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A Study of Selected Chemical and Biological Conditions of the Lower Trinity River and the Upper Trinity Bay

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A STUDY OF SELECTED CHEMICAL AND BIOLOGICAL CONDITIONS OF THE LOWER TRINITY RIVER AND UPPER TRINITY BAY

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All of the field work was done under the direction of J. Van Conner. Graduate students Hoyt W. Holcomb and Frank M. Truesdale accumulated most the data and perfomed well under strenuous field conditions.

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INTRODUCTION

Concern over the effects of water development projects on coastal nurseries prompted the Department of Wildlife Science of Texas A&M University, with the cooperation of the U. S. Bureau of Commercial Fisheries, Galveston, to undertake a study of a threatened nursery in the Galveston Bay System (Figures 1-2).

A long-range program for the development of the Trinity River Drainage Basin includes the construction of several multi-purpose reservoirs along the main river (Fickessen, 1965). Of immediate threat to Galveston Bay nurseries was the reservoir to be constructed at Wallisville, Texas (Trinity River Mile 3.9). The site is close to Trinity Bay and the dam will traverse the relatively wide deltaic region of the Trinity River (Figure 2).

The completed dam will serve as an effective barrier to salt-water. Approximately 12,500 acres of marsh behind the dam will become a freshwater conservation pool. The marsh area below the dam (8,200 acres) will also be modified through changes in the freshwater flow.

It is assumed that the Wallisville Dam will be completed and that many of the conditions described here for the study area will be drastically changed.

The aim of this study was to gather data which would establish the role of the threatened marsh as a nursery for important marine and estuarine species. It is recognized that these data will serve in planning and evaluating future water projects of this nature.

Data reported here cover the period from March, 1966, through May, 1968. The study was limited to commercially important species with special emphasis given to the shrimps.

The Bureau of Commercial Fisheries had maintained collecting stations in Trinity Bay and made several preliminary investigations in the area of the proposed Wallisville Reservoir, but the actual extent to which commercially important species were utilizing these threatened wetlands was unknown. This paper attempts to demonstrate the extent to which the marsh has been utilized by the white shrimp (Penaeus setiferus Linnaeus), the brown shrimp (Penaeus aztecus Ives), the blue crab (Callinectes sapidus Rathbun), and the Gulf menhaden (Brevoortia patronus Goode). Some of the information presented here may be pertinent to an understanding of the same species in other low-salinity environments.

A Brief on the White and Brown Shrimp

The first penaeid in the United States to be marketed commercially was the white shrimp (Penaeus setiferus) according to Williams (1965). As a consequence, the earliest studies on penaeid life histories were concerned with this species (Viosca, 1920; Pearson, 1939).

With the decline in white shrimp landings during the 1930's and the increased landings of brown shrimp after World War II, published information on brown shrimp has grown.

The early life histories of brown and white shrimp in the northwestern Gulf of Mexico are similar (Baxter and Renfro, 1966).

In general, spawning occurs offshore and metamorphosis through a series of larval stages takes place as the developing shrimp are swept shoreward by currents. The shrimp enter the estuaries as post-larvae, essentially miniature adults. Growth in the estuary is rapid, and upon attainment of a sub-adult size the penaeids return to the Gulf to spawn and to complete the life cycle.

Baxter and Renfro (1966) found brown shrimp postlarvae entering the Galveston Bay System from February to mid-December with a peak occurring between mid-March and mid-April. A second peak of brown postlarvae was noted by them in either August or September. The same authors first caught white shrimp postlarvae at the Galveston entrance in May and noted that this species was most abundant during the summer.

