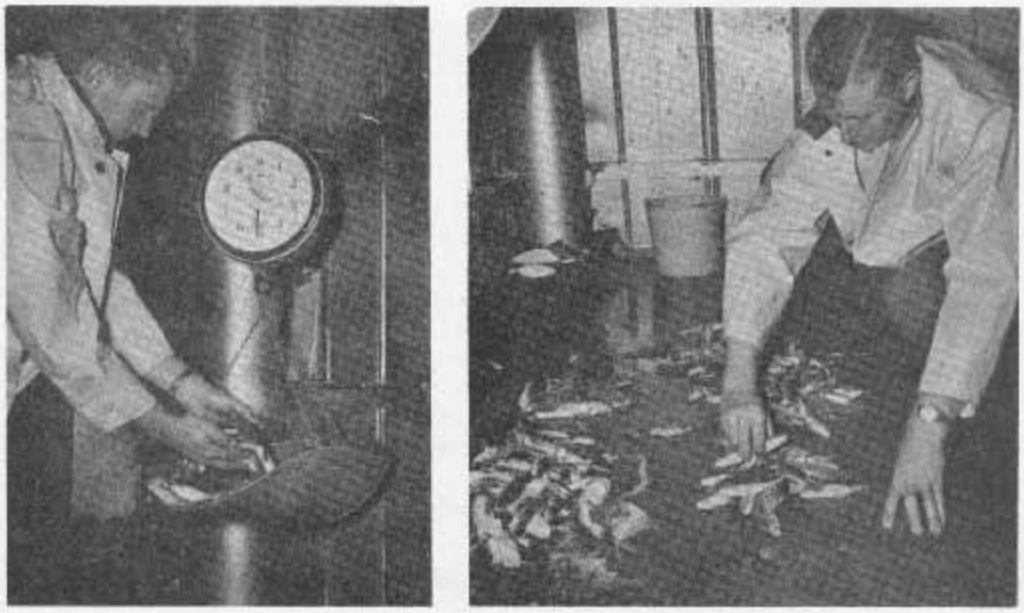
4. Seasonal distribution and abundance of the more important species
5. Life history of clupeoid fishes.
6. Biology of fishes collected on cruises of vessels of the Pascagoula Laboratory of the Branch of Exploratory Fishing and Gear Research.

Landings Total catch and the number of landings by month have been obtained from January 1956 through May 1959. With the exception of January, the landings during the winter months were lower than in the spring and fall, due to a combination of bad weather and a slow-down in production by larger processors. January had better weather, and production was more than 10 million pounds, the lowest monthly production in this period was approximately 6 million pounds in March. The average individual landing from 1956 through 1958 increased at one of the plants from 21,659 pounds to 31,946 pounds.

Sampling procedure Species composition by numbers and weight is obtained by sampling the landings. As most of the boats from different plants fish the same areas, it is reasonable to assume that the sampled species composition is representative of the total landings of the entire section. A standard sample of 20 pounds is obtained from near the bottom of each vessel load where the pumping system (used to unload the vessel) thoroughly mixed all strata of the load together. In the early phase of the investigation, various sample sizes and sample locations were tried from individual landings. Analysis showed a relatively small variation between samples from the same hold taken at different strata in the load, but a much greater variation between vessels. Treatment of each sample is as follows:

1. Separate sample by species
2. Determine number of fish of each species
3. Determine weight of each species
4. Determine total weight of sample
5. Determine percent composition of sample by number and weight for each species.

Boat interviews provide information on total catch, location of catch, depth of water fished, number of tows, occasionally the length of each tow, and whether the fishing was during the day or night, or both.

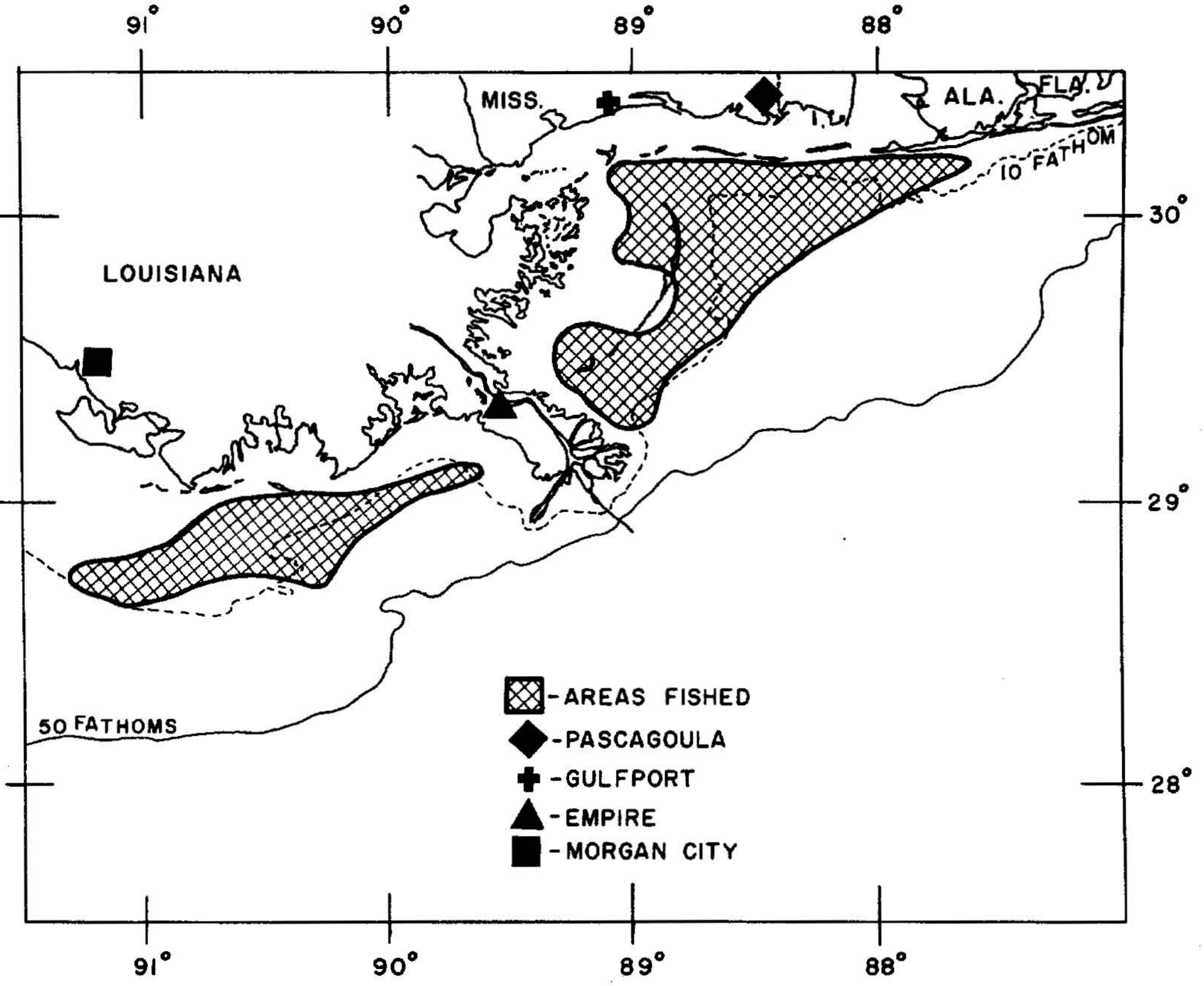


Sorting and weighing industrial fish samples.

Species composition At present 55 families of fish, comprising 104 species, have been identified in the landings. During the period of sampling, four species comprised approximately 75 percent of the total catch, and 25 additional species contributed almost all the remainder. Seasonal fluctuations in the numbers of each principal species are quite pronounced, some disappearing from the catch for extended periods. Other species only occasionally encountered contribute but a small percentage of the total.

Distribution of sampled landings The area fished extends from Port St. Joe, Florida, to west of Ship Shoals, Louisiana, and trawling is almost exclusively confined to within the twenty-fathom line. The general areas are shown on the accompanying map. A seasonal shift of fishing effort was observed during the period sampled. The most important trawling areas are in the immediate vicinity of the offshore inland passes. Observations during the period October 1958 through April 1959 indicate the appearance and disappearance of some species with change of seasons and areas fished. At present, it is not known how extensive these migrations may be. Presumably, the fish seek more favorable environmental conditions in areas not presently being fished. These could be either deeper or more shallow waters than fished, or areas outside the geographical area presently utilized by

fishermen. The commercial catch is presently the best source of information concerning the distribution and abundance of these fish. Areas are fished mainly where existing knowledge presages a successful venture. Extensive potential fishing areas extend east and west of the geographical area presently utilized. Catches by the Bureau's exploratory vessel OREGON and other vessels have shown commercial concentrations of fish in most of these



Major ports and fishing areas of the present industrial fishery based on trawl catches.

areas. Large numbers of clupeoids, chiefly thread herrings, were observed and captured by lampara and mid-water trawl off St. Petersburg, Florida, indicating potentialities for this type of fishing.

Menhaden

Edgar L. Arnold, Jr.

Routine sampling of commercial catches of menhaden for age and growth analysis continued until September at Moss Point and until the end of the season (October) at Sabine Pass. Sampling operations for 1959 are very limited in extent. Reading of the 1957 scale samples from both areas was completed. Analysis of age data showed that one- and two-year old fish made up 84 percent of the Sabine Pass samples in 1956, and 83 percent in 1957. For Moss Point, the percentages were 88 percent and 86 percent in 1956 and 1957, respectively. Three-year old fish comprised approximately 11 percent of the samples for both areas during the two-year period. Readings of the 1958 scale samples have not been completed.

The feasibility of using otoliths as a means of age determination was explored. This method was discarded, due both to the very irregular shape of the menhaden ear bones, and to the excessive time required for their dissection from the fish.

Recruitment from the unusually large concentrations of juvenile menhaden observed last spring in inshore Gulf waters seems to be reflected in the excellent fishing currently reported by the industry.

Occurrence of early stages From November 1953 through May 1958, periodic biological collections, averaging about one every 4 days, were made in local inshore waters, principally in East Lagoon, Galveston Island. Material was obtained by several types of gear; namely, plankton net, cast net, dip net, and beach seine. A detailed report has been prepared.

Larval, post-larval, and juvenile menhaden appeared in many of the collections throughout the period. Their occurrence in plankton net catches is given in the accompanying table. Specimens measuring 16-20 mm. were found in November, and still were present in early May, together with juveniles up to 50 mm. in length. From these data, it may be concluded that spawning of Brevoortia patronus in this area takes place, probably off-shore, from late October through April, with a peak in January.

Occurrence of B. patronus (larvae and post-larvae)

Average number per tow

	1953	1954	1955	1956	1957	1958
January		3679	77	671	21	189
February		701	332	1228	108	359
March		558	234	511	141	114
April		111	16	226	140	37
May		-	1	-	0	1
June		0	0	0	0	
July		0	0	0	0	
August		0	0	0	0	
September		0	0	0	0	
October		0	0	0	0	
November	62	0	2	1	145	
December	43	103	251	40	271	

Collections of menhaden in other areas indicate that this species utilizes many types of inshore waters as nursery areas, from the highly saline lagoons and bayous to the nearly fresh waters of ponds, streams, and lakes. Large numbers of B. patronus from 23-50 mm. were taken by cast net on April 4, 1957 in Moses Bayou and Moses Lake. Juveniles from 40-78 mm. in length were collected in August 1956 from thousands of dead and dying specimens observed floating in the Intracoastal Canal near the Port Arthur drawbridge. During late March 1958, several hundred post-larvae, 20-25 mm. in length, were dipnetted from dense schools observed in the yacht basins at Rockport and Corpus Christi. Juveniles were observed and collected on numerous occasions from mid-November to May in a drainage ditch some 2 miles from where it empties into Highland Bayou. During the course of the current shrimp investigations in Clear Lake, post-larval and juvenile menhaden frequently occurred in collections made in the autumn, winter and spring.

Menhaden Populations

J. Y. Christmas, Jr.

Gulf Coast Research Laboratory, Dr. Gordon Gunter, Director
(Contract No. 14-19-008-9335)

The objectives of this contract are to define discrete populations of menhaden in the Gulf of Mexico, to determine the distribution and location of spawning grounds, and describe in detail the life history of Brevoortia patronus.

Young menhaden Collection of larval and young menhaden has been continued through this year. Plankton sampling stations were extended to the 20-fathom curve, 35 miles off the Mississippi mainland. Ninety-six samples have been recorded in the plankton log. Eighty-one samples of eggs and larval and early post-larval fishes have been isolated for study. Sampling with haul seines was found unsatisfactory for catching young menhaden. Better results were obtained by hunting the young fish with a fine-mesh brail net. Approximately ten thousand young have been measured and preparation of length-frequency polygons for comparison by areas and time intervals is in progress.

The spawning population In addition to the gear already reported on, a midwater trawl was used in the search for spawning menhaden. On December 19, 1958, at the end of an unproductive two-day search off shore, large schools of young menhaden were seen in Dog Keys Pass. When the midwater trawl was hauled through one of the schools showing on the fathometer approximately 500 pounds of menhaden were taken. The mean total length was about 100 mm. Although small fish were taken on numerous occasions, large fish were not caught in the midwater trawl at any time.

One large male with full testes was gilled in the wing of the net on January 14. This haul was made approximately 25 miles off Petit Bois Island in an area where numerous small schools of fish were showing on the fathometer near the surface. Several large Poronotus triacanthus also were taken in the trawl. Many eggs and clupeid larvae, probably menhaden, were in the plankton tow made at the same time. A few menhaden with well-developed roe were taken by drift fishing a gill net in waters as much as 30 miles off the mainland.

In general, the study of developing gonads verifies the pattern already reported. Specimens of reproductive organs have been prepared for histological study of the development and seasonal variation of these organs. Mr. Ralph M. Combs, Professor of Biology, Northwestern State College,

Natchitoches, Louisiana, has sectioned and stained many of these specimens. Study of the slides is expected to get under way this summer.

Sampling of the purse seine catch A study of the purse seine catch brought to Mississippi processing plants was started in June 1958. During this study biologists made trips with commercial boats to cover each month of the fishing season. Samples were taken from each of 87 hauls made in 26 days of fishing. Assuming 130 fishing days for the season, approximately 20 percent of the seasonal catch of one boat was sampled. The total catch sampled on the fishing grounds, 2,977,500 "fish" (1,965,150 pounds), also approximates 20 percent of the annual catch of boats of the type from which sampling was done.

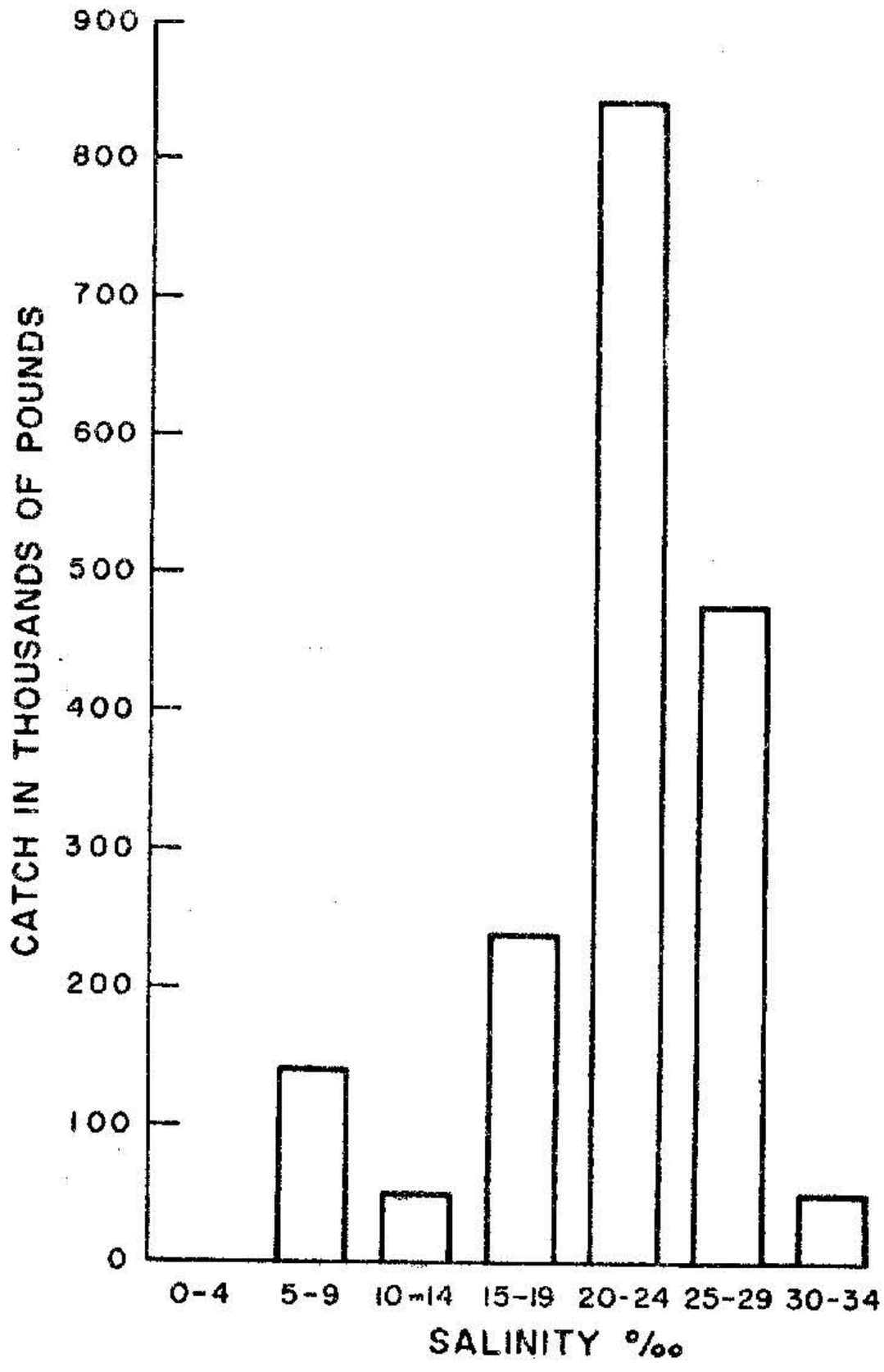
Location, time, weather conditions, and water depth were recorded when the net was set. As the "steamer" came alongside the purse boats, surface water temperature and a sample for salinity determination were taken. Samples of the catch were obtained from the chutes directing fish to the holds as they were pumped on board. Approximately equal portions from the beginning, the middle, and the end of the pumping operation made up the sample. All species observed in the net were recorded. An estimate of the catch was received from experienced personnel on the boat. When the total of these estimates was compared to the measurement made at the factory on unloading, they were found to be conservative, but reasonably accurate. Counts of each species in the sample were made after pumping was completed. Fork-length measurements, parasite counts, and various meristic measurements completed the work with each sample. In addition to the sampling on the fishing grounds, samples were taken from the holds of boats unloading at the Moss Point plants. Fork lengths of 10,313 menhaden were recorded. Length-frequency polygons were constructed for two-week periods.

In general, menhaden purse seiners working out of Mississippi plants start fishing about mid-April and complete the local season by October 15, or shortly thereafter. Practically all fishing observed in the course of this study was done in inside waters where depths seldom exceed 3 fathoms. Breton, Chandeleur and Mississippi Sounds were fished from June through October. Late in the season some fish were taken in Gulf waters off these areas.

The 1959 season started in April in Breton Sound. During the last week of May the boats moved to the west of the Mississippi Delta where conditions are essentially the same as those found in the sound areas to the east. A heavy run of fish from Grand Isle to West Bay produced excellent catches.

Surface water temperatures recorded show a minimum of 22.6° C. and a maximum of 30.5° C. The lower temperatures were taken at the beginning and the end of the 1958 season.

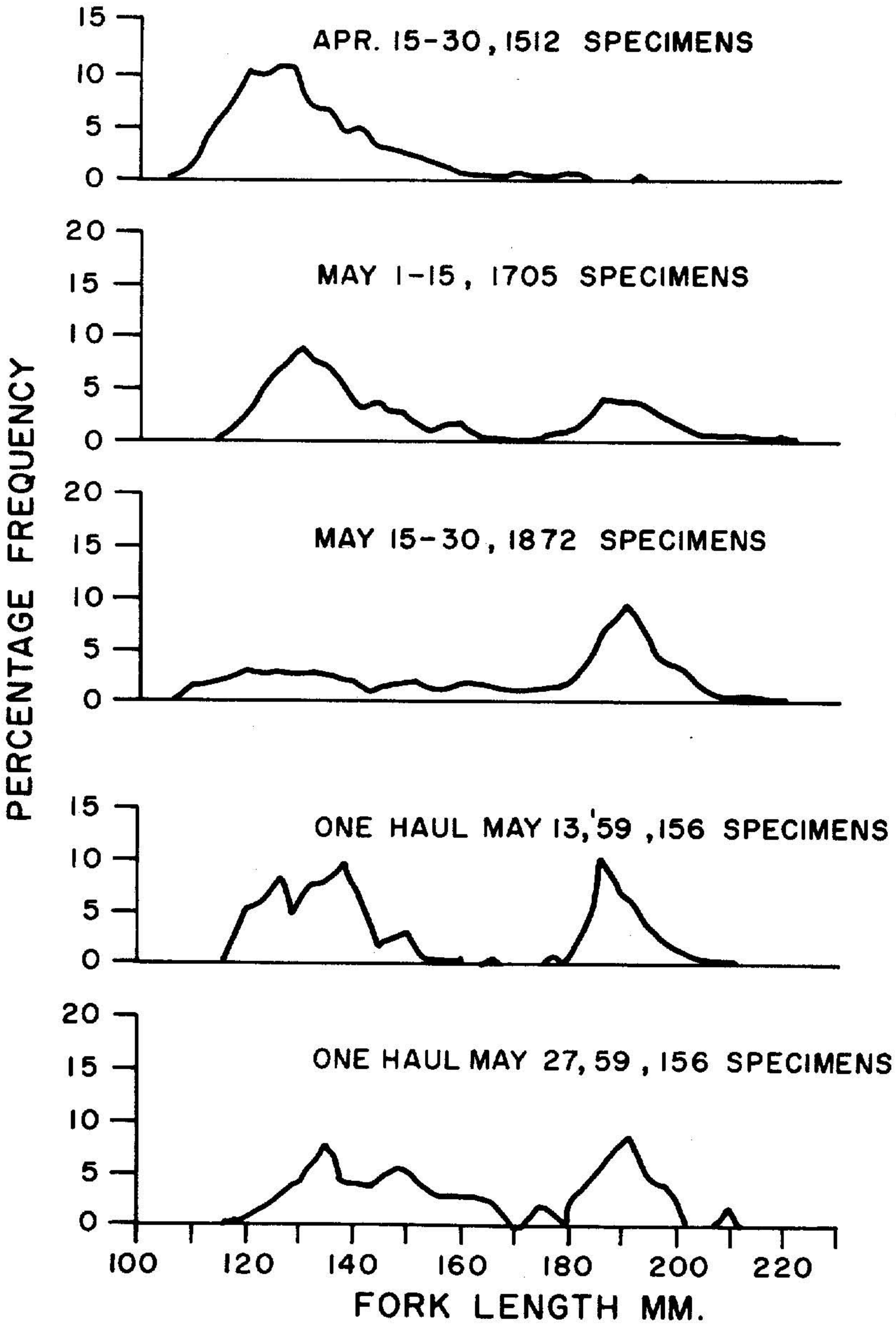
Salinities ranged from 6.15‰ to 31.58‰. Fifty-eight percent of the 84 samples taken showed salinities of 20-24‰, eighty-eight percent of the samples were in a salinity range of 15-29‰. The distribution of the catch over the observed salinity range is depicted in the accompanying figure.



Relationship of salinity and catch.