The mechanisms used by postlarval shrimp to reach estuarine nursery grounds are not clear. Currents probably play a part in bringing the developing larvae ashore and tidal currents may aid in bringing postlarvae through tidal passes and into coastal bays (St. Amant et al., 1966). Hughes (1969) has presented experimental data concerning tidal currents and rheotaxis in the pink shrimp (*Penaeus duorarum* Burkenroad). His results indicate that in the vicinity of tidal passes, young pink shrimp may respond to the decreasing salinities of an ebbing tide by dropping to the bottom, where the effects of tidal currents are reduced and where the young shrimp are less likely to be carried offshore. Increasing salinity of a flooding tide appears to result in the young shrimp rising from the bottom into the water column, where the tidal currents may carry them into the estuaries. Williams (1955) indicated that currents aided post-larval distribution within Carolina estuaries, but that in the absence of currents postlarvae were capable of penetrating deep into nurseries under their own locomotion. Viosca (1953) said that currents affect white shrimp distribution and that white shrimp orient themselves to and move with currents.

Since the currents are complex and poorly known within such large estuarine systems as Galveston Bay, their effects on shrimp distribution remains largely unknown.

The many factors in the role of the estuary in the life cycle of penaeid shrimps are unknown (Kutkuhn, 1966). Williams (1953) indicates that estuarine areas favored by shrimp possess soft bottoms with plant detritus or submerged vegetation for food and cover. Mock (1966) found penaeid postlarvae to be abundant along natural shorelines having emergent vegetation and a high organic substrate.

The importance of freshwater runoff in maintaining optimum salinity within nursery areas has been emphasized by some authors (Hildebrand and Gunter, 1953; Gunter and Hildebrand, 1954, Pearse and Gunter, 1957). Zein-Eldin (1963) presents laboratory data which suggest that salinity tolerances may not play a direct role in the growth and survival of postlarval and juvenile shrimp in the nurseries. She tentatively suggests that food requirements may be more important than purely physical factors. Diener (1964) stresses that freshwater runoff contributes to the fertility of estuaries by supplying terrigenous nutrients.

Whatever the role, it is clear that brown and white shrimp are dependent on estuaries (Gunter, 1961).

A Brief on the Blue Crab

Major contributions to the life history of the blue crab have come from studies done on the mid-Atlantic coast, in particular Chesapeake Bay. The major works have been those of Hay (1905), Churchill (1919), and Van Engle (1958).

Knowledge of the blue crab in the Gulf of Mexico is found in a less extensive literature. Contributions, however, have been made by Gunter (1950), Daugherty (1952) and Darnell (1959). Scattered references to blue crab life history are found in many publications dealing with the Gulf Coast, some of which are listed and commented upon by Darnell (1959).

In general, the life history of the blue crab as established for Chesapeake Bay populations appears to hold also for blue crabs in the northwestern Gulf of Mexico (Darnell, 1959).

The life history of the blue crab is complicated by its migratory habits (Williams, 1965). Mating occurs in the upper, less saline waters of estuaries. Females mate immediately following their terminal molt. This molting is marked by the change from a triangular to a broad oval shape of the abdomen. Mated females migrate to waters of higher salinity where spawning occurs, while the males remain in low salinity waters for the remainder of their lives (Van Engle, 1958).

Eggs hatch and larvae develop best in salinities of 21 o/oo-28 o/oo (Sandox and Rogers, 1944). After passing through several larval stages, the young crabs migrate up the estuary to low salinity areas, where feeding and growth take place (Van Engle, 1958).

The major difference between the life histories of blue crabs in Chesapeake Bay and the northwest Gulf of Mexico is probably in the spawning seasons. The relatively higher temperatures of the Gulf Coast appear to lengthen spawning periods and probably produce a higher annual growth rate.

Van Engle (1958) reports the mating period for blue crabs in Chesapeake Bay to extend from early May into October, with a peak in late August and early September. Darnell (1959) states that in Louisiana the peaks of mating occur in May and September.

Van Engle (1958) also reports that in Chesapeake Bay spawning takes place from 2 to 9 months after mating. Most female crabs mating in August and September delay egg laying till the following May or June, the peak spawning months. Young crabs probably do not reach the upper nursery grounds till the following spring, passing the colder months in lower portions of the bay where growth is probably negligible.