Fork lengths were recorded for 7,021 Brevoortia patronus measured on the fishing grounds. The least length recorded was 84 mm. and the maximum was 225 mm. Frequency polygons indicate that there are usually 2 distinct modal groups in the catch. In June 1958, fish of 180 to 200 mm. dominated the catch with a second group of 130-160 mm. making up about 40 percent of the catch during the last 2 weeks of the month. By mid-August the mode of larger fish had almost disappeared, and the second group dominated the catch for the remainder of the season. At the end of the season this modal group was made up of fish about 160-185 mm. In the last half of August young fish

from 85-135 mm. entered the catch, and comprised a small segment of it until the end of the season.



Menhaden length frequencies from purse seine catches, Mississippi.

At the beginning of the 1959 season, fishing started on small fish falling in a modal group of about 115-150 mm. By the end of May a second mode of larger fish was dominant. Approximately forty percent of the landings in this period were from 185-200 mm. All fish examined were in excellent physical condition. Heavy catches were producing large quantities of oil at the plants. According to local fishermen, the predominance of small fish at the beginning of the season in this area is unusual. Length-frequency polygons of fish taken in one set indicate that schools are often mixed within the area surrounded by the net.

Parasites Three external parasites are readily observed when present as adults on menhaden. Lernaeenicus radiatus is commonly attached to various parts of the body. Lernanthropus brevoortiae attaches itself to the gill filaments. Olencira praegustator sometimes nearly fills the mouth. Of 3600 fish examined in April and May 1959, 1.5 percent had Lernaeenicus attached or recently torn out. An infestation of 5.7 percent was observed in July and August of 1958, and in October 7.7 percent were found to be parasitized. Eleven hundred specimens were checked for Lernanthropus by pulling back the operculi, and showed an infestation of 37 percent. Olencira was not found in any of the 3600 specimens examined.

Other fishes A total of 55,949 fishes were counted in the samples taken on the fishing grounds. Brevoortia patronus was 96 percent of this count. When these counts are weighted according to the size of the haul we find that 97 percent are menhaden. Usually, larger hauls contain a higher percentage of menhaden. Seventy-five percent of the fish sampled were taken in hauls comprising over 99 percent menhaden. The average haul size in this segment of the catch was 50,000 "fish."

Only five hauls had less than 90 percent menhaden. Three of these five hauls caught 5,000 or fewer units of fish. Mugil cephalus and Micropogon undulatus accounted for most of the fish in the two larger hauls. Sharks of various species and Caranx hippos were seen in many hauls. Since these larger fish are thrown out of the net to prevent clogging of the pump, they do not enter the counted samples. The most abundant game fish observed in the nets was Scomberomorus maculatus. Bagre marina were present in considerable numbers at times. Food and game fish were not taken in quantities in any haul. Approximately fifty species other than Brevoortia patronus were recorded.

RED TIDE INVESTIGATION

William B. Wilson, Chief

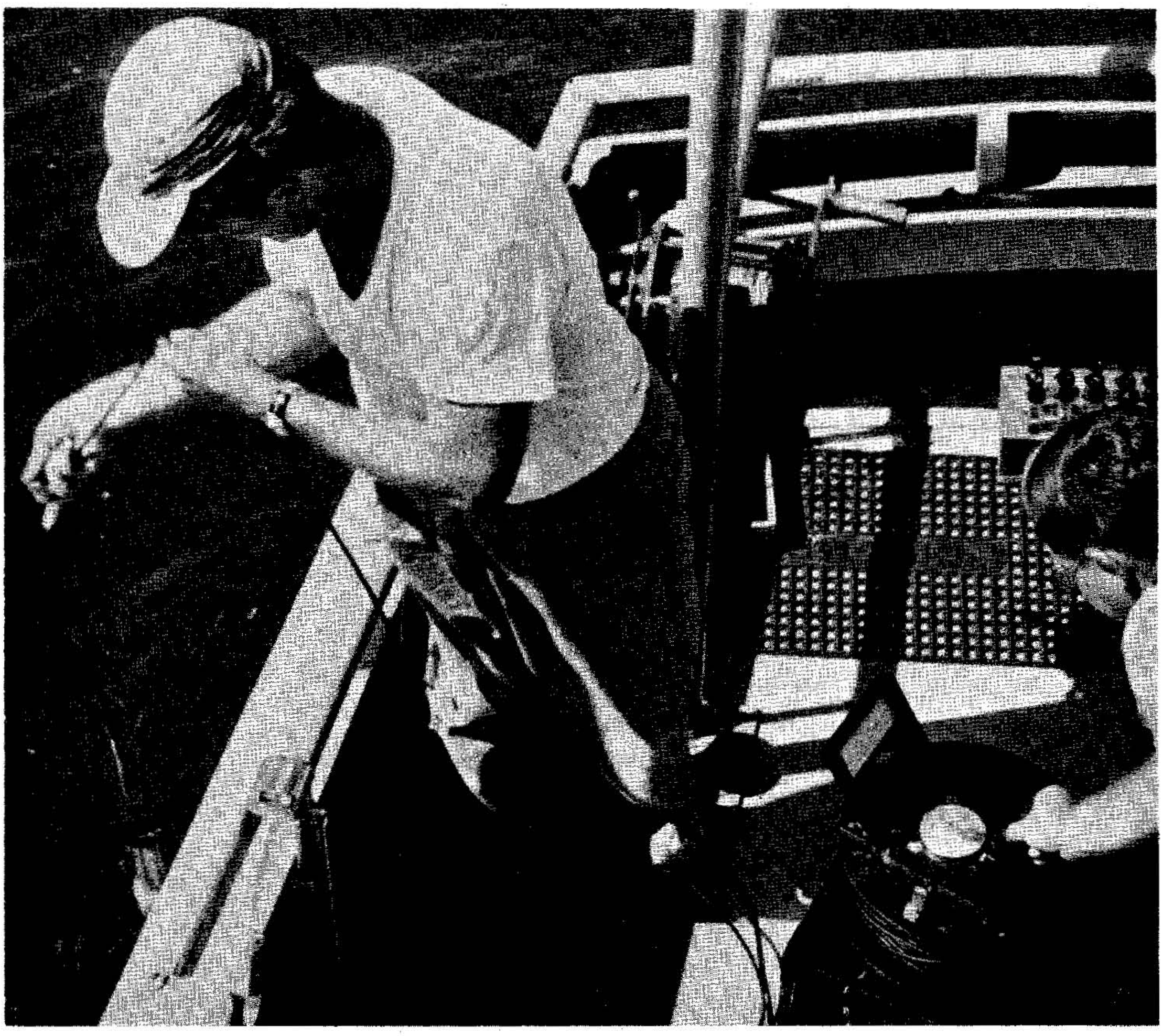
The abundance of Gymnodinium breve was low along the west coast of Florida during the past year. The incidence was occasionally high, but there was no tendency for these populations to increase.

The rainfall of southern Florida was below normal during the summer of 1958 and near normal during the fall and early winter months. The rainfall has been above normal during the first five months of 1959 (except for February). The March rainfall in the vicinity of Tampa Bay was the record for that month.

Three new projects were initiated during the past year. A project to determine the hydrological characteristics of Tampa Bay and adjacent Gulf water was started in October 1958. The area of the project extends from the rivers that flow into Tampa Bay to a location 40 miles west of the mouth of the embayment. Determinations of phosphorus, nitrogen, copper, temperature and salinity are the principal hydrological features of this project. A detailed study of the distribution of G. breve is the principal endeavor of another project also initiated in October, in conjunction with the hydrological project. Sampling for both of these projects is conducted simultaneously. The area is divided into six subareas and 36 stations, each subarea containing from one to four pairs of stations. Each station is sampled once monthly at the surface, bottom and two intermediate depths. Samples are taken for chemical analysis (except copper) with Nansen bottles. Samples for biological examination and for copper analysis are taken with polyethylene jugs. Thus far during the year, the St. Petersburg Field Station has made 8,577 individual analyses for inorganic phosphate, total phosphate, copper, nitrate-nitrite, and salinity.

The determination of the toxicity of organic compounds to G. breve was initiated during the year. The objective of this project is to find a compound which is toxic to G. breve at relatively low concentrations (compared to copper), but is not toxic to other forms of marine life. Several thousand chemicals will probably be tested.

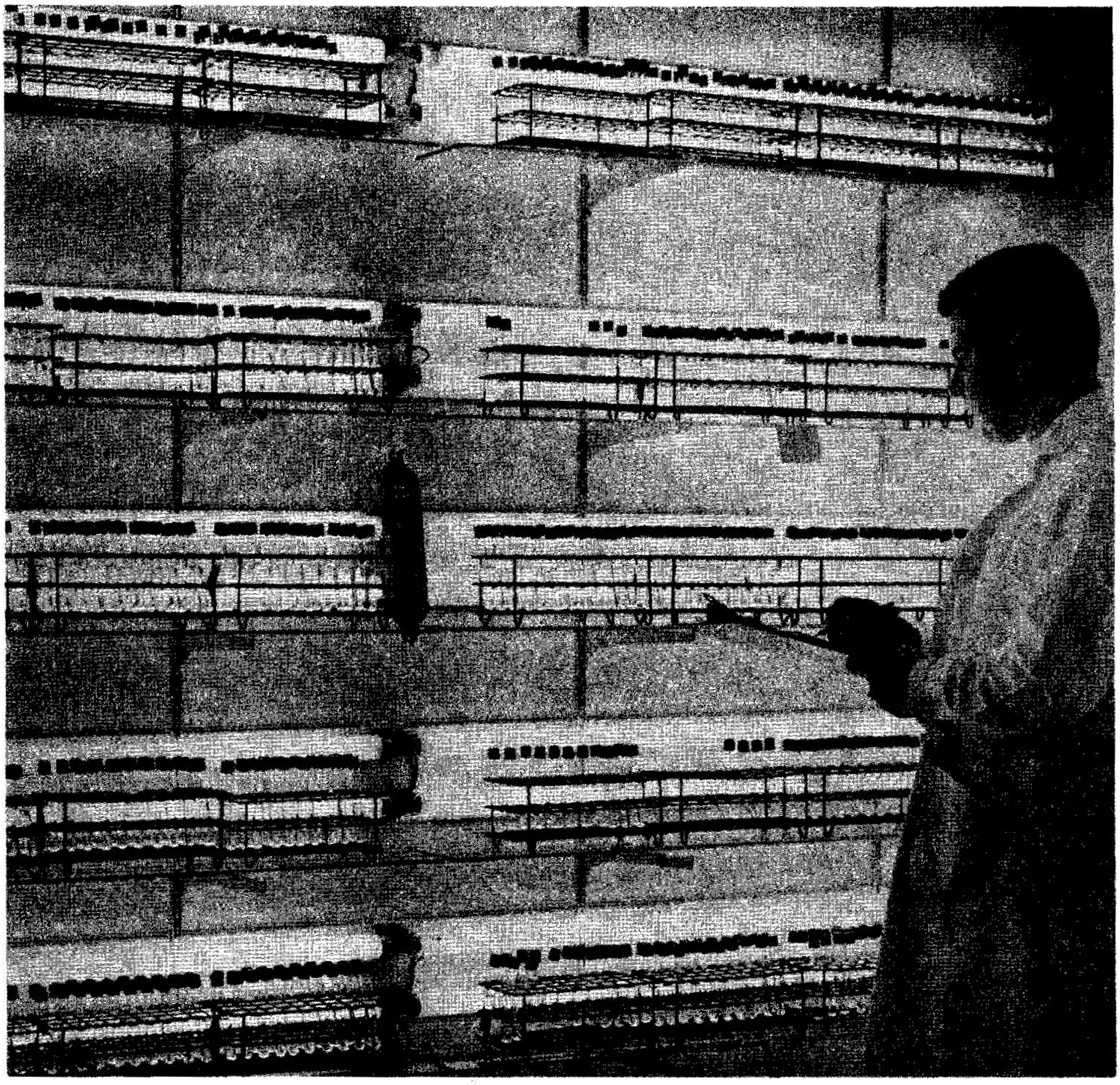
The field work of all phases of the project to determine the feasibility of the use of copper ore as a control agent for G. breve is virtually completed, and the final results will soon be the subject of a report.



Measuring water temperatures in Egmont Channel with the electric thermistor from the research vessel KINGFISH.

Studies of the effects of various salt concentrations of media on the growth of G. breve have been completed. The effects of various temperatures on growth and survival have progressed and the results to date indicate that naturally occurring high and low temperatures may at times limit the growth of this organism. The effects of the hydrogen ion concentration of the medium, and of variations in light intensity are other topics being investigated.

Nutritional studies emphasized the effects of phosphorus, vitamins and trace elements on the growth of G. breve. These studies indicated that thiamine (or perhaps similar compounds) is required by G. breve. Phosphate and calcium combinations which support good growth of G. breve were determined.



The modern light room for growing cultures just completed at the Galveston Laboratory.

During the past year unialgal cultures of G. breve were established at the Florida Field Station to use in developing counting techniques. An enlarged and modernized light room was completed at the Galveston Laboratory to speed up experimentation.

Physiological Studies of Red Tide

David V. Aldrich

The sporadic recurrence of the Florida red tide and the mortality of marine organisms associated with it have stimulated considerable interest in the biology of Gymnodinium breve. The lack of information concerning the physical and physiological growth requirements of G. breve has occasioned a series of controlled laboratory studies designed to provide this type of information.

Salinity Investigations of the growth response of G. breve to various total inorganic salt concentrations have been completed. Results show the optimal growth range for the bacteria-free organism to extend from 35 to 50 grams total salts per liter of distilled water base medium. Within this range, high growth levels occurred in at least 15 of the 20 replicate cultures in each salinity group. Occasional instances of good growth were observed in media containing 32 or 53 gm./l., but none occurred in 29 gm./l.

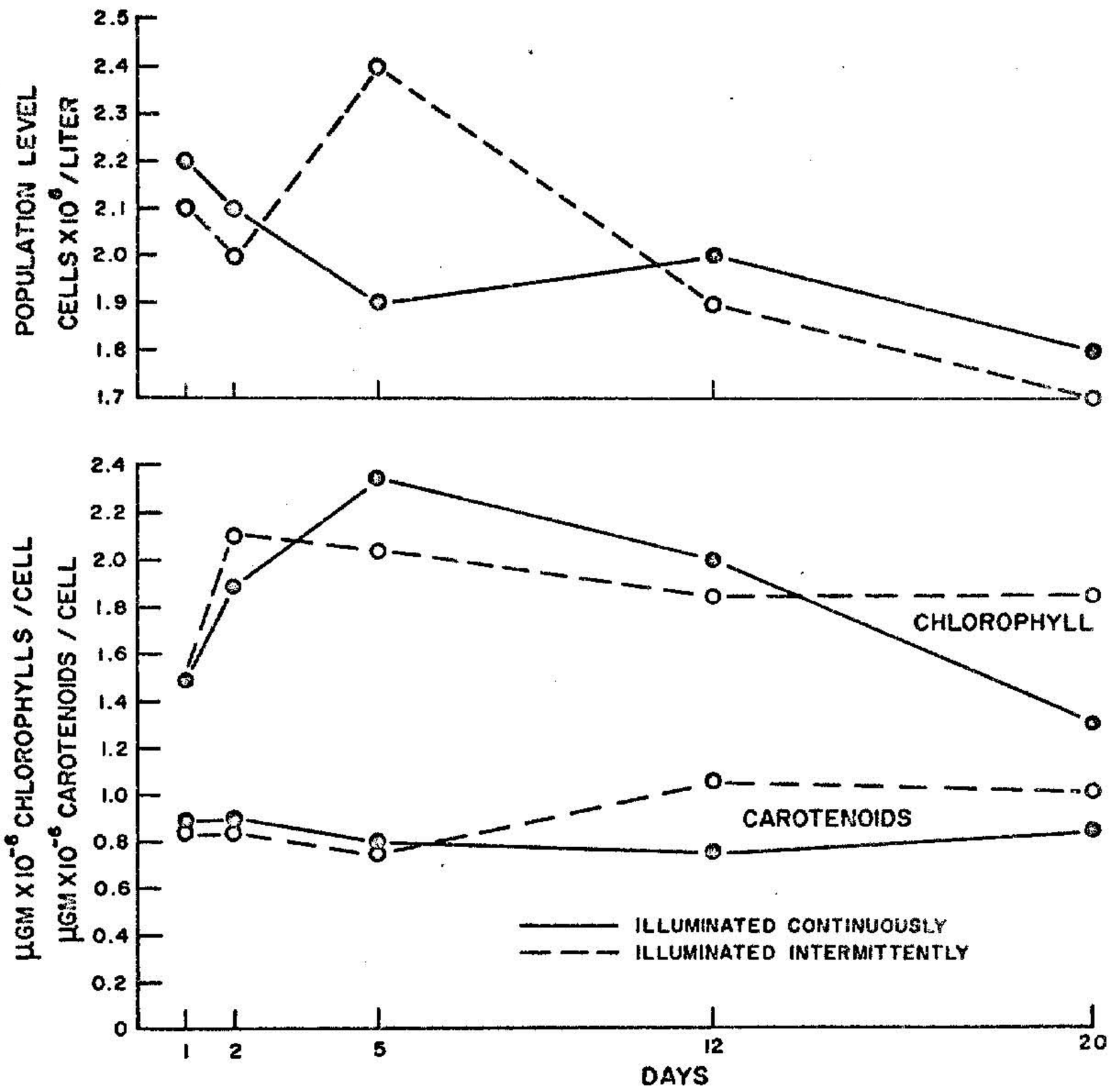
The development of high population levels in these relatively high salt concentrations suggests that salinity per se is not the limiting factor which precludes the frequent occurrence of G. breve in the open sea. However, the lower end of the tolerance range indicates that low salinity may be important in determining the distribution of this organism in estuarine environments.

Hydrogen ion concentration A study of the effect of pH on growth of G. breve in bacteria-free cultures shows that growth is unhampered by pH's of 7.5 to 8.3, inclusive. Growth took place at a reduced rate at a pH of 7.3, and lower values were definitely toxic. Medium having a pH of 7.2 was 100 percent lethal to this organism within six days, while 7.0 killed all cells within two days.

Temperature Over 800 individual cultures of G. breve have been exposed to specially controlled temperature conditions in a series of experiments intended to reveal the temperature tolerance of both established and freshly-seeded cultures. The results indicate that the organism did not survive temperatures of 7° C. and below, or 32° and above. Population growth did not occur at 30° (or above) and survival was very poor. Multiplication was visibly slowed at 15° C., but not completely halted. It is apparent that the level at which temperature becomes absolutely limiting to growth lies between 7° and 15° C., but the work which will determine this level more exactly is not yet complete. Optimal growth can occur in a range of temperatures including 20° to 27° C. Future studies will attempt to provide a more complete

coverage of the temperature tolerance scale. Further work will include slow acclimatization studies, which should show whether these temperature ranges can be extended by employing very gradual deviations from optimal temperatures toward the extremes.

These results strongly suggest that temperature can be an important factor in limiting the geographic distribution of G. breve. In this regard it may also be noted that Florida red tides occurring in the fall have ceased with the advent of the first cold weather of the subsequent winter.



Relation between population levels and pigments in G. breve illuminated either continuously or intermittently.

Light and pigments Recent experiments confirmed earlier work which showed that G. breve can survive less than a week without light under

laboratory culture conditions. Obviously, this organism is capable of photosynthesis, and probably derives most of its energy by this means. Supporting evidence for this point has been obtained by analyses of the cell pigments. This work indicated the presence of chlorophyll a, chlorophyll c, and carotenoids (pigments required in photosynthetic processes). These findings suggest a need for careful evaluation of the possible effects of light variation on this organism.

Other results suggest that the light levels used under present culture conditions are not limiting to the growth of G. breve in established cultures. The study was designed to show the effect of an artificial day-night type of intermittent illumination on pigment and population levels of this organism in five-liter unialgal cultures. The intensity of illumination, when provided, was 480 foot candles of fluorescent light, measured at the proximal surface of the culture vessel. (Our cultures are normally illuminated continuously with 400-800-foot candles of fluorescent light.) The results, presented graphically, indicate that under these conditions the cells are able to store sufficient quantities of photosynthesized nutrients to survive intermittent 12 to 16 hour periods of darkness without observable reduction of reproductive rate or pigment content. The pigment analyses in this and the above-mentioned study were carried out in collaboration with Zoula P. Zein-Eldin of this station.

Future work will investigate the effects of variation in intensity and wave length of incident light on G. breve.

Nutritional Studies on Red Tide

William B. Wilson

No study of the ecology of red tide can be considered complete without an understanding of the nutritional factors which may limit or stimulate growth of the associated algal population. In regard to G. breve, such information has been particularly sparse, due chiefly to a lack of adequate culture methods. The recent development of procedures permitting growth under controlled physical and chemical conditions has allowed nutritional research to proceed.

The aspects of G. breve nutrition which have been principally studied include the effects of calcium, phosphorus, vitamins, and trace elements.

The minimum calcium content of media in which G. breve grew was approximately one-sixth the amount of standard sea water (salinity - 35.5‰), or approximately 70 mg/l (1.7 mg at/l). An increase in calcium to twice the amount of open ocean water was not detrimental as long as the phosphorus content was less than 5 µg. at/l. If the calcium content is between 140 and 400 mg/l, cultures have grown very well in most concentrations of phosphorus. There was some limitation of growth if the phosphorus was less than 0.04 µg. at/l or more than 100 µg. at/l. In the latter case, the high phosphorus content caused precipitation, as did excessive calcium. When precipitation occurred, G. breve did not grow.

The results of the calcium-phosphorus experiments indicate that if the calcium concentration was the same as that of normal open ocean water (approximately 400 mg/l), inorganic phosphorus content should be 0.4 µg. at. per liter or greater for the medium to support good growth of G. breve. Optimum growth occurred within a range of 0.4 to 40 µg. at/l of phosphorus if the calcium content was between 140 and 400 mg/l. Media with phosphorus concentrations as high as 400 µg. at/l supported good growth of G. breve if the calcium concentration was between 140 and 250 per liter. On the other hand, media with calcium concentration as high as 1000 mg per liter supported good growth if the phosphorus content was between 0.04 and 4.0 µg. at/l. The above values for calcium and phosphorus should be revised slightly upward (less than 0.01 percent) because of the occurrence of these elements as contaminants in the other components of the medium.

Vitamins Three water soluble vitamins, thiamine (B_1), biotin (B_3) and cobalamin (B_{12}), have been used consistently in artificial sea water media for bacteria-free G. breve. Results of earlier experiments indicated that G. breve would not grow in these media unless these vitamins were added.

In addition, thiamine was the most effective of the three vitamins, but a combination of thiamine and biotin supported better growth than thiamine alone. During the past year, a series of nine experiments was conducted to define more clearly the role of these vitamins in the growth of G. breve.

Results of these experiments are similar in many ways to the results of previous work in that thiamine was the most active of the three vitamins and a combination of thiamine and biotin was better than thiamine alone. However, these experiments indicate that the inclusion of cobalamin along with the thiamine and biotin further improved growth. In the earlier experiments, we had omitted cobalamin in ten serial subcultures without diminution of growth. In recent experiments, omission of cobalamin has resulted in lesser growth. To ascertain the source of the apparent discrepancy in

Effect of some vitamins and a group of trace elements on the growth of G. breve in artificial sea water medium (Numbers represent percent of cultures with each addition in each growth category).

	Growth (millions per liter)			
Additives 1/	None to slight	Slight (less than 0.5)	Fair (0.5 to 1.0)	Good (More than 1.0)
No addition	100	0	0	0
B_{12}	100	0	0	0
B_1	50	22	28	0
B_3	92	2	4	2
T	100	0	0	0
B_1 and B_{12}	50	20	30	0
B_3 and B_{12}	70	4	26	0
T and B_{12}	72	6	22	0
B_1 and B_3	10	50	25	15
B_1 and T	28	35	28	9
B_3 and T	80	10	10	0
B_1, B_3 and B_{12}	23	0	22	55
B_3, T and B_{12}	92	0	0	8
B_1, B_3 and T	15	55	14	16
B_1, B_3, B_{12} and T	15	0	0	85

1/ B_1 (Thiamine), B_3 (Biotin), B_{12} (Cobalamin), T (Trace element group)

these results we will initiate growth experiments using cobalamin and the other vitamins from more than one supply house.