Daugherty (1952) reports that spawning occurs each month in Texas waters during mild years. Spawning peaks, however, occur in June and early July. Young crabs, probably from the early summer spawning periods, arrive in the nursery areas in winter or early spring (Chin, 1961).

The presence of blue crabs in very low salinity waters has been commented upon by many authors (Hay, 1905; Gunter, 1938; Odum, 1953). Van Engle (1958) reviews the correlation between salinity and size and indicates that larger sizes are associated with more time in low salinities, whereas high salinities throughout life produce dwarf specimens (Fischler, 1959).

Blue crabs have shown preference for the soft bottoms of shallow marsh creeks during the early stages of their postlarval development (Judy and Dudley, 1966). Darnell (1959) implies that young blue crabs seek out the shallow margins of estuaries for growth. Perhaps most important is that the blue crab is a true estuarine crustacean.

A Brief on the Menhaden

The menhaden fishery, the largest commercial fishery in North America, is supported principally by the Gulf menhaden (*Brevoortia patronus* Goode) and the Atlantic menhaden (*Brevoortia tyrannus* Latrobe). Although the Gulf menhaden fishery is the younger of the two, it is now forming a substantial portion of the total menhaden catch. In 1966 the menhaden catch in the Gulf of Mexico amounted to 788 million pounds, approximately 62% of the total menhaden fishery. However, recent catches in the Gulf and Atlantic have been relatively small compared to previous years. The 1966 Gulf menhaden catch was 22% below that of 1965, the lowest since 1960 (Henry, 1968). This downward trend has been attributed to increased fishing effort and indicates a fully or perhaps overly exploited resource (Nicholson, 1968).

It is apparent that the maintenance of this important fishery is dependent on an understanding of the ecology, life history, and population dynamics of the Gulf menhaden. Research is being conducted by the Bureau of Commercial Fisheries Gulf menhaden research center, located in Beaufort, North Carolina (Kutkuhn, 1968). However, studies of estuaries have been qualitatively, quantitatively, and geographically restricted. Since estuaries appear to be essential to the life history of the Gulf menhaden (Reintjes and Pacheco, 1966), it is imperative that studies be made on the young stages of this species as they occupy their nursery grounds. The rapid modification of estuaries, by either total destruction of low salinity areas or modification of fresh-water outflow, increases the need for local studies of estuarine ecology. Information on the extent to which the Gulf estuaries can be modified before causing population decreases is vitally important to the fishery.

Goode (1878) described Brevoortia patronus from specimens collected near the mouth of the Rio Grande and from Brazos Santiago, Texas. Menhaden were included in collections from Galveston and Pensacola by Jordan and Gilbert, 1883, and from Galveston by Evermann and Kendall (1894).

Catches of Gulf menhaden are recorded as early as 1880 from the west coast of Florida, with annual production in this area fluctuating very drastically until 1938. Additional catches in Alabama in 1902 and 1931, and in Texas during 1918 and 1923 are the only other records of menhaden catches from the Gulf until 1939. It may be stated that the Gulf menhaden fishery was established in 1939 with the establishment of processing plants in Mississippi (Gunter and Christmas, 1960).

Man-made Modifications of Estuaries

Since the role of estuarine areas to organisms apparently dependent upon them is not known, it is difficult to assess the effects of man-made environmental modifications on these organisms. However, Kutkuhn (1966) has reviewed a wide range of man-induced estuarine modifications along the Gulf Coast and the likely consequences of these to young penaeid shrimp.

There appear to be no published studies on the effects of inland reservoir construction on the character of coastal nurseries. Gunter and Shell (1958) and Gunter and Hall (1963) reported on estuarine areas modified by flood control structures; these areas, however, did not include the saltwater barrier and permanent storage plans as seen in the proposed Wallisville Dam.