The need for thiamine is pronounced in the experiments conducted to date. There is a possibility that similar organic compounds will substitute

for thiamine and we plan to conduct experiments to determine if such is the case. If not, assays of this vitamin in the field may be valuable for forecasting red tides.

Trace elements In earlier experiments we were unable to grow G. breve in artificial sea water media unless a group of trace elements was added. We have attempted to determine the elements of this group that are necessary for growth, but to date the results are inconclusive. Some elements, notably zinc, titanium, zirconium, and manganese and boron may be required by G. breve. The results of experiments using these as additives indicate that they may improve growth. Media containing copper, nickel, rubidium, molybdenum and barium have on occasions supported better growth than media to which they were not added. The addition of iron has not improved growth regardless of the concentration or form in which it was added. This does not mean that iron is not needed by the organism because it is a common contaminant of the major salts used in preparing the medium.

Aged sea water collected from an area of G. breve bloom will substitute for the group of trace elements. The addition of twenty milliliters of this water per liter of medium will support growth of G. breve when used to replace the trace elements. These results indicate that this water contains a relatively high concentration of the required group.

These elements, with the possible exception of zirconium, are normally present in sea water, and their absence would probably not be a limiting factor for red tides. The form and higher concentrations of these elements may be a limiting factor of red tides. We must add metal chelators or metal complexing substances to prepare a suitable sea water medium for G. breve, in most instances. Therefore, the occurrence of natural metal chelators or metal complexing substances may be necessary for red tides to develop.

A series of experiments was initiated to determine the source of nitrogen for G. breve. In these experiments, we were able to omit all inorganic nitrogen sources without reducing growth. These results indicate that either G. breve is obtaining nitrogen from the organic buffer (Tris-buffer), EDTA (ethylene-diamine tetra-acetic acid) or from the atmosphere. We will conduct tests to eliminate the organic nitrogen sources, if possible. If organic nitrogen is being utilized, analyses for total nitrogen may be more valuable than the nitrate-nitrite analyses which are being conducted at the present time.

Screening Chemicals for Red Tide Control

Kenneth T. Marvin

During the year a screening program was started to test several thousand chemicals to determine which, if any, are toxic at very low concentrations to G. breve, but non-toxic to commercially important organisms. Preliminary screening consists of determining the toxic and non-toxic chemicals without regard to their specific toxicity. A compound is considered toxic if its lethal effects to G. breve are detectable after a 24-hour exposure period at a maximum concentration of 1 ppm. This phase of the screening

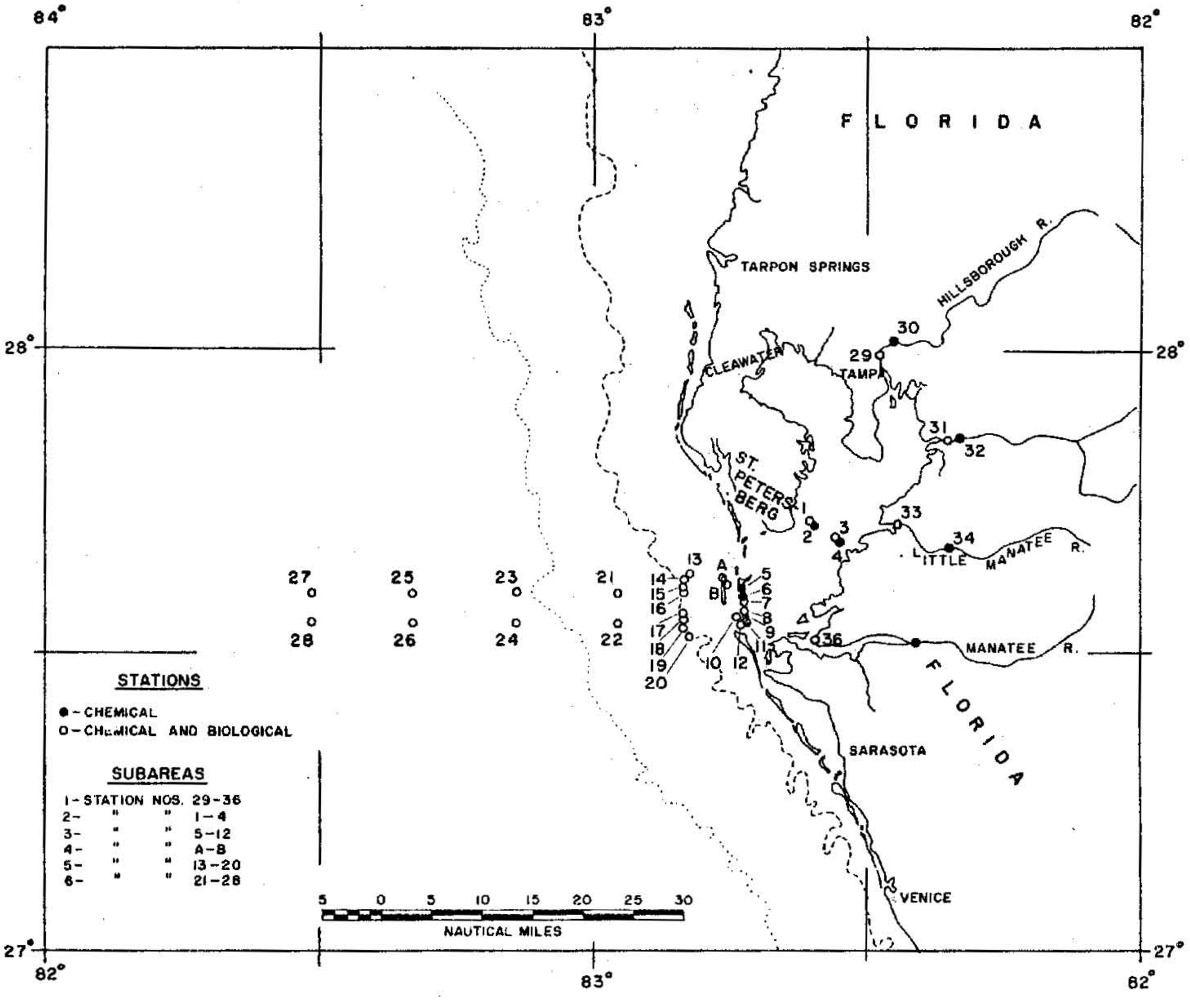
Examining aliquots of G. breve cultures.

consists of adding series of dilutions of each compound to aliquots of a G. breve culture. Several concentrations of each chemical between .01 and 1.0 ppm. are tested. After a 24-hour period, G. breve mortality is estimated by comparing counts of test aliquots with control tubes. Chemicals that show no effect at the maximum concentration are discarded. Those that do will be studied more intensively after the completion of the initial phase of the program. To date we have tested 250 compounds. About 6 of these are toxic within a 0.01 to 0.04 ppm. range.

Field Ecology Relating to Red Tide

John H. Finucane

Geographical distribution In an effort to further our knowledge on the ecology of Gymnodinium breve within a major drainage area, a series of 28 stations in Tampa Bay and adjacent neritic waters have been occupied monthly



Standard hydrographic stations in and adjacent to Tampa Bay.

since October 1958. During this period, 826 water samples were examined for the presence of G. breve and associated phytoplankton. Of these samples, 47 percent contained G. breve. The organism was found from the middle of Tampa Bay to 60 miles west of Egmont Key, the greatest incidence of G. breve

occurring offshore. This suggests that during periods of relatively low numbers this organism is still present in deeper neritic waters. During October-December 1958, G. breve was one of the dominant phytoplankton forms in these areas.

Percent of monthly samples from each subarea of Tampa Bay and adjacent neritic waters containing G. breve.

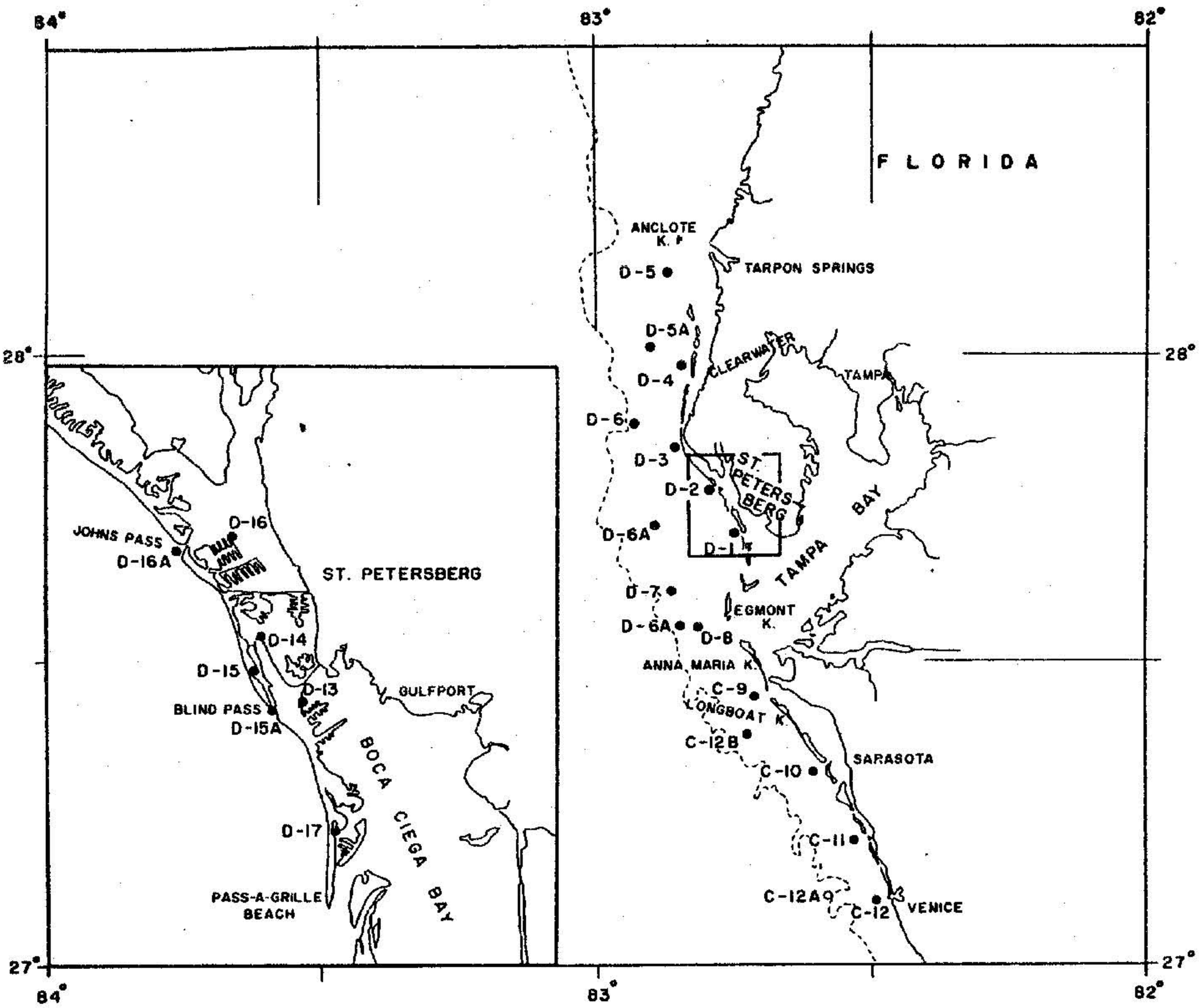
Subareas	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
2	100	100	0	0	0	0	0	0
3	75	50	25	0	50	0	75	50
4	100	100	0	50	100	0	0	100
5	100	50	38	13	67	25	63	67
6	88	100	100	25	50	50	67	50

To complement the intensive work in Tampa Bay by determining the coastwise range of the incidence and abundance of G. breve in adjacent waters, 24 coastal and bay stations have been sampled monthly since July, 1958. These stations are primarily within the five-fathom contour and extend from Tarpon Springs south to Venice, including Boca Ciega Bay. G. breve was present in 41 percent of a total of 767 water samples collected. The percentage incidence of G. breve was greater in the coastal stations south of Egmont Key, although it was present from Venice Inlet to our northernmost station at Anclote Key. In the neritic waters, G. breve has been found to depths of 128 feet, but occurs more frequently at the surface. In the shallower coastal and bay waters, where there is more mixing of the column, the highest number of G. breve occurred at the bottom or intermediate depths.

Percent of monthly samples from each depth containing G. breve (Tampa Bay and adjacent waters, October 1958-June 1959).

Depth	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total %
1 (surface)	63	60	39	17	42	21	58	17	40
2 (intermediate)	71	48	31	8	46	4	42	21	34
3 (intermediate)	67	40	31	4	29	4	25	33	29
4 (bottom)	54	28	27	4	21	4	25	30	24

During the past eight months, G. breve was present in low concentrations and reached a maximum of only 6,200 per liter in the neritic waters during November, 1958. The majority of the water samples showed the presence of G. breve in very small numbers, less than 100 per liter. The highest numbers of G. breve usually occurred in the surface waters with a gradual decrease with depth. This was especially true in the more stable waters offshore.



Auxiliary coastwise stations sampled chiefly for G. breve.

Seasonal occurrence G. breve was again present the entire year in both neritic and coastal waters. The greatest incidence occurred during the October-December 1958 period and gradually diminishing during the winter and early spring of 1959. G. breve was more abundant south of Egmont Key, especially from January to March 1959, when it was present in 42 percent of the water samples taken at southern stations and only 7 percent of the northern samples. G. breve was absent from the middle of Tampa Bay and Boca Ciega Bay from December 1958 to June 1959.

Associated phytoplankton Since October, 1958, the dominant phytoplankton associated with G. breve in the water samples were recorded qualitatively in the inshore and offshore waters of Tampa Bay. Quantitative counts (commenced in January 1959) of dinoflagellates, diatoms and algae, made from preserved organisms stained on millipore filter paper, will be used to supplement these qualitative data.

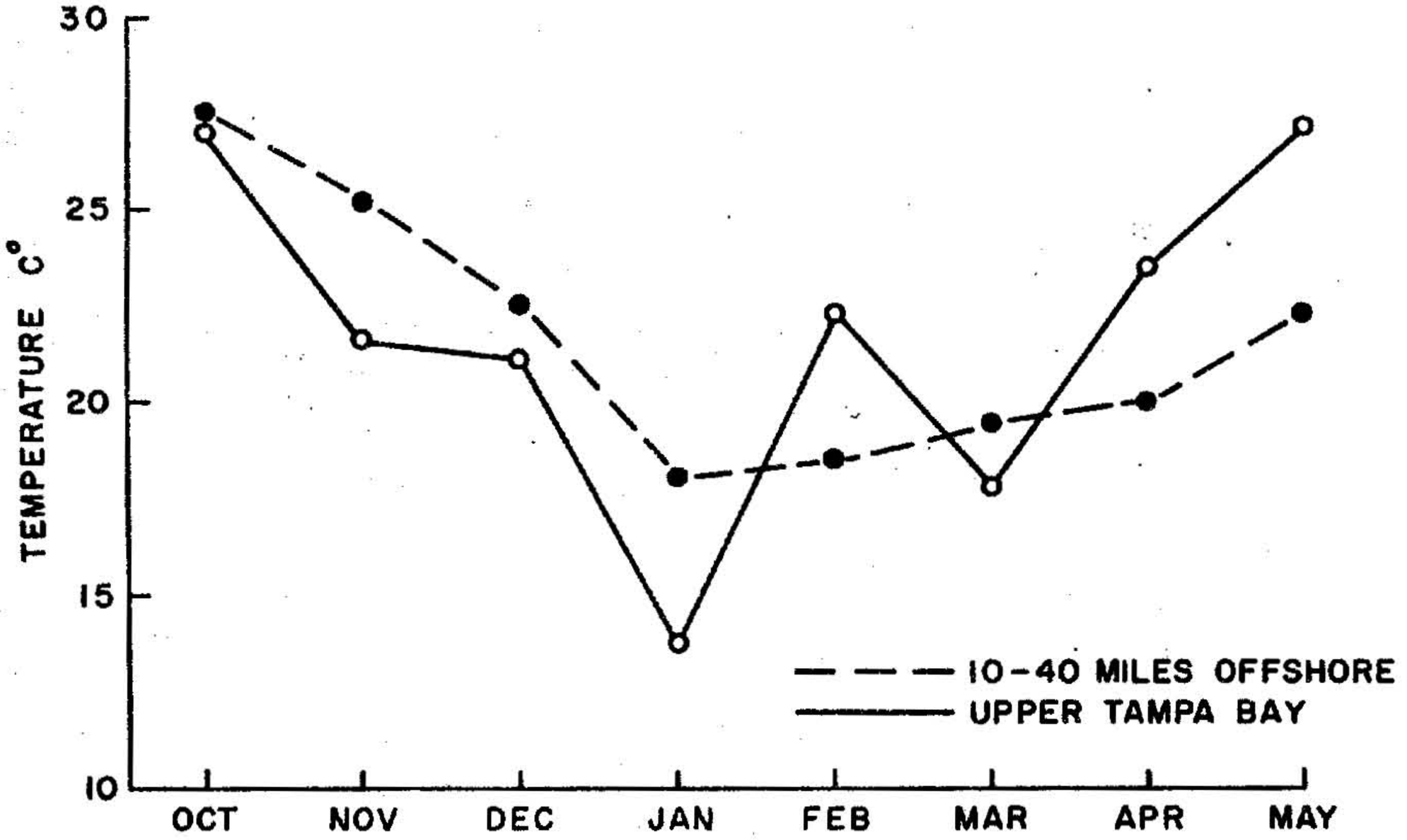
The only blooms of phytoplankton found in the neritic waters were of the blue-green alga, Skujaella erythraeum, which dominated the surface waters as far as 40-60 miles offshore in the fall of 1958 and spring of 1959. Skujaella blooms have been reported in past years and they may serve as an indicator of the phytoplankton productivity of these neritic waters. In the inshore waters of Tampa and Boca Ciega Bay, a bloom of the diatom Sceletonema sp. was observed in April and May. What effect these blooms have on G. breve is still unknown.

We have not had a spring increase of phytoplankton populations in Florida waters such as has commonly been reported in more northern latitudes. The past year was characterized by the extremely low numbers of dinoflagellates and diatoms both inshore and offshore.

Environmental Hydrology in Relation to Red Tide

Alexander Dragovich

Temperature The minimum water temperature (12.8°C.) was observed on January 20th in Tampa Bay and the maximum (30.3°C.) in October 3-½ miles WNW of Egmont Key. A seasonal drop in water temperature occurred at the end of December and continued through January. In February, an unusual



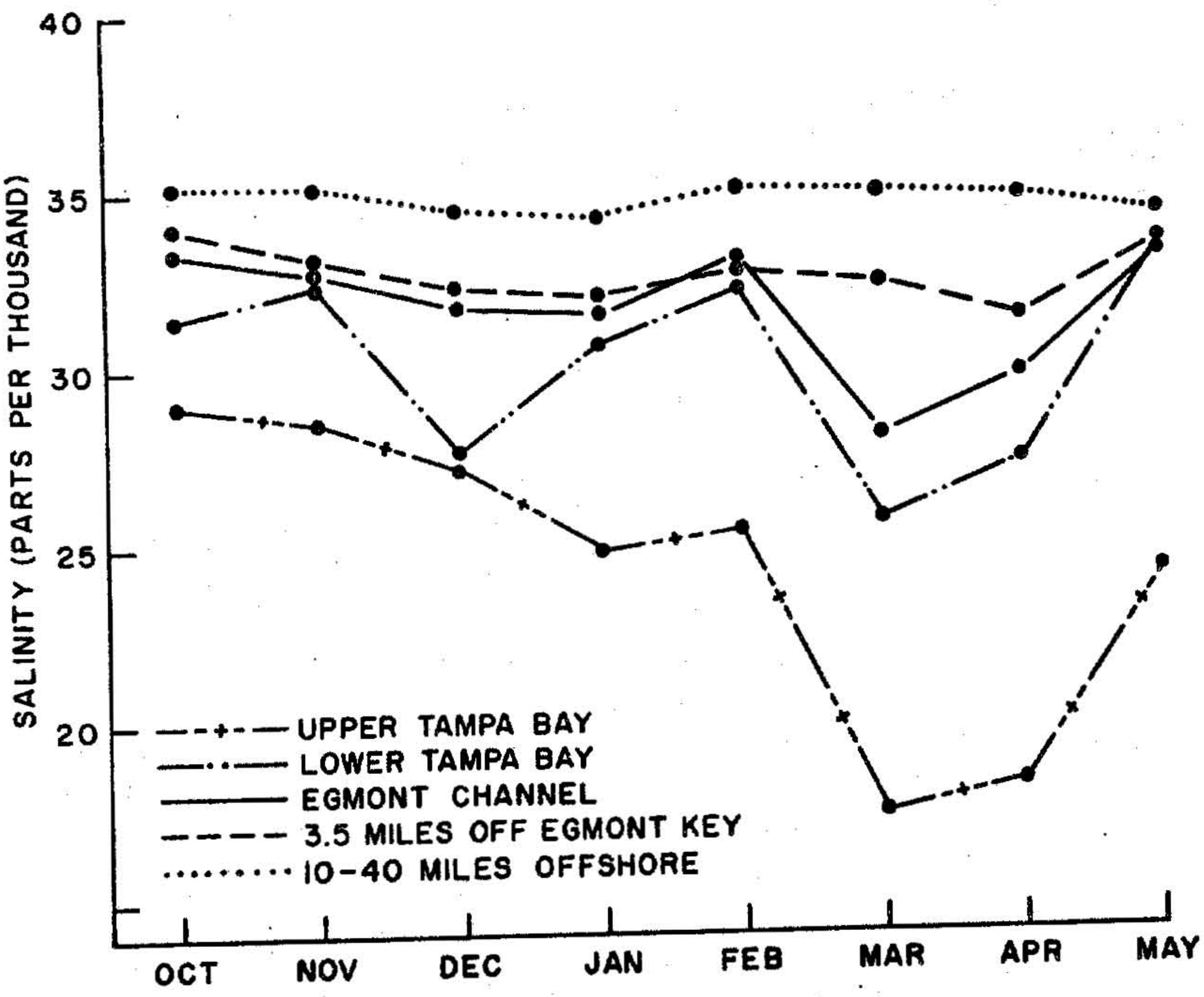
Mean monthly bottom water temperature for Tampa Bay area (October 1958-May 1959).

period of warm weather increased the water temperatures. After a decline in March, the temperatures rose slowly and steadily through April and May.

The water temperatures from surface to bottom were uniform in Tampa Bay and off the mouth of Tampa Bay (subareas 2, 3 and 5). Slight vertical temperature variations were observed in subarea 6, extending 10 to 40 miles from shore with depths gradually increasing from 50 to 130 feet. The seasonal temperature changes of the bottom water in this offshore area were gradual with surface layers cooling or warming before the deeper layers. Comparison of the average monthly temperatures with incidence of G. breve

indicates a relation to temperatures may exist, especially during cold periods. During the winter water temperatures nearest to the G. breve optimum growth temperature range observed in the laboratory were found in subarea 6 (10-40 miles offshore). These observations suggest that the sampling area should be extended farther than our present limit of 40 miles.

Salinity The salinity of rivers flowing into Tampa Bay varied from 0.04 to 24.83‰; the highest was observed in the Manatee River at Palmetto, and the lowest in Little Manatee River. In March, a month of heavy rainfall, a sharp salinity decline occurred in all rivers. The salinity of Tampa Bay and adjacent neritic waters increased from upper Tampa Bay seaward with minor exceptions. Monthly fluctuation of salinity in lower Tampa Bay can be partially ascribed to the tidal stage at the time of sampling. In February, the



Mean monthly surface salinity for Tampa Bay area (October 1958-May 1959).

precipitation was below average and salinities increased in all areas. There was a great deal of rainfall and a subsequent sharp decline in salinities in March. In April and May, the salinities increased in Tampa Bay and Egmont

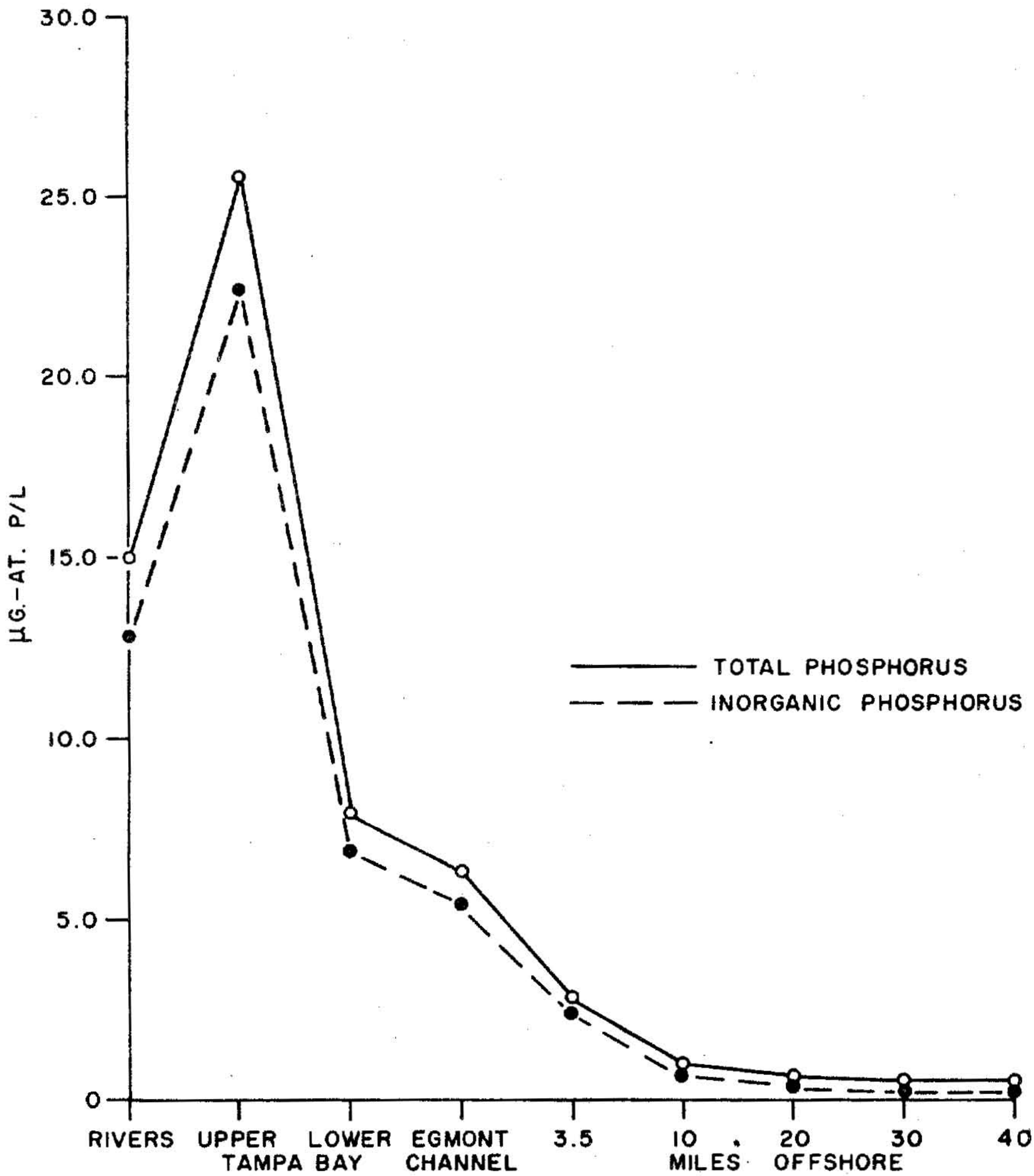
Channel, whereas they dropped slightly in April and increased in May in the area 3½ miles off Egmont Key.

Total and inorganic phosphorus One of our objectives is to determine whether the outflow of the Hillsboro, Alafia, Little Manatee and Manatee Rivers influences the phosphorus content of Tampa Bay and adjacent neritic waters. These rivers are rich in phosphorus, especially the Alafia River (mean inorganic phosphorus 24.7μg. at. P/l), which flows over surface deposits rich in phosphates. The water of upper Tampa Bay (subarea 2) contained more phosphorus than any of the rivers, except the Alafia. These data indicate that phosphorus may, on occasions, accumulate in this portion of Tampa Bay.

River	Station Number	PO_4-P Inorganic Surface	PO_4-P Inorganic Bottom	PO_4-P Total Surface	PO_4-P Total Bottom	NO_3-NO_2 Surface	NO_3-NO_2 Bottom
Hillsboro	29	4.2	9.7	5.4	10.8	6.4	4.3
Hillsboro	30	3.9	5.4	4.8	6.6	3.8	3.7
Alafia	31	25.0	23.1	28.6	27.9	2.8	2.5
Alafia	32	25.9	24.9	29.5	30.0	4.4	4.2
Little Manatee	33	14.1	15.8	16.1	15.8	0.8	0.7
Little Manatee	34	10.1	9.4	11.7	12.2	0.8	1.3
Manatee	35	8.4	9.0	10.9	10.4	1.8	1.0
Manatee	36	10.4	10.3	11.7	11.8	1.2	1.2

The phosphorus content declined sharply from upper to lower Tampa Bay and this decrease continued less rapidly from lower Tampa Bay seaward. Variation in phosphorus concentration in Tampa Bay and Egmont Channel was much greater than variation in salinity. For example, a 24-hour study was conducted on February 12, 1959 at Mullet Key Dock in lower Tampa Bay. The total phosphorus content varied from 4.9 to 10.4 μg. at. /l, while the salinity varied only from 30.08 to 31.46‰.

In March, a month of heavy rainfall, a drastic increase in phosphorus content was noted in all areas except at stations located 20-40 miles offshore. In April and May, the precipitation continued to be heavy and in May a nominal increase of phosphorus content in the areas 20 to 40 miles offshore was observed. At this time, the salinity of the surface water of the same area decreased slightly. Inorganic phosphorus exceeded organic phosphorus within 20 miles of shore. Beyond this distance, the concentrations of both forms of phosphorus were similar. During the first 8 months of this

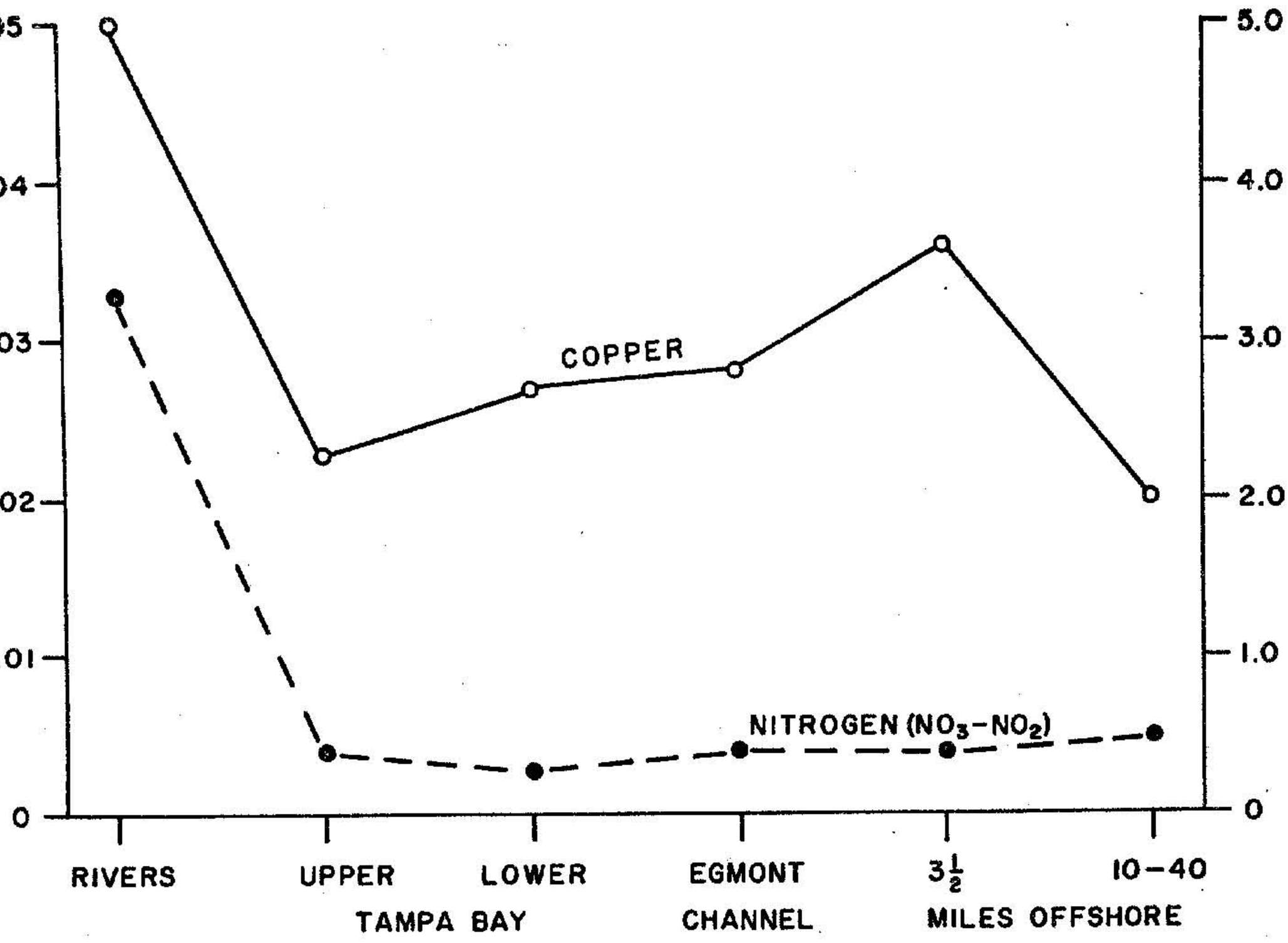


Average phosphorus values by area, October 1958 - May 1959.

investigation, G. breve was present in low concentrations and no relationship was observed between the phosphorus content and incidence of this organism.

Nitrogen (nitrate-nitrite) The mean nitrogen (NO_3-NO_2) of 1,855 samples collected during the first 8 months of this investigation varied from 0.0 to 13.7 µg. at. N/l. The concentrations were considerably higher in the rivers, especially the Hillsboro. From upper Tampa Bay to 40 miles offshore, the mean nitrogen concentrations were between 0.3 to 0.5 microgram-atoms per liter.

Tampa Bay and adjacent neritic waters are poor in nitrate and nitrite in comparison to such other marine areas as Friday Harbor, Washington, the English Channel or the Gulf of Maine. No correlation was observed between the incidence of G. breve and the nitrate-nitrite nitrogen concentrations.



Mean monthly copper and nitrogen (NO_3-NO_2) for Tampa Bay area (October 1958-May 1959).

Copper In a total of 960 samples collected since October 1958, the copper concentration has varied from 0.00 to 0.11 µg. at. /l with an average of 0.03 µg. at. /l. Although the Tampa drainage basin is poor in copper, the highest concentrations of copper were observed in the rivers (average = 0.05 µg. at. /l). Excluding the rivers, the highest mean copper values were observed $3\frac{1}{2}$ miles offshore, the lowest values occurring 10-40 miles offshore. Similar results were obtained in previous studies in the area between Cape Romano and Tampa Bay. No copper enrichment from land drainage is evident since the copper content did not increase with lower salinity conditions in March.

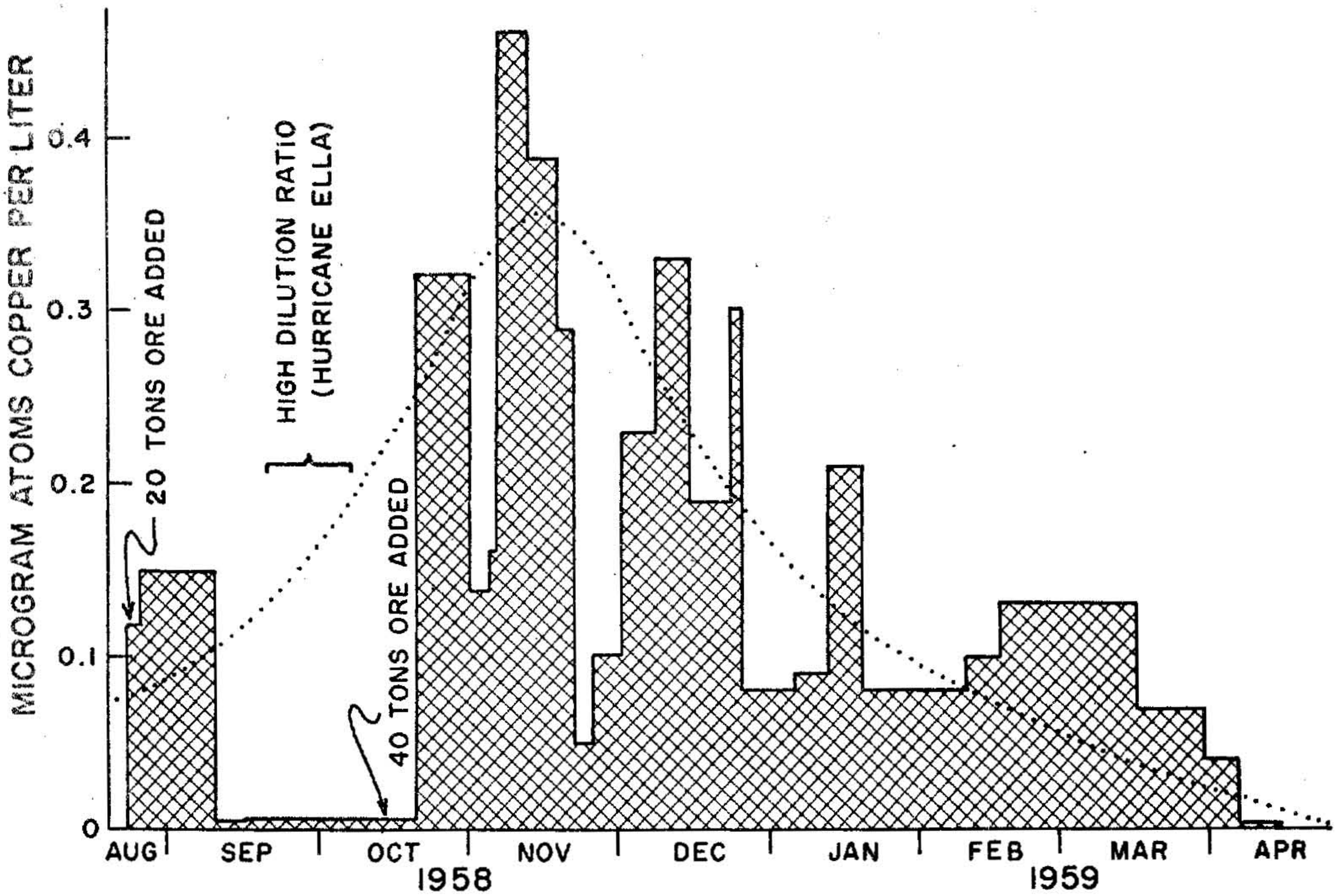
Hydrology of coastal waters north and south of Egmont Key In addition to the ecological study of the Tampa Bay area, a study of north-south distribution of G. breve and associated hydrology is in progress. Four geographically representative stations are located off Indian Rocks Beach (2) and off Venice Inlet (2). The area off Venice Inlet had higher temperatures and salinities, slightly higher copper content, and less total phosphorus and nitrogen (NO_3-NO_2) than the coastal waters off Indian Rocks Beach. Near shore, seasonal changes in temperature and salinities have been more gradual in the area off Venice Inlet than off Indian Rocks Beach, but offshore these features are similar.

G. breve was present during every month of the year except April off Venice Inlet, being especially high at the station 6 miles offshore. The incidence is lower off Indian Rocks Beach.

Testing Copper Ore for Red Tide Control

Kenneth T. Marvin

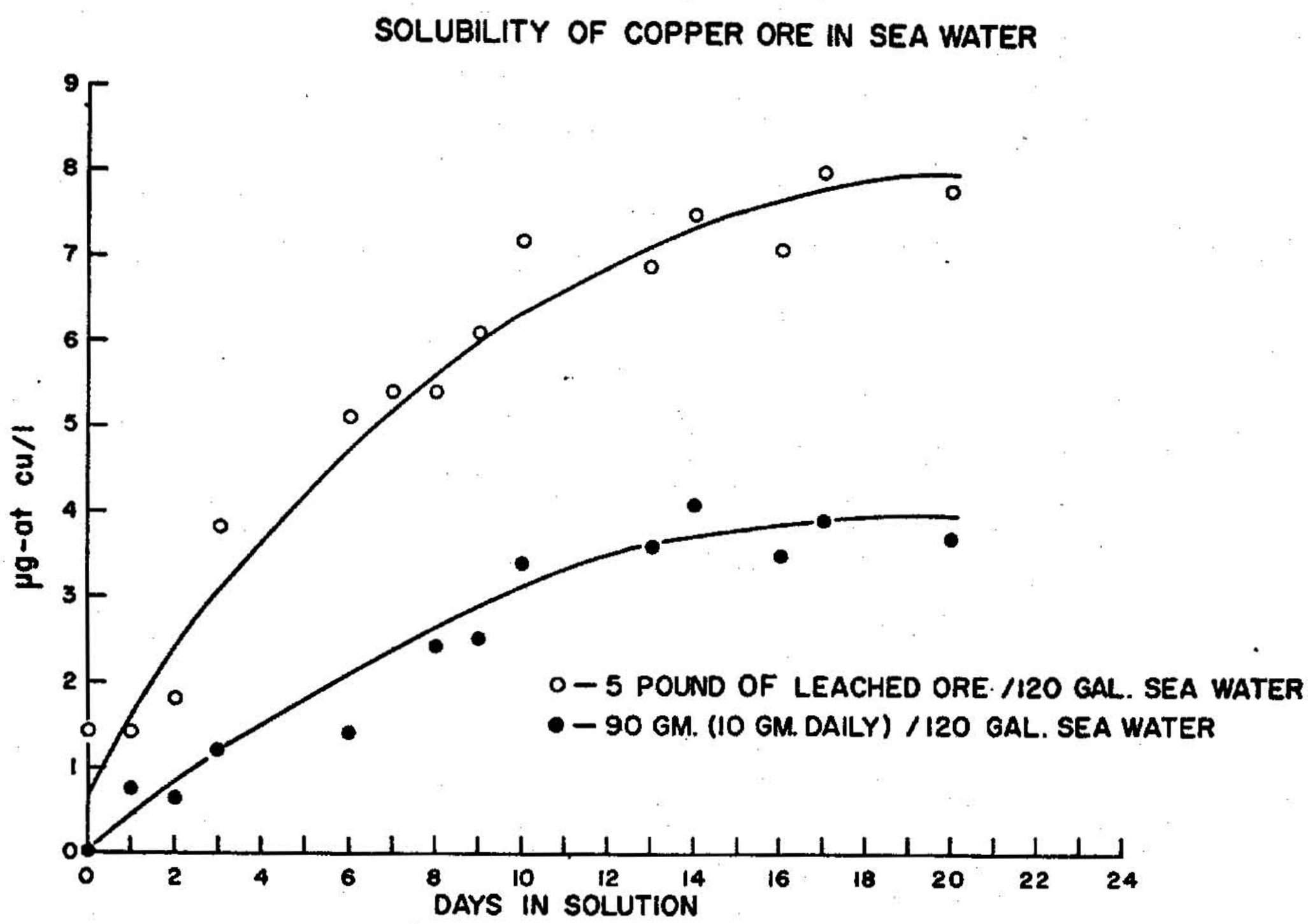
This phase of the red tide program was initiated during the latter part of 1957 to find a practical means of limiting or preventing the over-blooming of Gymnodinium breve with copper. Copper in concentrations between 0.8 and 1.6 microgram atoms per liter has been demonstrated to be lethal to laboratory cultures of G. breve. Under some conditions slightly lower concentrations may be effective.



Copper content of waters of East Lagoon.

Field tests have been conducted to determine the effects of copper sulphate on G. breve when applied as crystals and also as a concentrated solution. These tests were conducted during red tide outbreaks on the west coast of Florida in 1952, 1953, 1954, and 1957. Copper sulphate dissolves rapidly in sea water supersaturating the ambient water with copper. The resulting concentration is many times that of the required lethal level as determined in laboratory toxicity experiments, but this high condentration does not last long. The bulk of the copper precipitates as the basic carbonate and is dispersed by tides and currents and the copper concentration is reduced to an ineffective level.

To surmount this difficulty the source of copper would have to release relatively small amounts of copper into solution over a long period of time. Copper ore was tested to determine whether it would fulfill these requirements. The sulphide ore used contained approximately 1% copper, 3.5% iron, and 6% sulphur. The particle size varied from that of dust to coarse gravel.



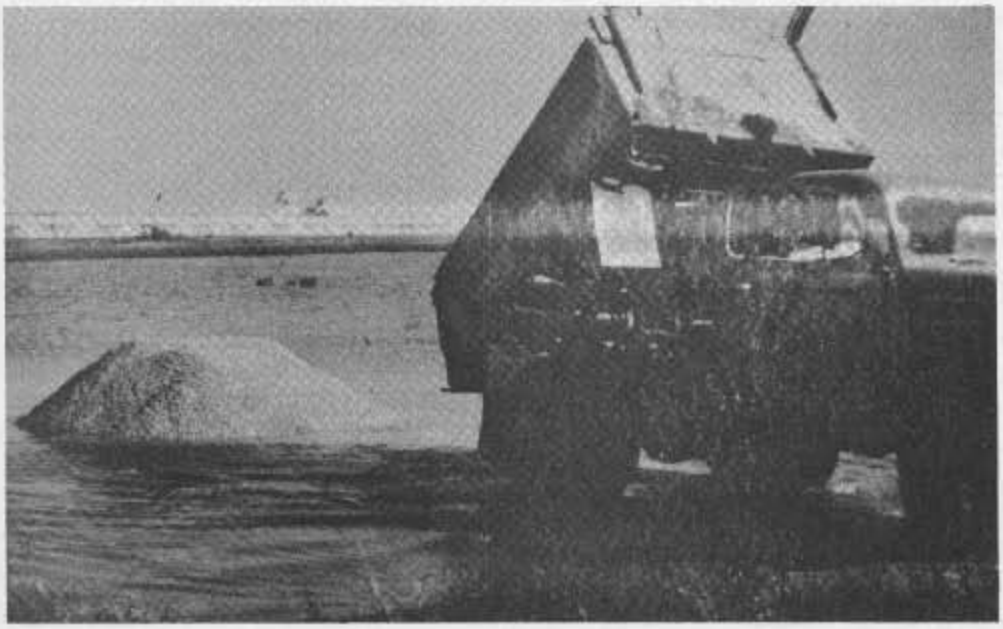
Showing results of test to determine leaching rate of copper ore.