THE STUDY AREA

Description of the Area

The general location of the study area can be seen in Figure 1, a map of the Galveston Bay System. The study area is located in a moist sub-humid zone with an average precipitation of 50 inches distributed throughout the year (Leifeste and Hughes, 1967). It consisted of approximately 22,000 acres of low salinity marsh in Chambers County, Texas. The marsh represents the delta of several old channels of the Trinity River; these channels plus several lakes were conspicuous features of the area (Figure 2).

Other than the main channel of the Trinity River, the middle and upper portions of the study area connected with Trinity Bay through the meandering Cross Bayou and the shorter Mud Bayou. The deltaic marsh portion of the study area located west of the main channel of the Trinity River connected with the main Trinity River through the lower extension of Old River (designated as Old River Cut in Figure 2).

The substrate was a soft mud-silt type, as its alluvial origin would suggest. Sand bars were formed in several areas, particularly along bends in Cross Bayou. Other firm substrates within the study area were formed from the shells of the marsh clam, Rangia cuneata. This mollusk was widespread and abundant in the study area as evidenced by dead shell and by the living organism. The fact that live specimens were frequently taken in the trawl emphasizes the abundance of Rangia. The larger lakes (except Lake Charlotte) showed conspicuous beaches of bleached Rangia shell alternating with cane (Phragmites) that grows almost to the waters' edge.

During the study period cattle were grazed on the firmer portions of the marsh, and the plentiful nutria were heavily trapped in season. Fishing within the study area included bank fishing and trotlining, mainly for blue catfish, *Ictalurus furcatus*. Several commercial fishermen operated hoop nets on the main channel of the Trinity River.

Description of the Stations

The location of each station is shown in Figure 2, which also indicates the proposed Wallisville Dam and reservoir. Stations were located either above or below the proposed dam. All but one of the stations at which only hydrographic samples were taken were located on the main channel of the Trinity River. Six biological stations were located below the dam site. Five of these were located on or close to Cross Bayou and one was on Mud Bayou. Hydrographic samples were taken at each station, but not all stations were used for biological sampling.

Station A, at the mouth of Cross Bayou, was the most "bayward" station. Trawl samples were taken in the bayou on a mud substrate. The water depth averaged approximately 4.5 feet during the study period. Seine and marsh net samples for Station A were taken on Trinity Bay on the east side of the mouth of Cross Bayou. The substrate here was clay-mud and Rangia shell. The bay beach to the west of the mouth of Cross Bayou had considerable amounts of sand and was not sampled.

Station B was located on Red Bayou, a branch of Cross Bayou. The trawl sample was taken in water averaging 5 feet deep. The substrate was mud. The channel that extends from Red Bayou into Trinity Bay is deeper than that of Cross Bayou. The Red Bayou channel remains open when low water prohibits boat passage from Cross Bayou to Trinity Bay. During periods of low water, the deeper channel of Red Bayou may serve as the major avenue for organisms moving in and out of the study area.

Station C was located on Cross Bayou proper. Trawl samples were collected in water averaging approximately 5 feet in depth on a mud substrate, and marsh net samples were taken from a small cove next to an old spoil bank. The substrate of the cove consisted of mud and detritus of plant origin.

Station D was located on Cotton Lake. The water depth averaged approximately 3.5 feet during the study period. The bottom of the lake was predominately mud, but beds of Rangia were common. Several different shoreline types were evident on Cotton Lake. The extreme western shore of Cotton Lake marks the western extent of the Trinity River Flood Plain. Considerable erosion of the terraced banks was evident along this western part of the lake shore. The reddish soil washed from these banks forms a layer of very soft mud on the bottom for approximately 30 feet from shore. North and south shores for the most part had emergent vegetation, while the eastern shore near the bayou-lake junction had a beach of *Rangia* shell. It was at this latter site, over a *Rangia* shell substrate, that marsh net samples were taken. Trawl samples for Station D were taken in the northern portion of the lake over a mud substrate.