The copper ore was tested in a lagoon at the eastern end of Galveston Island. Twenty tons of ore were added on August 21, 1958 and the remaining 40 tons from October 11 through the 13th. The test was designed to answer the following questions:

1. Would 60 tons of copper ore raise the copper concentration of the lagoon water to the lethal level for G. breve?

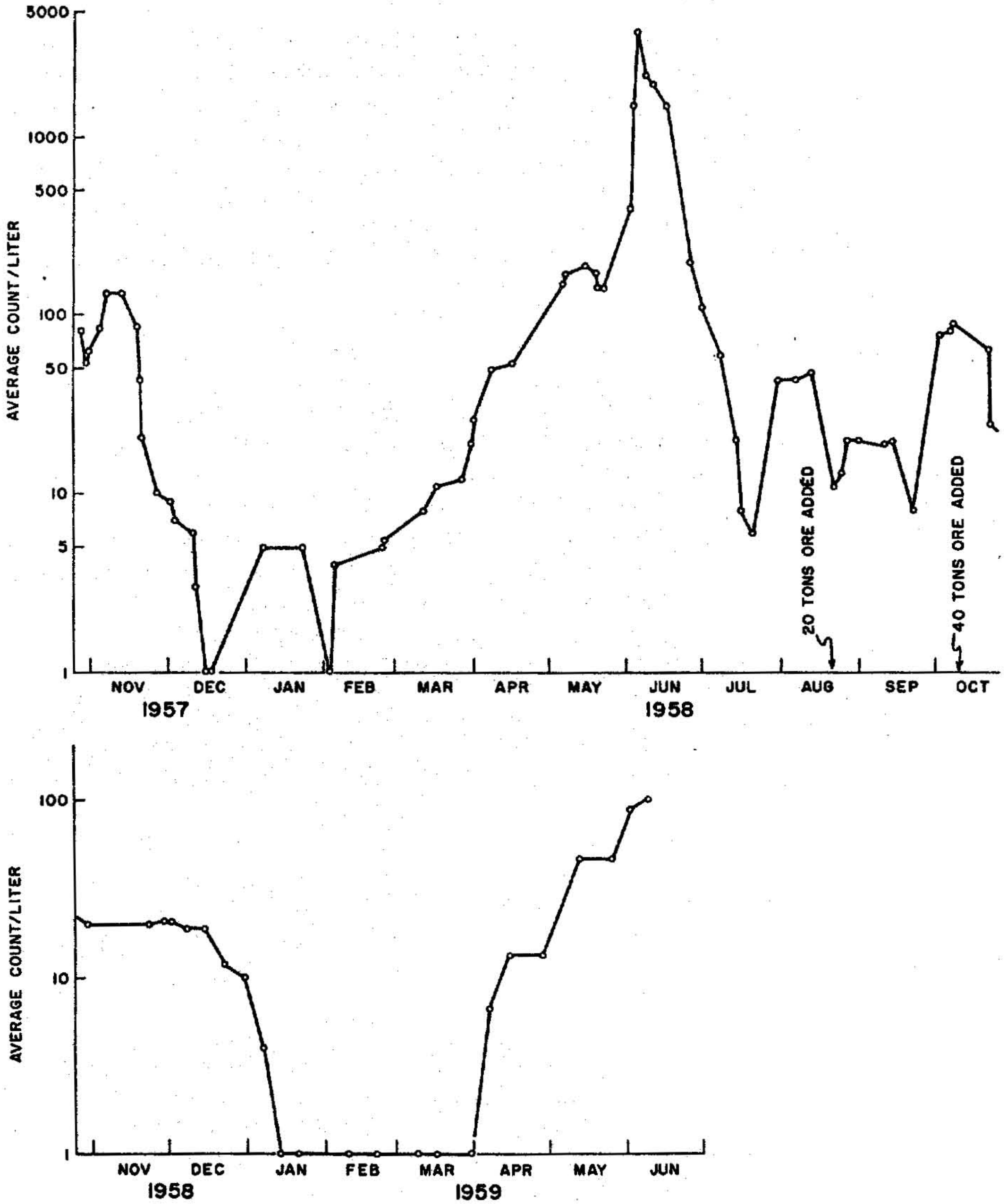
2. If so, how long would the level be maintained?

3. What would be the effects of the copper on other lagoon organisms?



Dumping copper ore into East Lagoon, Galveston.

The first question was answered by observing the effects of the ore on Prorocentrum sp. in dialysis bags and also on Gymnodinium splendens, that occurred naturally in the lagoon. As the sensitivity of these organisms to copper had been found to be identical to that of G. breve in



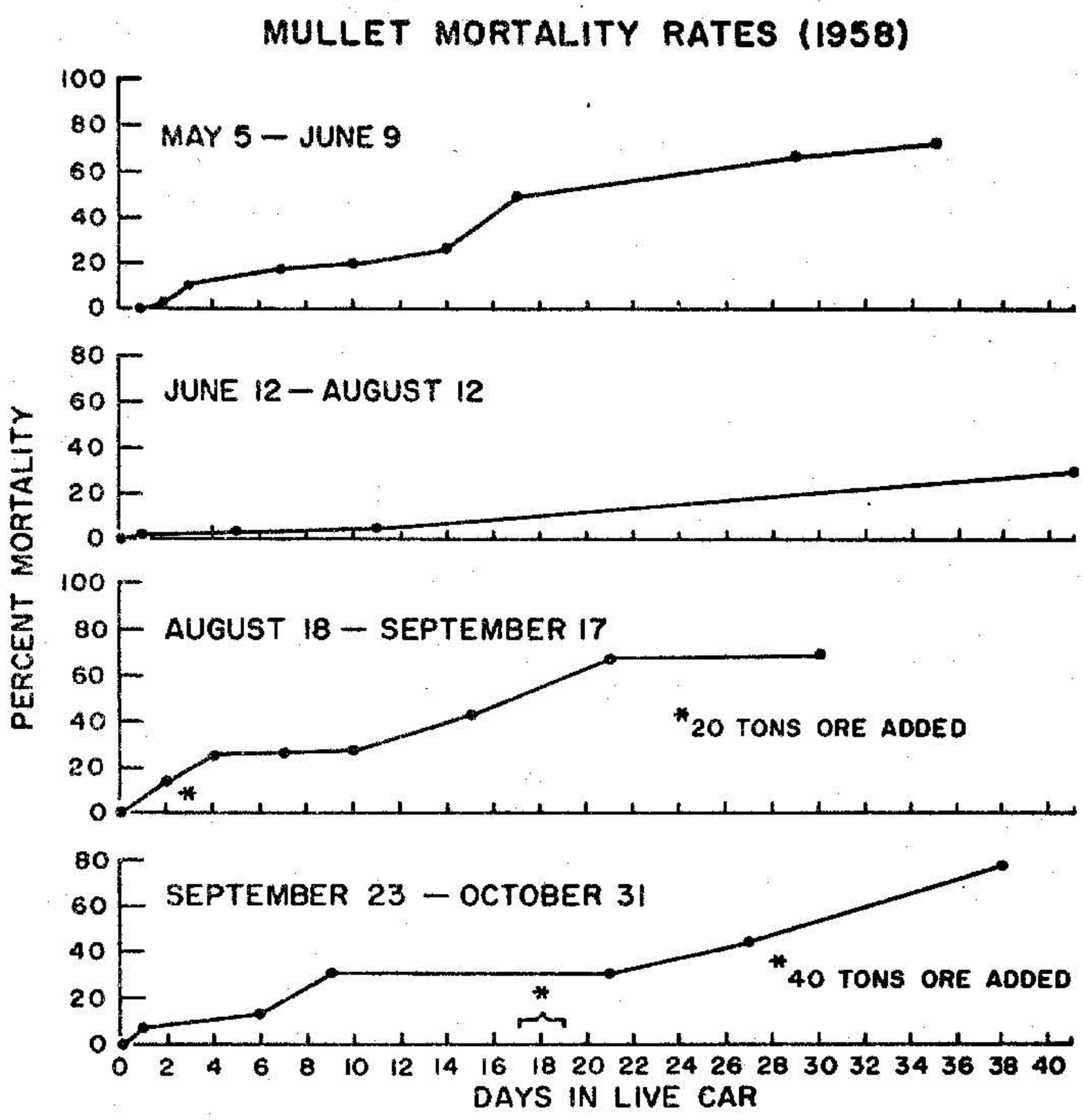
The trend of counts of Gymnodinium splendens in East Lagoon from October 1957 to June 1959.

laboratory experiments, they were used as indicator organisms. Question 2 was answered by chemically following the copper concentration level after the ore was added, and number 3, by studying the ecology of the lagoon prior to the addition of the ore and then comparing the results of a similar study made after the addition of the ore. The ecological conditions of the lagoon before and after were based on chemical and biological analyses of the water, on the mortality rates of various organisms placed in the lagoon in live cars, on the variation of barnacle setting rates, and also on the mortality rates of Prorocentrum sp.

Representative coverage of the lagoon was obtained by establishing 8 sampling stations. Stations 1, 2, and 3 were 600 feet apart; 3 and 4, which were located on either side of the ore dike, were 100 feet apart, 5 and 6 were 1000 feet apart; and the remaining ones, 25 feet. Stations were sampled 3 times a week until the ore was added and then twice a week. Several months after the ore addition, the rate of sampling was reduced to once a week and the number of stations sampled to 3 (Nos. 1, 4, and 7). Samples were collected from a 14-foot outboard motorboat. All water samples taken at a station were fairly homogeneous, as a large volume was first pumped by means of a stainless steel neoprene impeller pump into a polyethylene drum. The pumping rate of 25 gallons per minute insured a thorough mixing. While filling the drum the inlet end of the weighted suction hose was continuously raised and lowered. Thus, the water mixed in the drum was representative of the entire column. The station sample bottles were filled from the mixed volume of water.

The zooplankton samples were collected at 3 locations only, 1, 4, and 7, by pumping 250 gallons of water through a No. 10 nylon plankton net. The variation of the barnacle setting rate was checked by submerging setting plates at each station, which were removed, counted, and replaced once a week.

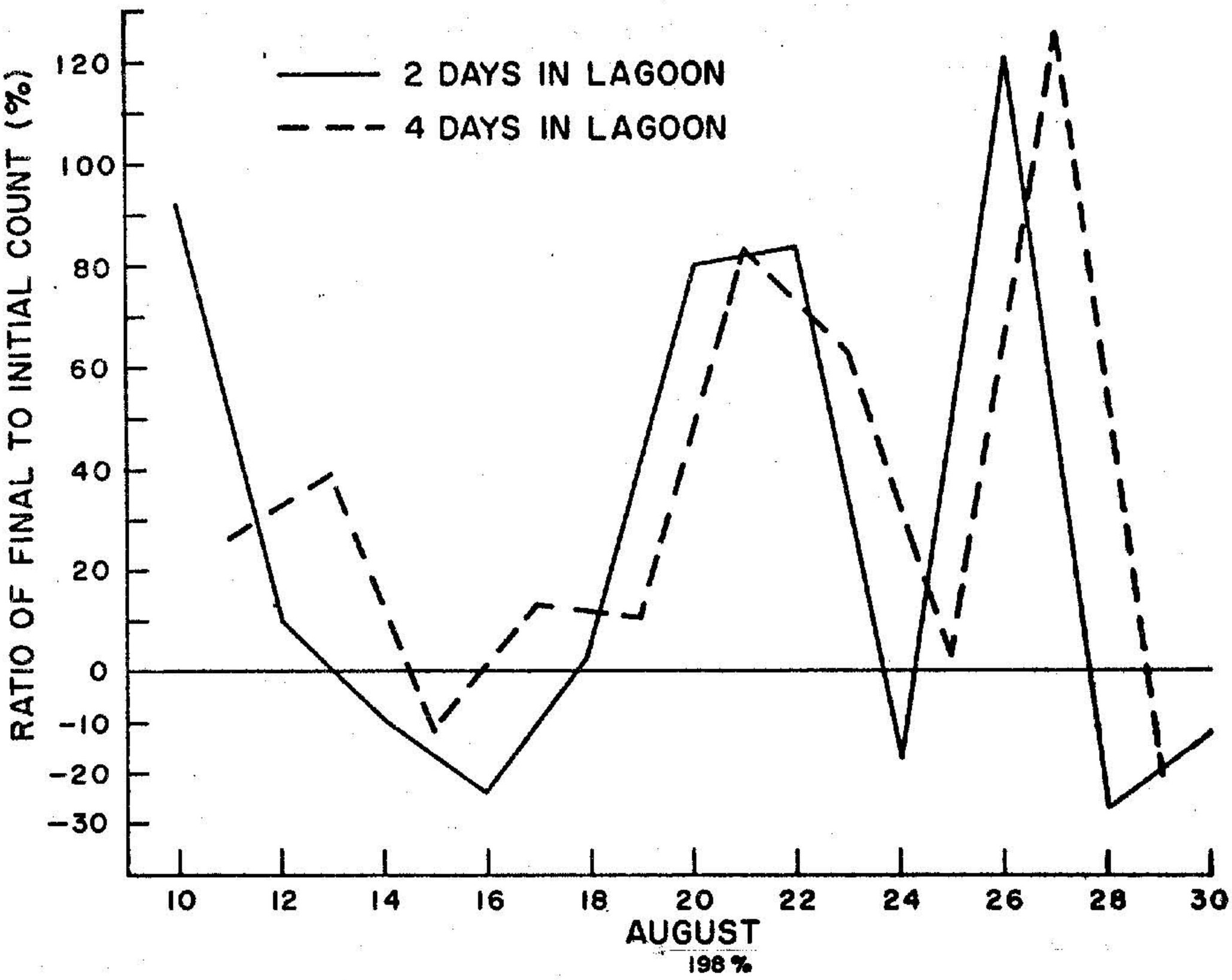
To check the effects of the copper ore on commercially important species various organisms including mullet, oysters, conchs, and snails were placed in live cars. Initially, the test animals were placed at both the surface and the bottom, however a high rate of mortality occurred in the bottom cars, apparently caused by surges of oxygen depleted water containing traces of sulphides. For this reason the use of bottom live cars was discontinued.

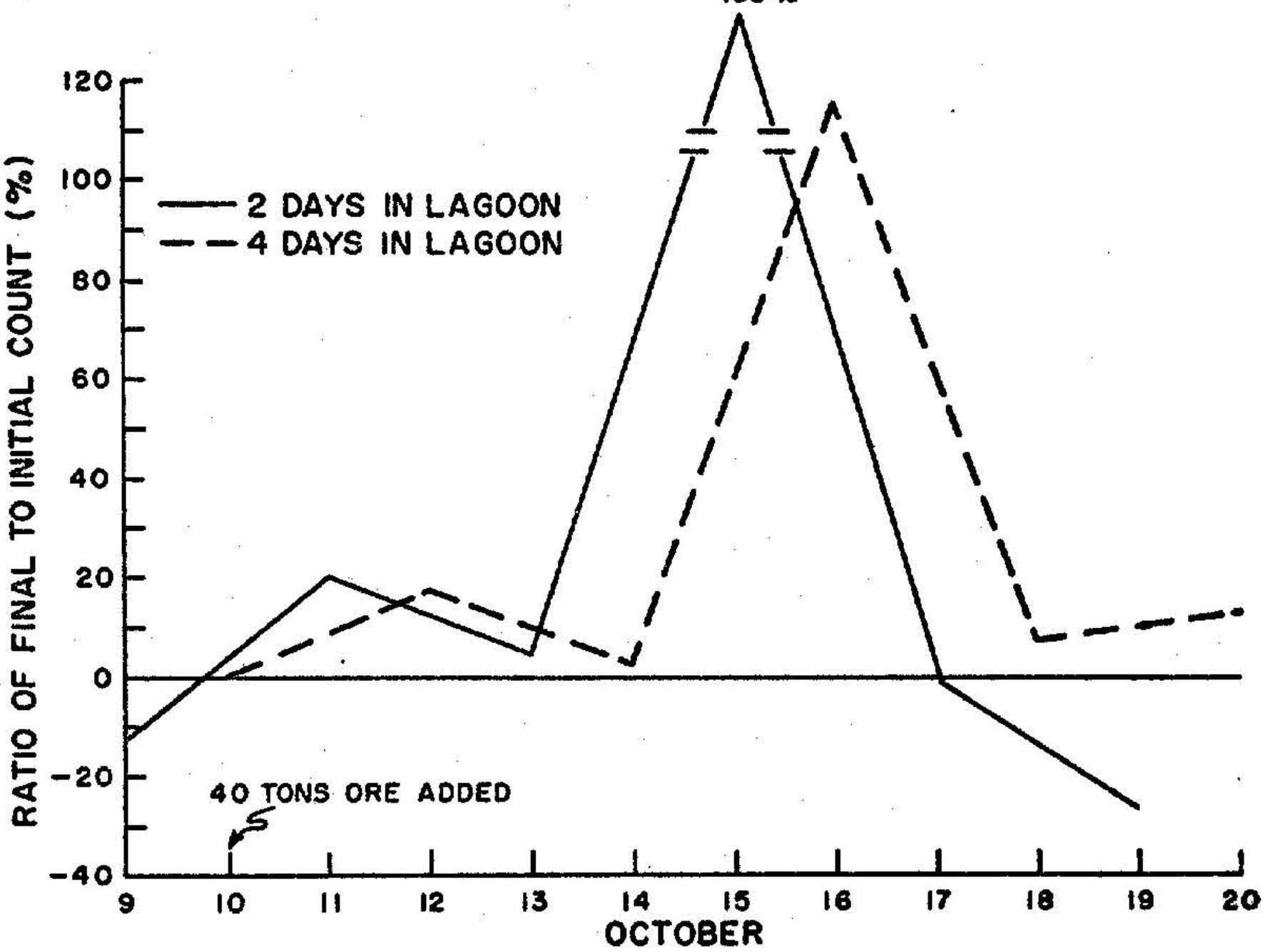


Mortality rates of mullet held in live cars in East Lagoon.

A 2-liter water sample was analyzed for chlorophyll as an indicator of productivity.

Two weeks before the first addition of ore, and 3 days before the second, dialysis bags containing Prorocentrum sp. cultures of known concentrations were placed 3 feet below the surface at stations 2, 4, 5, 6, and 7. These bags were re-placed so that some of them remained in the water for two days and others for four days. Upon removal the count of the organisms in each bag was determined. The first check was discontinued two weeks after the first addition of ore and the second, one week after the second addition of ore.

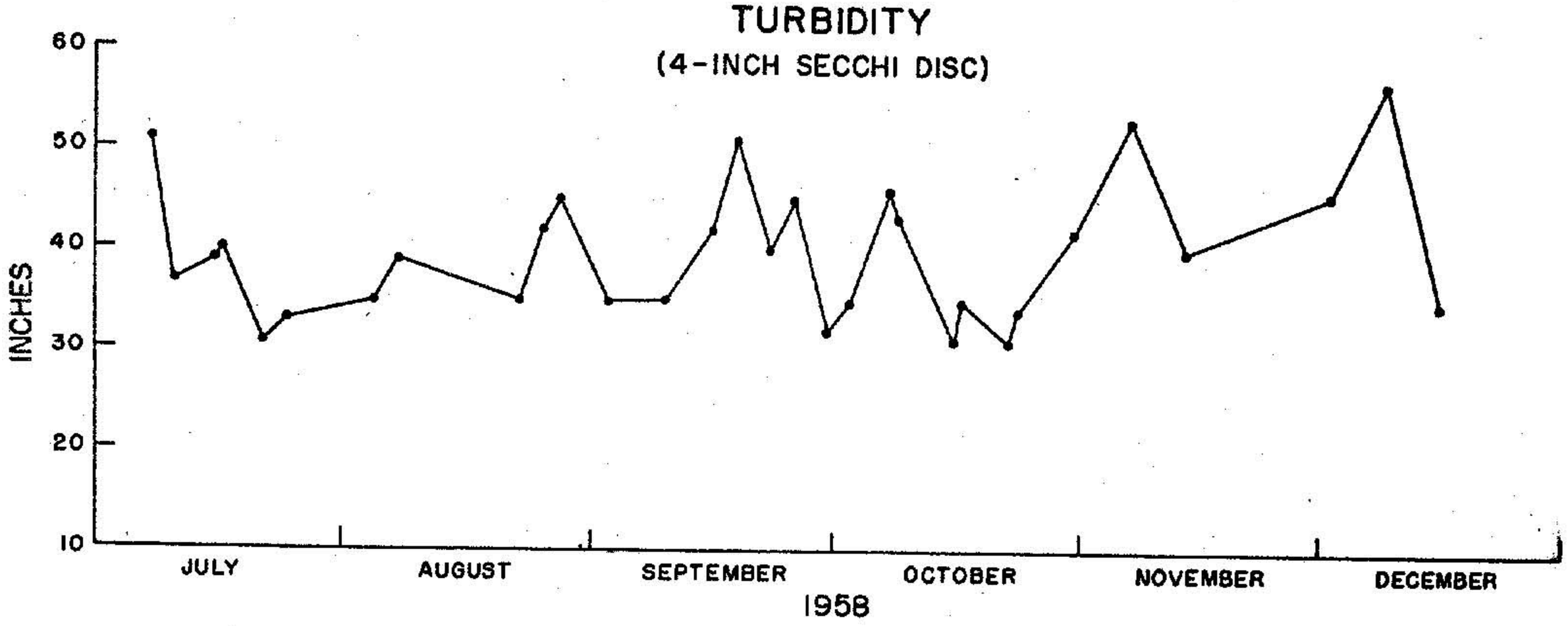




Results of holding Prorocentrum in dialysis membranes in East Lagoon.

A 2-liter water sample was examined for numbers of G. splendens. These analyses along with the results of the dialysis bag experiment were used to measure the direct effect of the copper ore.

Various physical and chemical measurements were collected. Copper analyses were not made on a routine basis until after the addition of the ore. A preliminary 100 analyses made prior to ore addition indicated that the naturally occurring copper concentration of the lagoon was quite low and not subject to excessive fluctuation. Salinity measurements of each drum of water were used as a measure of rainfall and drainage dilution and as such could be related to some of the fluctuations of those biological parameters that are sensitive to salinity changes, such as barnacle setting rate, type of zooplankton, etc. Turbidity was measured with a 4-inch secchi disc. Water and air temperatures were taken at each station. The water temperature represented that of the collection drum and therefore was an estimate of the average temperature of the entire column. At each station estimates were made of wind velocity, wind direction and cloud coverage.



Turbidity in East Lagoon during last six months of 1958.

Discussion The data indicate that the copper ore used in this experiment was not capable of maintaining a high enough concentration of copper to kill G. breve. The dialysis bag experiment shows that the Prorocentrum sp. count increased after the bags were placed in the lagoon both before and after the addition of ore. This fact indicates that the copper concentration in the lagoon was not high enough to discourage a dinoflagellate bloom. The copper level after the addition of the ore increased to a maximum that was just short of the laboratory estimate of the minimum toxic level, and then gradually dropped to the low value shown. These results corroborate the dialysis bags results which show that the ore in economically practicable quantities is not capable of maintaining a sufficiently high copper concentration to be considered as a means of controlling red tide outbreaks.

As far as the effects on the ecology of the lagoon is concerned, the chlorophyll, zooplankton, G. splendens, etc., data show no effect that can be definitely attributed to the copper ore.

Hydrological Studies for the Corps of Engineers Proposed Mississippi River-Gulf Outlet Project, Louisiana

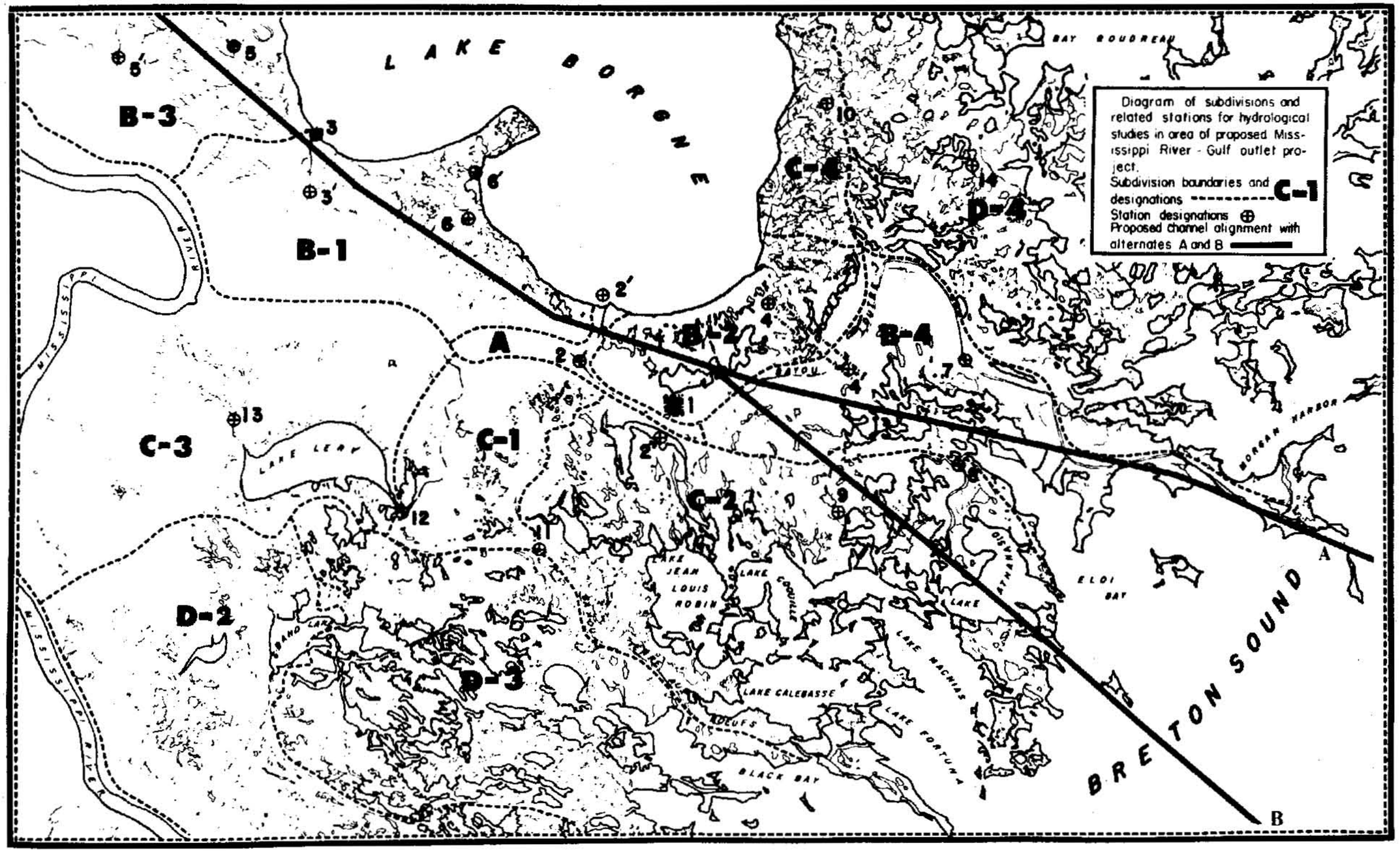
Dr. Kenneth M. Rae, Texas A & M Research Foundation
(Contract No. 14-16-008-523)

Despite its somewhat formidable title, this program offers a fascinating study both in its fundamental and applied aspects.

The Corps of Engineers are in the process of constructing a ship canal from New Orleans along the eastern side of the Delta to the open Gulf by way of Breton and Chandeleur Sounds. On completion, the channel will be 500 feet wide and 36 feet deep, but in the process of construction an "access channel" (140' x 18') and then a "usable channel" (250' x 36') will be dredged in each section. While work at the New Orleans end is now well under way, some doubt still remains about the alignment of the lower stretches. The figure gives an impression of a major part of the area involved and shows the route the channel will take down to the region of Hopedale and two alternative alignments which have been considered for its seaward end.

The problem facing the Fish and Wildlife Service is to forecast, and later to establish, the potential effect of the dredging, and subsequent maintainence, of the canal on the wildlife resources. The proposed alignment cuts across extremely valuable territory from the point of view of the commercial and sport fisherman, the hunter and the trapper. Oyster and shrimp grounds are involved as is some of the best shooting and fishing terrain on the Gulf Coast.

In June, 1958, under contract, the Texas A. and M. Research Foundation reviewed the project area to recommend a program calculated to provide the most useful hydrological background for the ecological studies. Very little was known, or at least adequately recorded, about the physical and chemical variables in the area. As will be seen from the figure, it comprises a system of bayous, lakes and ponds, interconnected in a complicated manner. On the one side it appeared to be under the influence of the comparatively fresh, river-fed Lake Borgne and on the other the more marine conditions of Breton Sound and the open Gulf; the relative importance of the two was unknown. Cyclic tides are not pronounced in the Gulf and it seemed likely that any water flow would be largely conditioned by meteorological conditions such as rainfall, evaporation, and wind driven surges.



Proposed channel alignment and area under study for the Corps of Engineers' Mississippi River-Gulf Outlet Project.

The project area was large and in many parts inaccessible. The engineering work had already started and time was short if conditions before and after the dredging were to be compared. Consequently, compromises were necessary. Arbitrary selection had to be made of the stations or regions and of the physical and chemical variables to be sampled. The most important consideration was to obtain a record of the natural variations in the environment that might be expected before the channel was dredged. Without this knowledge few, if any, subsequent changes could be attributed to the development of the canal with any degree of confidence. The emphasis, therefore, had to be on close systematic sampling of chosen stations rather than on extensive coverage.

It was decided to set up a Base Station at Hopedale (Station 1 on the figure) which is strategically placed on a major bayou leading to one of the main outlets to Lake Borgne (Station 2). Here daily, and in some cases continuous, observations were taken. The area was then divided into a series of sub-areas (by the dotted lines on the figure) each designed to be as nearly self-contained as possible. Stations were selected in each sub-area in such a way that they monitored the junctions of what appeared to be the more important waterways. It was hoped that the selected stations would prove to be reasonably typical of their sub-areas so that the conditions within each sub-area could be correlated with those prevailing at the Base. Providing such correlations could be established, the variations at the Base could be used as indices of the natural fluctuations over most of the project area. Again, as more or less continuous observations would be available at the Base, these could be related to the day to day meteorological conditions and a certain amount of extrapolation to the extremes of weather might be acceptable. Records of the local weather are, of course, available for many years previously.

The variables to be measured regularly at the Base, and on each visit to a station, were as follows: (1) water movements as they could be measured with current meters; (2) chlorinity, measured by either recording conductivity meters or titration in the laboratory; (3) water level, measured by recording tide gauges or tide staffs; (4) temperature; (5) dissolved oxygen; (6) pH; (7) total phosphates; (8) suspended solids; (9) primary production. It was also proposed to make a comprehensive bathymetric survey of the bayou system to permit subsequent calculations of water transport.

In February, 1959, a second contract (14-16-008-572) was entered under which the Research Foundation put this program into operation. A house, to accommodate four field workers, was rented in Hopedale and a field laboratory was set up in its garage. A continuous conductivity/temperature recorder was placed on a landing stage at the Base Station near a recording tide gauge previously installed by the Corps of Engineers. Wind

and range gauges were also installed in the grounds. A fast 17' cabin cruiser was found to be most suitable for the waterways; and the acquisition of a jeep and trailer saved considerable time in taking it overland to the more remote regions. A battery operated Raytheon D 119 model echo sounder proved extremely accurate in charting depths even in the relatively shallow lakes.

It is, of course, somewhat premature to comment on the results after so short a period of operation. Already it is clear that the whole complex is subject to rapid and drastic fluctuations. Any statement must carry the codicil that it only applies under the meteorological regime then prevailing. There will certainly be considerable seasonal and other non-cyclic variations about which we have yet no knowledge.

From the current measurements, however, the general situation appears to be a flow of water from the Sounds across the area into Lake Borgne. This does not by any means take the route which one might expect from examination of the map. Certain bayous show surprisingly rapid movement, as fast as 2 feet per second, while others are relatively stagnant. The salinity gradient across the area is commonly of the order of 10-12‰ and there is little indication of "salt wedges" in the bayous which, in view of their unevenness in depth, is not now surprising. The construction of an impermeable barrier along the proposed alignment of the channel would undoubtedly lower the salinity of the wetlands on the Lake Borgne side and increase it to the southwest. However, if as preliminary results suggest a major portion of the water transport is in comparatively few bayous, then a few strategically placed openings across the channel may do much to mitigate this effect.

Phosphates are generally high and extremely patchy, one station near New Orleans giving values up to 7 µg. at. /l. A general average for dissolved oxygen is 2 to 3 ml/l but, in the inhabited reaches of Bayou La Loutre, estimates showed such violent fluctuations that the results were almost meaningless. Hourly titrations gave variations of the order of 2 ml/l between successive samples. The reason, which warrants further investigation, probably lies in the local disposal of domestic waste combined with the stirring effect of power boats passing along the shallow canal.

In May, the near approach of storm center "Arlene" provided an opportunity to record extreme conditions. The results were spectacular, although the rise in water level at Hopedale was well below that reported for storm surges in other years. First there was a general lowering of salinity due to an influx from Lake Borgne but this was soon followed by a counter flow from Breton Sound which flooded the area and raised salinities by as much as 10‰ in a few hours.

Soon, it is hoped, biological data will be forthcoming from the same stations and cruises. The prospect of being able to compare these with the physical and chemical conditions is attractive. Rarely before has there been so good an opportunity to trace the distributions of aquatic forms along such steep and variable environmental gradients. The prospect of learning about their tolerance and reaction to changes, be they natural or caused by man's engineering work, seems excellent.

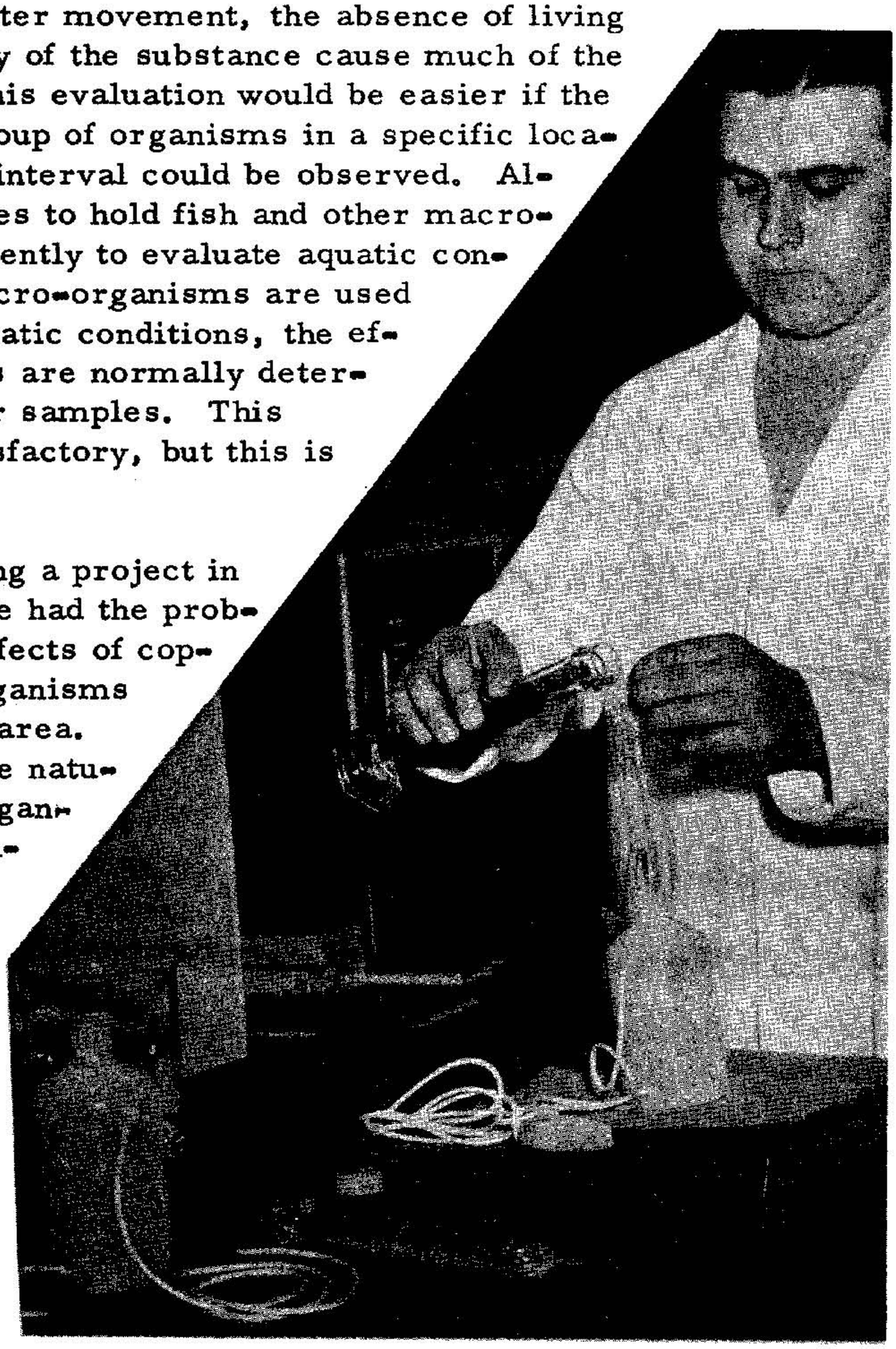
Evaluating Toxicity of Dissolved Substances to Microorganisms Using Dialysis Membranes

William B. Wilson

The evaluation of the effects of dissolved substances on aquatic life is often difficult. Water movement, the absence of living organisms and the identity of the substance cause much of the difficulty. Frequently, this evaluation would be easier if the effects on a particular group of organisms in a specific location during a known time interval could be observed. Although live boxes and cages to hold fish and other macro-organisms are used frequently to evaluate aquatic conditions, the effects on micro-organisms are used frequently to evaluate aquatic conditions, the effects on micro-organisms are normally determined by examining water samples. This method is frequently satisfactory, but this is not always the case.

While conducting a project in a marine environment, we had the problem of determining the effects of copper on specific micro-organisms within a relatively small area. Since the fluctuation in the natural population of these organisms in this area was considerable, the evaluation of the effects of copper on the organism was difficult.

To overcome this difficulty we suspended sections of dialyzing membrane, filled with aliquots of a culture of Prorocentrum sp., in the water of the area. Our first trials were unsuccessful because the membranes were ruptured by



Pouring unialgal cultures of Prorocentrum into bags made of dialysis membranes and protected by polyethylene bottles.

macroscopic organisms. This difficulty was eliminated by placing the membranes in perforated polyethylene bottles. Prorocentrum normally survived in the membranes and the membranes remained intact for approximately one week. After a week, the membrane weakened and often broke.

It was assumed that the copper in solution would pass through the membrane until an equilibrium was reached. Tests to determine the validity of this assumption, indicated it to be generally correct; however, the relative rate of movement of copper ions through the membrane was slow. In fact, the concentration of copper within the membrane was probably never as high as the original concentration outside, since copper precipitates to a great extent in sea water within a 24-hour period.

Prorocentrum sp. (number per 0.01 milliliter) surviving outside and inside of dialyzing membranes after the addition of various amounts of copper.

Copper additions µg. at. Cu/l [1]		Time after copper addition						
		Before	10 min.	30 min.	1 hr.	5 hr.	18 hr.	24 hr.
0.0	Outside	15	29	34	36	23	45	34
	Inside	23	24	26	22	24	25	19
0.8	Outside	27	0	0	0	0	0	0
	Inside	26	19	21	18	37	26	27
1.6	Outside	19	0	0	0	0	0	0
	Inside	20	22	25	23	2	0	0
3.2	Outside	22	0	0	0	0	0	0
	Inside	24	21	34	3	0	0	0
6.4	Outside	31	0	0	0	0	0	0
	Inside	22	25	22	0	0	0	0

1/ All copper was added to that aliquot of the culture on the outside of the membrane.

Previous tests had shown that the minimum lethal concentration to Prorocentrum sp. was between 0.6 and 0.8 microgram atoms per liter (µg. at. Cu/l). The results of an experiment using a culture of Prorocentrum sp. indicate that between 30 and 60 minutes are required for a concentration of 6.4 µg. at. Cu/l outside the membrane to establish the lethal concentration within the membrane. An outside concentration of 3.2 µg. at. Cu/l produced an inside concentration approaching the minimum lethal concentration within the same time interval. Between two and five hours were

required for the inside concentration to approach 0.8 μg. at. Cu/l with an outside concentration of 1.6 μg. at. Cu/l. An outside concentration of 0.8 μg. at. Cu/l did not raise the inside concentration to a comparable amount within 24 hours.

The results of a test in which dialyzing membranes were placed in sea water containing 4.0 μg. at. Cu/l gave similar results. The copper concentration of the water in the membranes increased gradually to 0.1, 0.2, 0.4, 0.8 and 1.1 μg. at. Cu/l in 7.5 min., 15 min., 30 min., 1 hr. and 2 hrs. respectively.

One limitation of this procedure is inability to measure short period effects. If the toxic concentrations of a substance persist for a short time period or if the concentration of the substance is near the minimum toxic level for the test organism, the procedure is inadequate. Another limitation is that the molecules of many organic compounds are too large to pass through the membranes generally available. In addition, cultures of test organisms are needed in most cases.

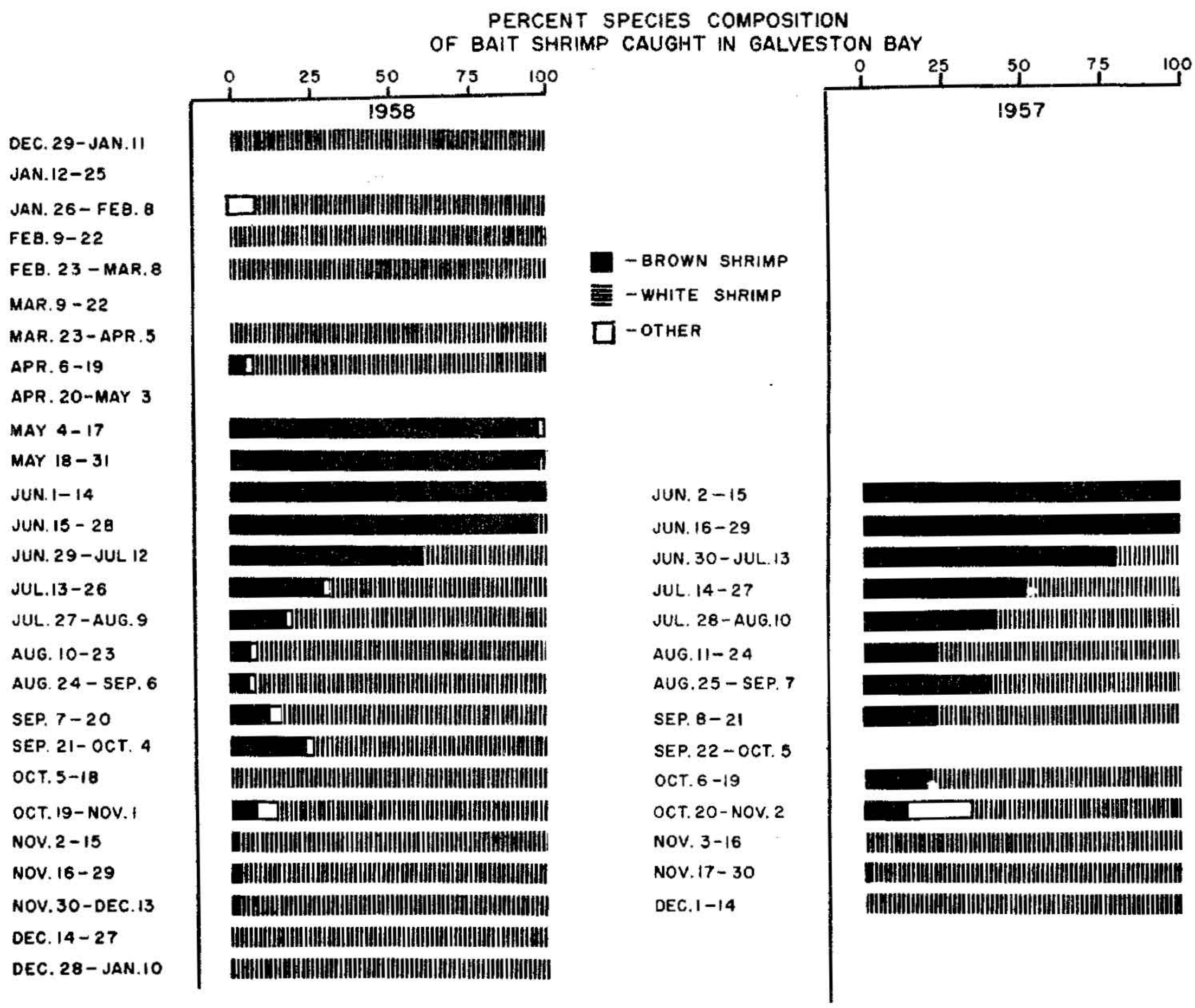
Despite these limitations, the proper application of this method may be of considerable value in permitting a more direct type of field bioassay than has heretofore been possible.

The Bait Shrimp Fishery of Galveston Bay

Edward Chin

Brown shrimp (Penaeus aztecus) dominate the catch from early May through mid-July, and white shrimp (Penaeus setiferus) the rest of the year. Occasionally, pink shrimp (Penaeus duorarum), seabobs (Xiphopeneus krøyeri) and species of Trachypenaeus enter the catch.

During 1958, 90 percent of the brown shrimp used were equal to or less than 5.5 grams (90 millimeters total length) and 90 percent of the white shrimp used were equal to or less than 8.0 grams (103 millimeters total length).



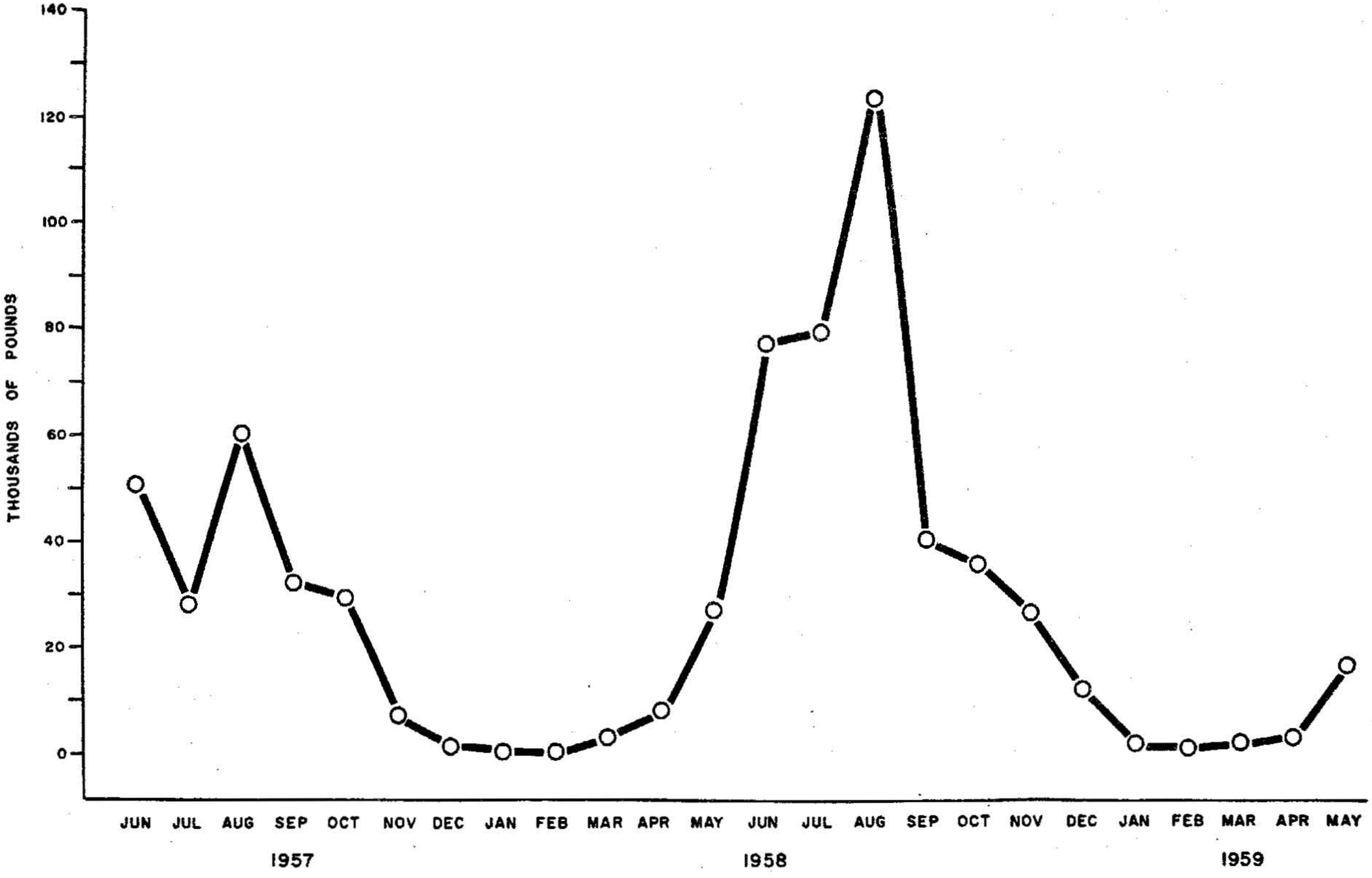
Fluctuations in species composition of shrimp utilized by bait industry.