Station E was located on Cross Bayou. The water depth here averaged 4.5 feet, and the bottom was mud.

Station I was located on a narrow tributary of Mud Bayou. Water depth was approximately 3.5 feet; the bottom was mud. Nutria were particularly abundant in the vicinity of this station.

Station F was located in Old River Lake, above the dam site. The water depth was approximately 5 feet and the bottom was mud with scattered patches of *Rangia*. Marsh net samples were taken on the north shore of Old River Lake, on a point of land built up largely of *Rangia* shell. The *Rangia* shell is replaced by sand along the shore east of this point. Marsh net samples were taken from the sandy area. Wave action continually reworked the shoreline here.

Station G was located on Round Lake. Trawl hauls had to be made from downstream of the lake-bayou junction, because the lake proper was too shallow. The water depth in the bayou averaged approximately 3.5 feet. Marsh net samples were taken on a mud substrate along the shore of the bayou near its junction with the lake. *Phragmites* grew to the waters' edge and plant detritus was often abundant in the shallows. Nutria abounded at this station.

Station L was located on the Old River upstream of the Interstate Highway 10 bridge. The water depth averaged approximately 3.5

feet during the study, and the bottom was composed of soft mud. Access to this station was often made with difficulty over the extremely shallow areas separating Old River Lake from the Old River. This station was discontinued as a biological station on December 16, 1967, because of difficulties in sampling, but hydrographic samples were taken whenever the station was accessible.

Station K was located at the mouth of the Lost River, immediately below the Interstate Highway 10 bridge. The water depth averaged 4.5 feet during the study, and the bottom was mud.

Station M on the Lost River averaged 4.5 feet in depth and had a mud substrate. This station was discontinued as a biological station on February 29, 1967, when the presence of trotlines crossing the river made trawling impossible. Hydrographic data were gathered here throughout the study.

Station O was also located on the Lost River. Water depth at Station O averaged approximately 4.5 feet during the study period. The bottom was mud.

Station U on Lost River was added on October 8, 1966, and sampled continuously until the end of the study. The water depth averaged 4.5 feet, and the substrate was mud.

The Lost River remained fairly unifrom in depth (approximately 4.5 feet) from Station K to Station U. This uniformity in depth was in sharp contrast to the Old River which became very shallow immediately above Station L.

Station S at the junction of Lake Charlotte and Lake Charlotte

Bayou was essentially a freshwater environment. The shores of the lake and the banks of the bayou were heavily wooded. The average depth of the bayou was approximately 4 feet, and the bottom was covered with abundant plant debris. Beaver were observed at this station and seasonally large flocks of white pelicans were seen on the lake. The waters abounded in young catfish (Ictulurus sp.) and various centrarchids; the river shrimp (Macrobrachium ohione) was also abundant.

Stations R, T, P, J and J^1 were located on the main channel of the Trinity River. Stations R, P, J and J^1 were used for hydrographic samples only, whereas at Station T, marsh net samples were also taken along the river's east bank. Station H, another hydrographic station, was located on the Old River Cut.

Station R was located just upstream from where Lake Charlotte Bayou enters the Trinity River.

Station T was located on the Trinity River immediately downstream of the Interstate Highway 10 bridge.

Station P was located on the Trinity River just off the Wallisville public boat launch. This station was discontinued on March 4, 1967, when it was decided that Station T and J were adequately monitoring hydrographic conditions in that area of the river.

Station J was located at the junction of the Trinity River and the Old River Cut. Station J^1 was added on February 25, 1967, to provide a comparison with Station J. Station H was located west of Mud Bayou on the Old River Cut.

METHODS

During the study period from March, 1966, through May, 1968, collections were made semi-monthly from a 16-foot aluminum "john" boat powered by an 18 h.p. outboard motor. At times, a second "john" boat was utilized for collecting hydrographic samples while the other boat pulled the trawl. The field crew consisted of three or four men.