As noted in previous studies, the bait shrimp fishery is relatively inactive during the winter, due to lack of shrimp, but shrimp are occasionally brought in from the Sabine and Port Aransas areas by means of aerated tank trucks. In May, as the young of the year reach desired sizes, fishing activity is increased, and by August, the bait catch has reached its peak and begun to decline. In January of the following year, the catch has dropped to less than three percent of the August catch.

Total production during the two-year period from June 1957 through May 1958 amounted to slightly over 676,000 pounds with a retail value of almost $780,000. Comparison of the bait shrimp catch with the commercial shrimp catch in the same area shows that from May through August, the bait catch considerably exceeds the commercial catch. From September through November the situation is reversed.

PERIOD	BAIT CATCH (Pounds)	COMMERCIAL CATCH (Pounds)
June-Aug. 1957	139,336	46,730
Sept.-Nov. 1957	69,516	710,409
Dec. 1957-April 1958	16,040	None
May-Aug. 1958	307,510	105,242
Sept.-Nov. 1958	102,736	659,385
Dec. 1958-April 1959	21,822	33,527 1/

1/ Incomplete, only data for December available.

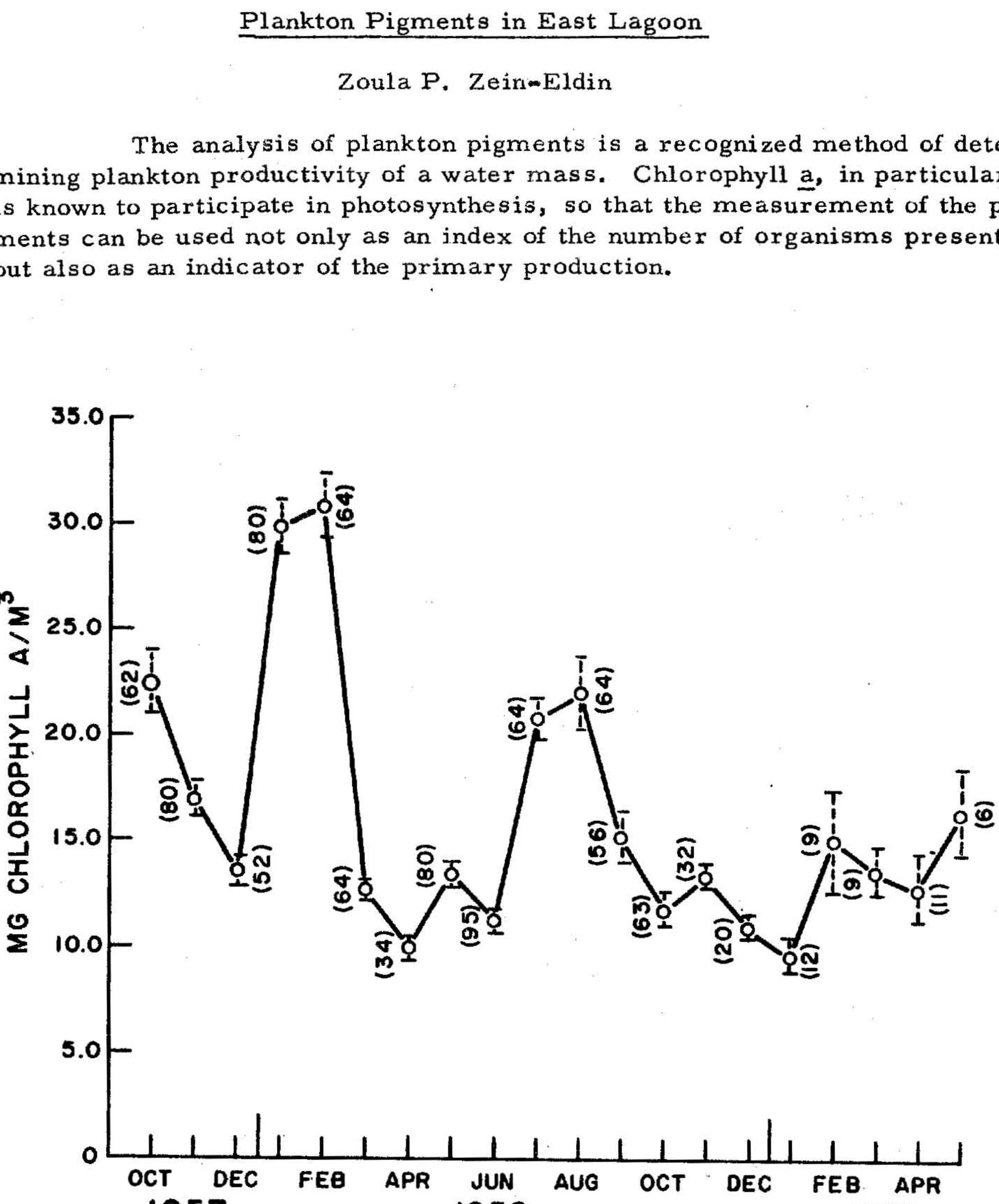


Production of bait shrimp in Galveston Bay by months.

Plankton Pigments in East Lagoon

Zoula P. Zein-Eldin

The analysis of plankton pigments is a recognized method of determining plankton productivity of a water mass. Chlorophyll a, in particular, is known to participate in photosynthesis, so that the measurement of the pigments can be used not only as an index of the number of organisms present but also as an indicator of the primary production.



Mean monthly chlorophyll a in East Lagoon.
(Number of determinations in parentheses)

Plankton pigment determinations on water samples from East Lagoon, a part of the copper ore dike study, were started in October of 1957. Samples were taken from eight stations along the length of the lagoon until December 1958 when sampling was reduced to three stations corresponding to those originally at the head, the middle, and the mouth of the lagoon. In all cases, water samples were pumped and contained water from the entire water column at a given location. Samples were stabilized with magnesium carbonate and, if not analyzed immediately stored overnight in a refrigerator. Filtration, using a millipore apparatus, was generally completed within 18 hours of collection, although in a few instances it was necessary to store samples over a weekend before filtration. Chlorophylls a, b, and c, as well as the astacin-type and non-astacin-type carotenoids were determined by the method of Richards with Thompson, using 90 percent acetone as extractant.

The accompanying graph indicates the mean monthly value for chlorophyll a for the entire lagoon. The number of individual determinations is given in parenthesis by the point, and the standard error of the mean is indicated by bars. Phytoplankton blooms were noted during October 1957, January and February 1958, and again in July and August 1958. The bloom in January and February occurred at all stations and may be considered the characteristic vernal flowering noted in semiprotected waters of other temperate areas. The late summer blooms, however, were more localized and the highest values occurred at the head end of the lagoon. These values might be considered abnormal for the lagoon as a whole. It was during this latter bloom that a single station yielded 80.4 mg. chlorophyll a/m^3, the highest value recorded during the entire sampling period. The lowest value occurred in March 1958, when two stations produced only 3.1 mg. chlorophyll a/m^3. Ignoring blooms, there is an overall average of 12-13 mg./m^3, indicating that this estuary is highly productive. There is not a great deal of data available on long-term plankton pigment investigations. Marshall, however, reported a mean value in a year's study of Tampa Bay (the most productive Florida bay investigated) only half that found in East Beach Lagoon. Riley reports a mean in Long Island Sound of 17.4 mg./m^3, while in the lagoon, the overall mean, including blooms, was 17.6 mg./m^3.

Fixing and Staining of Dinoflagellates

John H. Finucane

Due to the extreme fragility of living G. breve, we are experimenting on techniques for the preservation of plankton samples in the field which will permit more precise quantitative and qualitative analyses of samples.

Field samples were fixed immediately after collection with 0.5 ml. of 2 percent osmic acid in 1 percent chromic acid solution per 50 ml. of the sample. So far this fixative has been the most effective in preserving G. breve and other phytoplankton.

Fixed water samples were stored under refrigeration at 36° F. These samples were later filtered under reduced pressure, using HA gridded millipore filters. After serial washes and the application of a mordanting solution, the organisms were stained on the millipore filter pad. The 3 most promising stains have been 1 percent Fast Green FCF, $\frac{1}{2}$ percent Gentian Violet, and $\frac{1}{2}$ percent Crystal Violet. These filters are first cleared in cedar oil or Cargille oil, then cut in half, and mounted with balsam or Permount on a glass slide. A permanent slide index of the phytoplankton taken since January 1959 at selected stations is being maintained. There is some tendency for G. breve cells to round up during filtration, but no distortion or cytolysis of armored dinoflagellates or diatoms was noted.

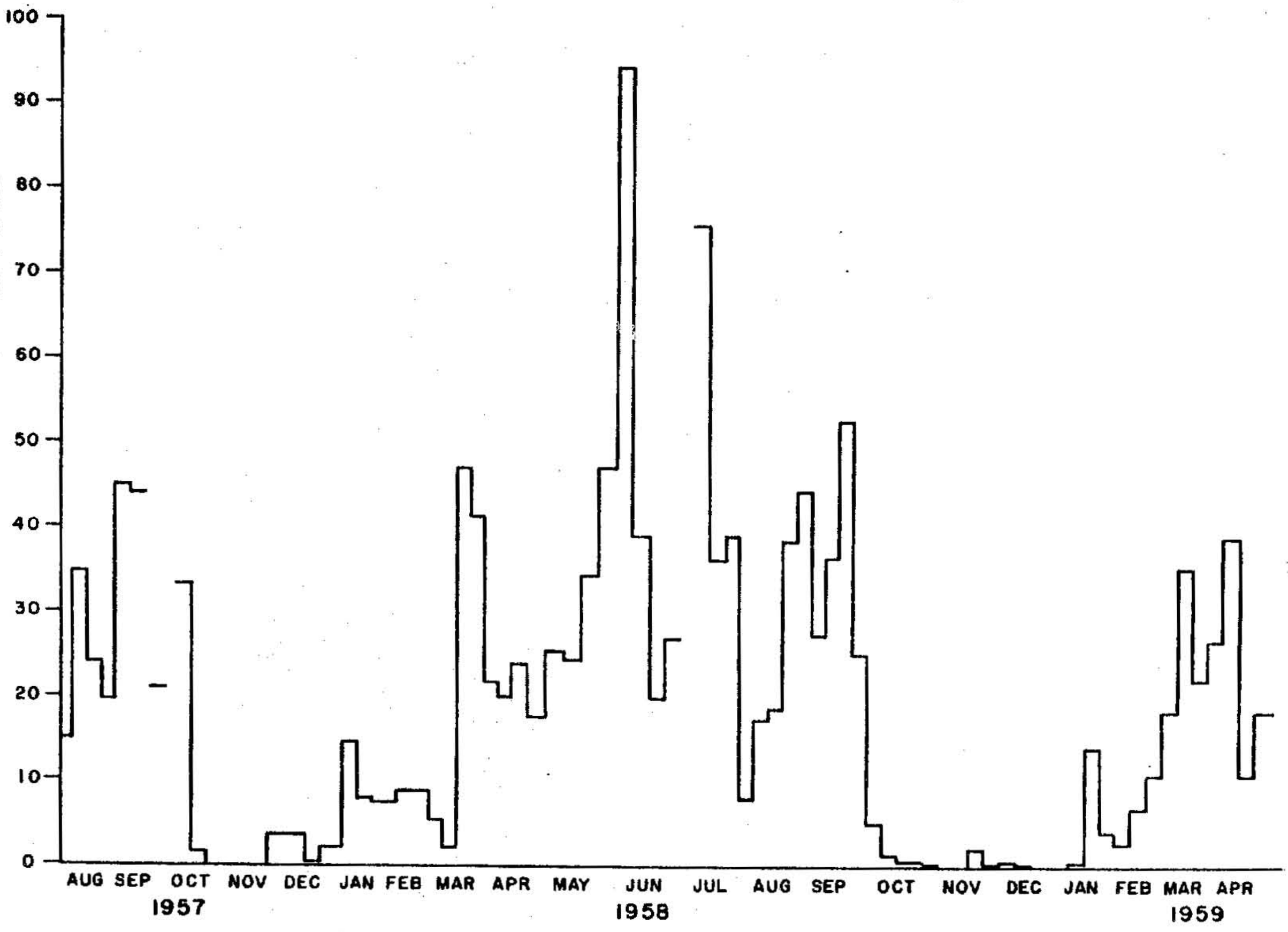
This technique can be used to supplement living counts of G. breve and associated phytoplankton and may be valuable during extended offshore sampling trips when large changes in the number of organisms could occur before examination of the samples.

Seasonal Barnacle Attachment in East Lagoon

David V. Aldrich

In cooperation with other studies conducted in the East Lagoon, estimates of barnacle attachment rate have been continued. Since the barnacle is the dominant sessile form in the Lagoon, it has been included among those organisms whose prevalence has been followed in an effort to estimate the possible effect of a copper ore dike on the Lagoon biota.

The cement board fouling plate method was the basic tool in this study. The plates were usually exposed for a one week period in a horizontal position at a depth of two feet at anchored, floating stations. The rate of barnacle attachment was recorded in terms of number of individuals per square centimeter of plate surface per week at each station. The graph is based on the mean of all station values for each exposure period.



Barnacle attachment rate in East Lagoon, Galveston, Texas

The established adult barnacle population of the Lagoon consists almost exclusively of one species, Balanus eburneus, a common inhabitant of brackish waters in this part of the Gulf. The young adults attached to the exposed plates were identified as this species and one other, B. improvisus, a form which also occurs in low salinity water.

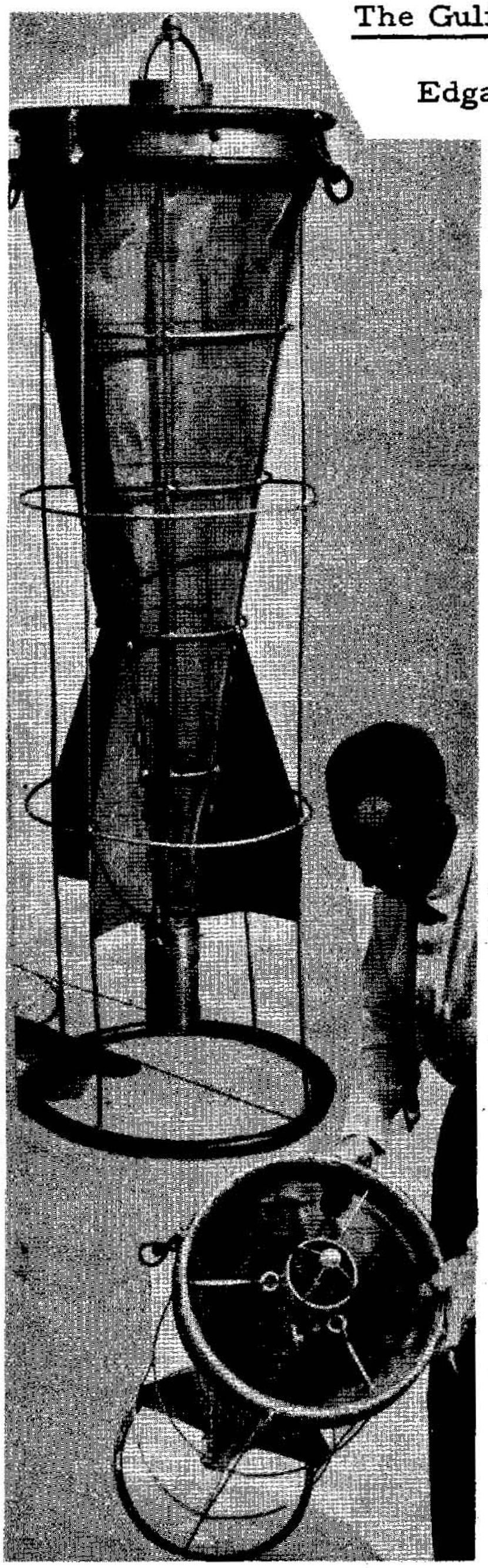
The most striking feature of the barnacle set in the Lagoon was its seasonal nature. The rate of attachment was quite low from October to January, most plates had less than one barnacle per square centimeter. This seasonal cycle is similar to those reported by other workers in North Carolina, Chesapeake Bay, California, and Japan.

No explanation has been found for the wide variation in setting rate throughout the summer season. During this period there is no simple relationship between attachment rate and any of several classical ecological factors. These factors include the temperature, salinity, and chlorophyll content of the water, as well as rainfall and length of exposure to incident sunshine of the area. A further lack of correlation seems to exist between the numbers of barnacle larvae present in the plankton (as determined by Dr. Fleminger) and rate of barnacle attachment.

Despite the large number of fouling studies which have been reported, the factors controlling the successful attachment and metamorphosis of barnacles are not well understood. A careful review of the data taken in this study may clarify some areas of uncertainty which exist.

The Gulf V Plankton Sampler

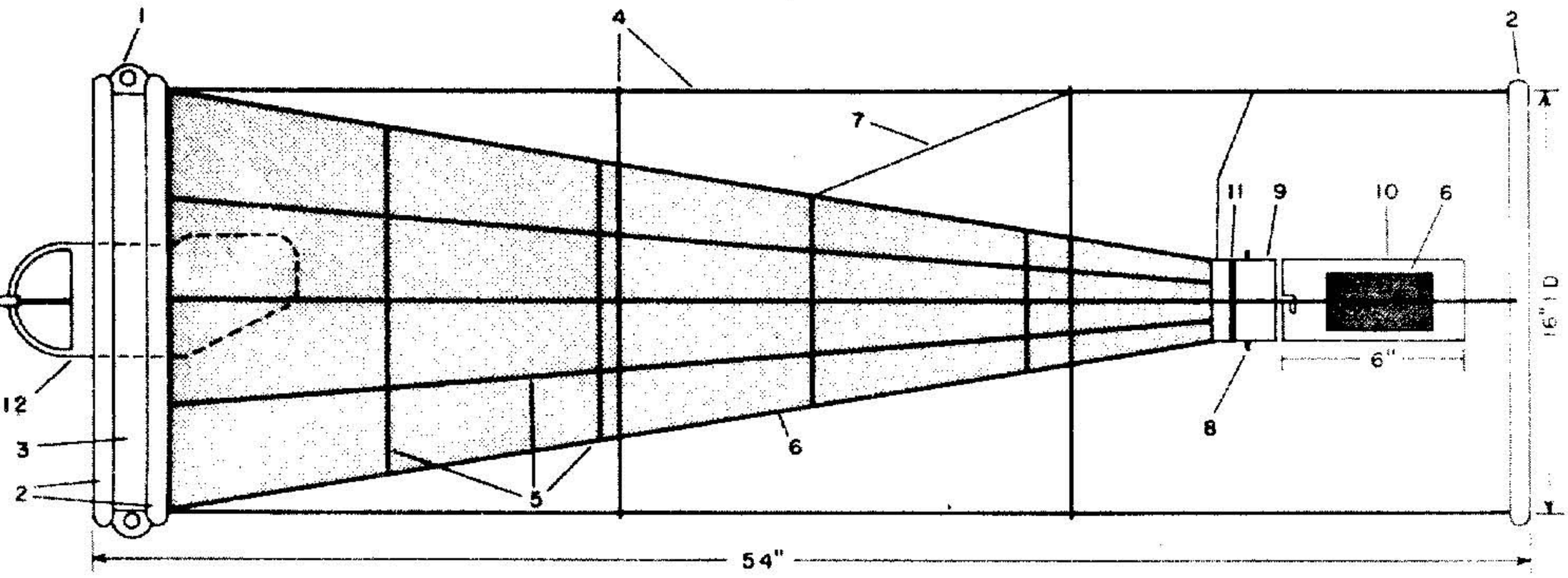
Edgar L. Arnold, Jr.

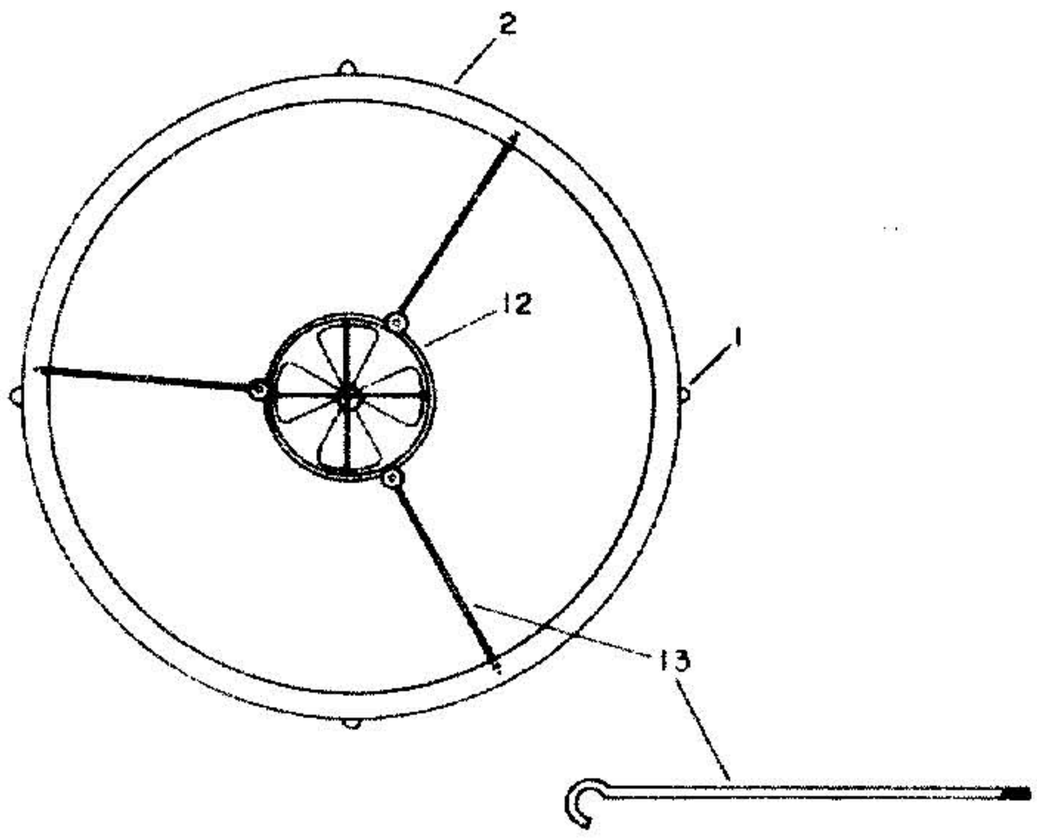


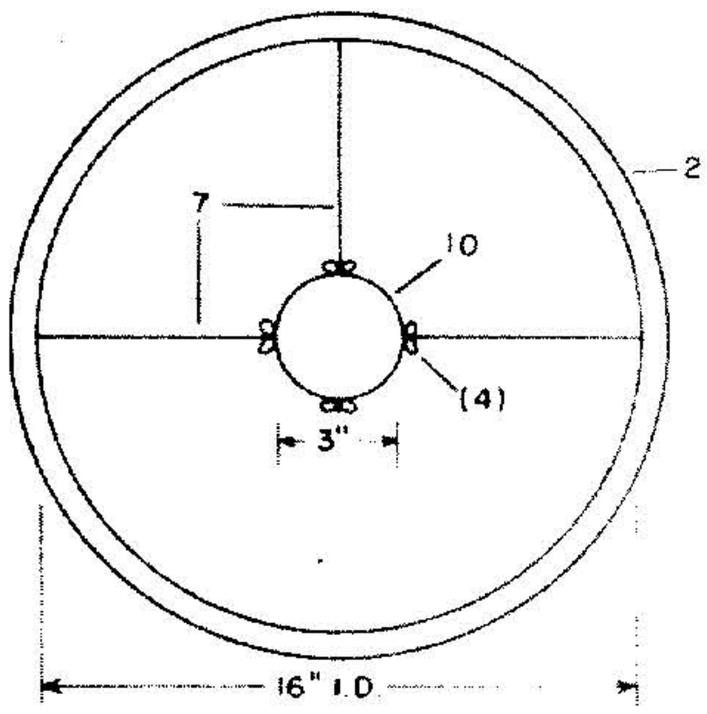
Side and front views of the Gulf V plankton sampler.

In April 1951 the Galveston Laboratory began a plankton-sampling program as part of a biological survey of the Gulf of Mexico. Recognizing the limitations of conventional collecting gear, nets fabricated of monel wire cloth were designed to carry out this study aboard the ALASKA, research vessel of the Fish and Wildlife Service (Arnold and Gehringer, SSR-Fisheries No. 88), and were operated successfully throughout the cruises made from January 1952 to July 1953. One sampler, the Model Gulf III, used for making tows at 4-5 knots, consisted of a removable conical net of #1 mesh with a detachable bucket, enclosed within a monel tube. The net and bucket measured 59½ inches, and tapered from a ½-meter mouth opening to a 3-inch diameter collar. The monel tube (3 sections) was 7 feet in overall length. Towing stability was effected by means of 3 fins and a 40-lb. depressor of the type developed at Scripps Institute of Oceanography by John Isaacs. The amount of water strained was measured by 2 current meters, one located within the mouth opening, one behind the net within the tube.

Anticipating future plankton sampling aboard smaller vessels, and considering the excellent results obtained with the G-III model, the need for a smaller and more easily handled sampler was apparent. It seemed logical that the conical wire cloth net of the G-III (which was essentially a standard ½-meter net), could be adapted for towing without the enclosing tube. Such a net was designed and fabricated in 1956, using the G-III net as a prototype. The new model, designated as Gulf Model V is shown with details of construction. Modifications from its G-III prototype are a reduction in size of the mouth opening from 19½" to 16", reduction in length from







The Gulf V Sampler

1. Towing Plate, Monel, $\frac{1}{4}$" - (4).
2. Brass Pipe, 3/4", (3).
3. Collar, Monel, 16-gauge, 3" wide.
4. Monel rods, 5/16", for protection and support of net.
5. Monel rods, $\frac{1}{4}$", to support wire cloth.
6. Monel wire cloth, 75 meshes/inch.
7. Monel Fin, 16-gauge, (3).
8. Studs, threaded, to secure plankton bucket (4) with wing nuts (brass).
9. Monel collar, 16-gauge, 3" O.D., 2-5/8" long.
10. Monel plankton bucket, 8-gauge, 3" I.D. 6" long. Slots (4).
11. Flange, 1/8" monel, to insure against leakage of material from bucket.
12. Atlas current meter.
13. Brass rods, $\frac{1}{4}$".

60" to 51", and an improved method of installing and removing a current meter. The net was further modified by:

1. Strengthening the mouth collar with 2 encircling 3/4" brass pipes.

2. Adding 4 monel towing plates on collar between the pipes.

3. Adding a protective and strengthening framework of $\frac{1}{4}$" monel rods along and around the net. Lengthwise rods (4) extend from inner brass pipe to a similar pipe 8" below net. Latter pipe enables net to stand upright.

4. Adding 3 monel stabilizing fins as shown.

The G-V was tried out during Cruise 41 of the M/V OREGON, in December, 1956. Launched and retrieved manually from an outboard platform, and using a 6-pound depressor, the net fished well at speeds up to 5 knots, although it was necessary to stop the ship during retrieving. As an indication of its catching ability, sorting of the catches of the 8 tows revealed many larval, post-larval, and juvenile fishes (including several thousand striped mullet and a juvenile dolphin), 40 juvenile squid, 120 eel leptocephali and 26 lancelets, as well as an abundance of smaller plankters. Successful operation of two Gulf Model V nets during the intensive plankton sampling for larval shrimp now being carried out by the Galveston Laboratory proves the value of this type of net.

East Lagoon Zooplankton

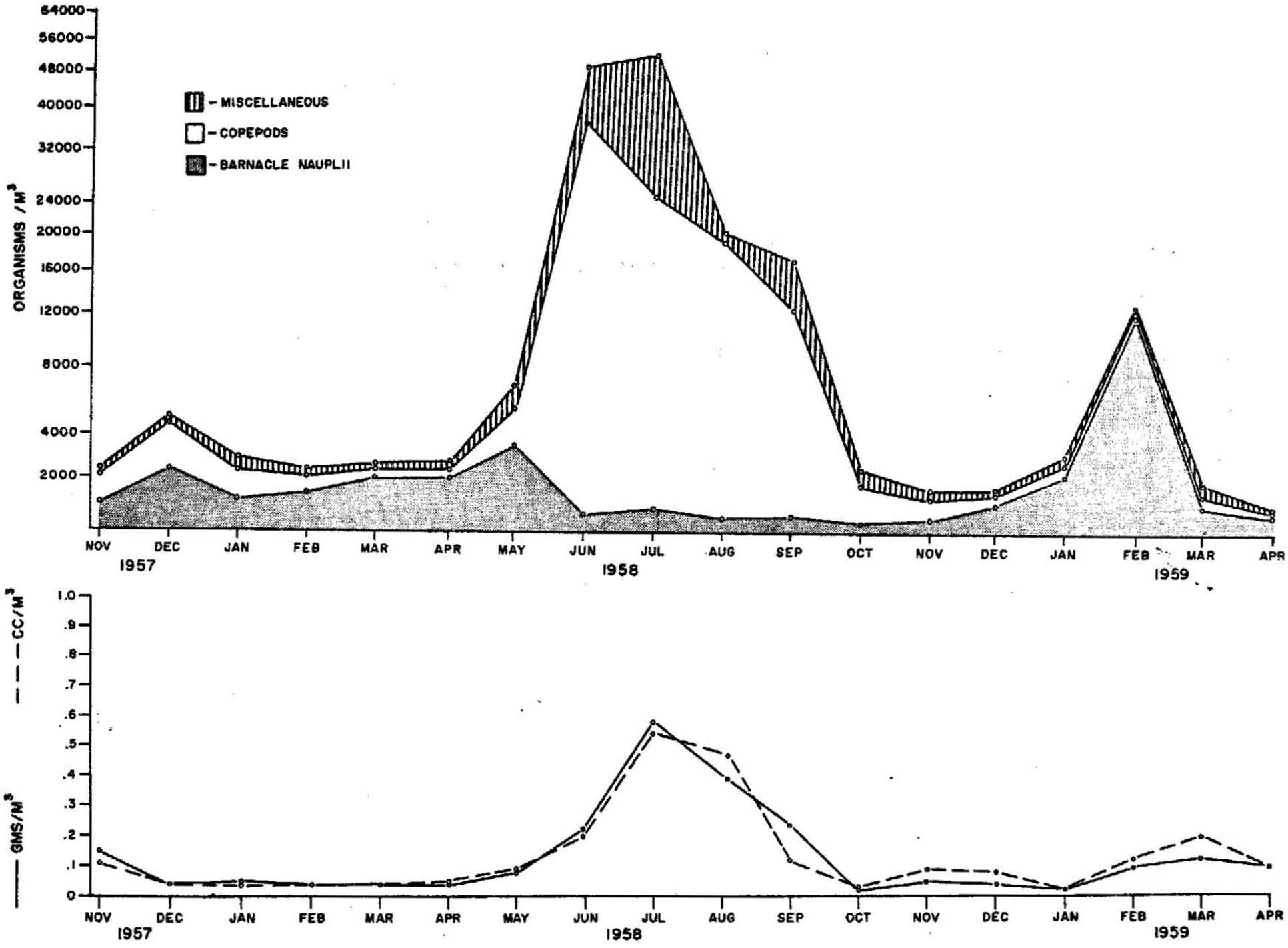
Abraham Fleminger

As a part of the project investigating the effect of copper ore on estuarine populations, we have accumulated eighteen consecutive months of qualitative and quantitative data on the standing crop of zooplankton in East Lagoon, Galveston. The interest of this information extends considerably beyond the original needs. This Lagoon, a comparatively high salinity permanent-tidal pond, communicates with Bolivar Roads, the entrance to Galveston Bay. It represents one type of local environment found in the rich shrimp and fish producing northwestern Gulf estuaries of which, systematic studies are sorely lacking; the closest comparable account of Gulf zooplankton is a study of the copepods in open coastal waters off west Florida.

Three plankton collecting stations are maintained in the Lagoon, one at the head end, another at mid-length, and the third near the zone of contact with Bolivar Roads. Collections have been made at approximately weekly intervals since November 1957 by pumping 250 gallons of water through a number 10 mesh bolting cloth net using a $1\frac{1}{4}$ inch, gasoline driven, centrifugal pump. Sample analysis methods do not deviate from generally accepted techniques in current use. Concomitant Lagoon projects with which the zooplankton results should be compared include systematic recording of chlorophyll concentrations, barnacle set and physical and chemical characteristics. To provide a general description and source for comparison of the cycle of events, daily measurements at the three stations have been combined into monthly means, derived from 12 or more independent measurements.

Considering that this portion of the Texas coast is generally classified as temperate or warm temperate, the abundance of zooplankton varied in an unexpected fashion during the 18-month period. The broad peak in abundance spanning the summer months and the indication of a brief mid-winter secondary peak combined with troughs in early spring and the entire autumn are the outstanding features. Qualitatively, copepods and the larvae of benthic organisms dominated the summer bloom, whereas barnacle nauplii comprised the most abundant form in the winter plankton.

This pattern is conspicuously out of phase with the more familiar conditions at cooler temperate latitudes. In Long Island Sound, for example, an early spring bloom and a less extensive rise between late August and early October represent the peak periods with troughs falling in mid-winter and, to a lesser extent, in mid-summer. Qualitatively, the Galveston summer bloom appears to compress the elements of two blooms in more northern



Monthly mean number, drained wet weight (gms.) and displacement volume (cc.) per cubic meter of water.

estuaries. The earlier phase in June and July, rich in the larvae of benthic organisms, resembles the early spring bloom in the north, whereas the later phase, comprised mainly of copepods, reflects the north's fall bloom. Comparable aspects of the mid-winter increase in barnacle nauplii are more obscure.

Differences of a general nature between the Lagoon and northern estuarine areas, such as Long Island Sound, may be better understood by faunistic comparison. The regular constituents of the Lagoon and their monthly relative abundance are listed in the accompanying table. Based on the planktonic copepods this fauna is clearly an extension of the more thermophilic fraction of the temperate estuarine fauna such as dominates Long Island Sound in summer. The loss of cold temperate species in the Lagoon and in the Bay proper is not compensated for by a significant quantitative gain in tropical forms (e.g., Temora turbinata, Eucalanus pileatus, and Centropages furcatus). In open coastal waters just off Galveston, however, these warm water species comprise a substantial fraction of a zooplankton vastly superior in abundance to that of the Lagoon. Only one northern winter species, Centropages hamatus, occurs in Galveston waters, but Lagoon conditions are not as favorable to this species as conditions in the lower Bay and along the open coast. Fluctuations of the dominant species in the Lagoon, (omitting barnacle larvae) such as Acartia tonsa, Paracalanus crassirostris and the Oithona group, resemble the seasonal cycle of their Long Island Sound counterparts. They achieve peak numbers only during the warmer months but they differ somewhat by not disappearing during the unfavorable winter period. With respect to the relative productivities of the two regions rough estimates indicate a six- to ten-fold difference in the size of the yearly mean standing crop with the Lagoon being the poorer; the variation results from different types of measurement.

As the Lagoon is an exceedingly small water body teeming with plankton-feeding fish, we could attribute some of the differences in zooplankton quantity to excessive predation. However, other evidence suggests that the quality of the environment for plankton production is considerably below adjacent areas, as well as Long Island Sound. Breeding and growth of the numerically dominant copepod, Acartia tonsa, provides a good indication of this.

Based on age composition of the Acartia population in the Lagoon, gonad development in adult females, and rearing experiments in the laboratory, it is fairly certain that the species spawns continuously throughout the year and can reach maturity in the relatively short period of four to five weeks during most of the year. Furthermore, numerically, the species equals or exceeds the combined total of the remaining Lagoon copepods.

Estimated monthly abundance of zooplankton in East Lagoon
(Mean number per cubic meter: 1 = 1-100; 2 = 101-1,000; 3 = 1,001-10,000; 4 = 10,001-100,000)

Organisms	1957		1958												1959			
	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Larval forms																		
Copepod nauplii	2	1	2	1	2	1	2	3	3	3	3	2	2	1	1	1	1	1
Barnacle nauplii	3	3	3	3	3	3	3	2	2	2	2	2	2	3	3	3	2	2
Barnacle cyprids	1	1	1	1	1	2	1	2	2	1	1	1	1	1	1	1	2	1
Crab zoea	0	0	0	0	0	1	1	2	2	2	1	1	0	0	1	0	0	1
Polychaetes	1	1	1	1	0	1	1	2	2	2	2	1	1	1	1	1	1	1
Molluscs	1	1	1	1	0	1	1	2	2	3	2	1	1	1	1	1	1	1
Sagitta spp.	1	1	1	1	0	0	0	0	0	1	0	1	0	1	1	1	1	0
Oikopleura dioica	0	1	0	0	0	0	1	1	2	2	1	0	0	0	0	0	0	0
Copepoda																		
Acartia tonsa	2	2	2	2	2	2	2	4	4	4	3	2	2	2	2	2	2	1
Centropages hamatus	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1
C. furcatus	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0
Eucalanus pileatus	1	1	0	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0
Labidocera aestiva	1	1	0	1	1	0	1	1	0	1	1	1	1	1	0	0	1	1
Paracalanus crassirostris	2	2	2	2	1	1	2	2	2	3	3	2	2	2	2	2	2	1
P. parvus	0	1	0	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1
Pseudodiaptomus coronatus	1	1	1	0	0	0	1	1	2	2	2	1	0	1	0	0	0	0
Temora turbinata	1	0	0	0	1	0	1	1	0	1	0	0	1	1	0	0	0	0
Oithona spp.	2	2	2	2	1	1	3	4	3	3	3	2	2	2	1	1	2	1
Remaining Cyclopoida	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1
Harpacticoida	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

In Long Island Sound the species is known to have about four yearly broods, maximum developmental rates for perhaps only two of these generations, and it successfully co-exists with several potential competitors that equal its abundance during its most prolific period in the summer and exceed it by far in winter. Despite the potential advantage held by Lagoon Acartia, the yearly mean standing crop of Long Island Acartia is roughly twice that found in the Lagoon.

With regard to growth, we have followed monthly length-frequency distributions of adults in the Lagoon and in coastal waters just off Galveston's beachfront. The coastal Acartia on the average exceeds Lagoon Acartia by a factor of 1.2. Furthermore, Lagoon Acartia shows no sign of seasonal variation, whereas coastal Acartia varies in the expected fashion: mid-summer adults comprise the lowest portion of the yearly range and mid-winter adults the highest. The strongest indication that marginal conditions for zooplankton prevail in the Lagoon lies in the fact that the mean and the mode of the length-frequency distribution for mid-summer coastal Acartia exceed those for the Lagoon population.

It is interesting to speculate that the difference between standing crops of the Lagoon and Long Island Sound does not reflect the magnitude of differences in productivity potential. It could represent the vector of (1) a denuded plankton fauna existing at the outer limits of its environmental range and unable to compete with (2) the hordes of developing post-larval shrimp and menhaden young who, being better adapted to environmental conditions, are able to utilize more of the Lagoon's and also the Bay's productive capacity.

LIBRARY

Stella M. Breedlove

The library collection consists of a total of 5276 items, including books, journals, magazines, reprints, and reports. The record of translations was organized to correspond with that of the Department of the Interior Library, and copies of translations forwarded to Washington. The reprint collection was rearranged alphabetically by author and unbound series consolidated alphabetically by title. The library has contacted over fifty Government offices and laboratories for official publications relating to fisheries. The volumes borrowed through interlibrary loans decreased during the past year but loans to other institutions and to the field stations of the laboratory have increased. Shelving in the library totals approximately 420 linear feet.

Statistical Summary of Library Collection

	On hand 1957	Additions 1958	Additions 1959	On hand 1959
Books	798	211	217	1226
Journals (Bound)	24	87.	163	274
Journals (Unbound)		420*	94	514
Reprints		983*	301	1284
Institutional			1597*	1597
Other	17	12	352*	381
Total items	839	1713	2724	5276

*First complete inventory.

STAFF ATTENDANCE AT MEETINGS

Meeting	City	Month	Number
American Fisheries Society	Philadelphia	August	3
American Institute of Biological Sciences	Indianapolis	August	1
Gulf States Marine Fisheries Commission	New Orleans	October	2
Southern Division American Fisheries Society	Louisville	October	1
Gulf and Caribbean Fisheries Institute	Miami	November	3
American Association for the Advancement of Science	New York	December	1
American Fishery Advisory Committee	Miami	December	1
Southwest Field Committee, Interior Department	Shreveport	December	1
Texas Shrimp Association	Galveston	January	2
Gulf States Marine Fisheries Commission	New Orleans	March	3
Southwest Field Committee, Interior Department	Austin	March	1
Biological Seminar on Pollution	Cincinnati	April	2
Mosquito Control Symposium	Washington, D. C.	April	1
Southeastern Fisheries Association	Miami	May	1
Shrimp Association of the Americas	Mexico City	June	1
	120		

SEMINARS

The epipelagic calanoid fauna of the Gulf of Mexico. Dr. A. Fleminger

Factors affecting the precision of a chemical analysis. K. T. Marvin

The relationship of phytoplankton pigments to marine productivity. Z. P. Zein-Eldin

Fish scales and their role in fishery research. E. Arnold

*Effects of sedimentation due to mudshell dredging on oysters in Copano Bay, Texas. W. B. Wilson

Methods of fish food habit studies. A. Inglis

*The proposed tidal-power dam in the Bay of Fundy. B. E. Skud

Barnacle attachment in the Galveston Lagoon. Dr. D. V. Aldrich

Causes of population changes in sockeye salmon. Dr. G. A. Rounsefell

Review of "Reproduction and larval ecology of marine bottom invertebrates", by Gunnar Thorson. R. S. Wheeler

The California ocean shrimp fishery. Dr. J. H. Kutkuhn

The effects of a parasite, Dermocystidium marinum, on oysters. Dr. S. M. Ray (Texas A. and M. Research Foundation)

Bay productivity. Dr. H. T. Odum (Institute of Marine Science, University of Texas)

The decomposition of organic matter. Dr. C. H. Oppenheimer (Institute of Marine Science, University of Texas)

Role of vitamin B_{12} in marine ecology. Dr. T. J. Starr (Medical Branch, University of Texas)

*Presented to Texas Game and Fish Commission and Institute of Marine Science at Rockport, Texas.

PUBLICATIONS

Aldrich, David V., see Harry

Allen, Donald J., see Chin

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1958. Gulf of Mexico plankton investigations: 1951-1953. U. S. Fish and Wildlife Service, Spec. Sci. Rept. Fish. No. 269, 53 pp.

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MANUSCRIPTS

*Undergoing field review
**Submitted.

Aldrich, David V.
Setting and seasonal occurrence of barnacles in a Texas lagoon.
Effect of salinity on growth of G. breve.

Allen, Donald M.
A method of size grading large numbers of live shrimp.

Andrews, Rupert E.
Factors influencing the seaward migration of smolt steelhead trout Salmo gairdneri gairdneri, Richardson in the Alsea River, Oregon.

Arnold, Edgar L., Jr.
Fauna of East Lagoon, Galveston Island.
Seasonal occurrence of larval menhaden.

Cating, James P. and Rupert E. Andrews
The industrial fish catch from the Gulf of Mexico, 1953-1958.

Chin, Edward
**The bait shrimp fishery of Galveston Bay, Texas.

Collier, Albert W., Jr.
Gulf of Mexico plankton survey with the G-II sampler, 1951-53.

Costello, Thomas J.
Procedures for marking shrimp with vital stains.
Growth of pink shrimp, Penaeus duorarum, in impounded waters.
**Marking shrimp with biological stains.

Costello, Thomas J. and Donald M. Allen
Growth and offshore movement of pink shrimp, Penaeus duorarum.

Dragovich, Alexander
*Chemical composition and phytoplankton of waters at Naples, Florida.
Nitrate-nitrite concentrations in waters of the Florida west coast.

Finucane, John H.
*Seasonal occurrence and distribution of Gymnodinium breve along the Florida west coast, 1954-58.

Finucane, John H. and Alexander Dragovich
**Enumerations of the red tide organism and associated oceanographic data in Florida waters from February 1954 to July 1957.

Fleminger, Abraham
Biogeography of calanoid copepods in the North Atlantic-Caribbean system.
The epiplanktonic calanoid copepods of the Gulf of Mexico.
Zooplankton of East Lagoon, Galveston.
Distribution of calanoid copepods in the Gulf of Mexico.

Gates, Jean and William B. Wilson
**The toxicity of Gonyaulax monilata Howell to fish.

Inglis, Anthony
Role of juvenile fishes as predators on young shrimp in inshore waters.

Kutkuhn, Joseph H.
Estimating absolute age composition of California salmon landings.

Marvin, Kenneth T., Larence M. Lansford, Ray S. Wheeler, and Ray Proctor
Copper ore as a red tide control.

Marvin, Kenneth T., Zoula P. Zein-Eldin, Billie Z. May and Larence M. Lansford
**Procedures for chemical analyses of marine and estuarine waters.

May, Billie Z.
*Stabilization of the carbohydrate content of sea water samples.

Ray, Sammy M. and William B. Wilson
Techniques for culturing G. breve.

Rounsefell, George A.
*Relationships among North American Salmonidae.

Skud, Bernard E.

*S. E. Alaska herring mortality from marking experiments.

*Statistics of the Alaska herring fishery.

*An aerial survey of herring spawning grounds.

Wheeler, Ray S.

Chemical changes in East Lagoon waters during a 24-hour period.

Wilson, William B.

Toxicity of copper to G. breve.

Nutritional studies of G. breve.

Zein-Eldin, Zoula P.

Chlorophyll in East Lagoon, Galveston, Texas.

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