At each biological station a trawl haul of 3 minutes duration was made. The trawl was a shrimp trawl or "try net" measuring 10 feet between the boards with a 1-3/8-inch stretched mesh in the body and a 1-inch stretched mesh in the cod-end. The cod-end had a cover of 1/16-inch mesh to retain smaller specimens. The trawl plus cover is here considered as one piece of collecting gear and was used for all designated "trawl" sampling.

A marsh net, a 1/32-inch mesh net on an aluminum sled (Pullen, Mock and Ringo, 1968) was pulled along the shallow edge zone for a distance of 50 feet at six stations (A, C, D, F, G, T).

At Station A on Trinity Bay, seine hauls were made with a 20 x 4 foot bag seine of 1/16-inch mesh. Drags were made with this seine from a point 50 feet offshore to the beach.

Additional (miscellaneous) seine collections of a qualitative nature were made at various stations throughout the study period. Seines of different dimensions and mesh sizes were often used and not all specimens were kept. Crustacean data from these miscellaneous collections were not utilized in this report.

Marsh net, seine and cover samples were preserved in 10% formalin in the field. Samples from the trawl proper were placed on ice for immediate study in the laboratory.

Departures from the normal collecting methods were kept to a minimum. On several occasions a trawl with a 6-foot mouth and 1/4-inch stretched mesh in the cod-end was employed at Stations B and D. Such departures in methods are noted in the text.

Water samples for salinity, nitrogen and phosphorus determinations were collected at each station. Such samples were collected by submerging three separate vials by hand beneath the surface of the water. This was considered to give a representative sample of the water column at the biological stations, due to the shallow depth and constant mixing of the water by wind and currents.

Temperatures were taken with a mercury thermometer held approximately 1 foot below the surface of the water.

A galvanic cell oxygen analyzer was utilized during part of the study period, but frequent malfunctions of the instrument rendered the data highly doubtful. The thermistor portion of the instrument was used frequently to determine water temperatures at various depths. Wind direction, wind velocity and general weather and physiographic conditions were recorded at each station.

All chemical analyses were made by chemists at the Bureau of Commercial Fisheries, Galveston, Texas. Salinity was determined by the modified Knudsen titration and the total phosphorus was determined by the molybdate-blue method (Marvin et al., 1960). Total Kjeldahl nitrogen was determined as outlined by the American Public Health Association et al. (1965).

Tables 1, 2, 3 and 4 present the values for salinity, water temperature, total dissolved nitrogen and total phosphorus determinations, respectively. Salinity is reported in parts per thousand (o/oo) and temperature in degrees centigrade (^{0}C). Values for Kjeldahl nitrogen and total phosphorus are reported in microgram atoms per liter (μg at/l). Entries of 0.0 in these tables indicate no data collected.

All crabs from the trawl samples were sexed, weighed and measured in the laboratory. The width of each crab, the distance between lateral spine tips, was determined to the nearest millimeter on a standard fish measuring board. Weight determinations were made on a Mettler balance to the nearest 0.1 gram. Crabs from seine, marsh and cover samples were preserved in the field and measured and sexed in the laboratory. Such crabs were not weighed.

Shrimp were measured but not weighed, as rapid decomposition of the viscera gives inaccurate results. Total length (distance from the rostral tip to the tip of the telson) was determined to the nearest millimeter on a small fish measuring board. All large samples of shrimp were sub-sampled; in such cases, 350 randomly selected shrimp were measured and the rest were only counted.

Reference is made below to "postlarval", "juvenile" and "sub-adult" penaeid shrimp. These terms refer, with slight modification, to the definitions of Renfro (1966). Postlarvae are defined as those shrimp measuring through 25 mm in total length; juveniles are those individuals from 26 mm through 90 mm in total length; and subadults from 91 through 140 mm in total length. As shrimp were grouped at 5 mm intervals in this study, Renfro's original designations were advanced 1 millimeter.

Data on all blue crabs and penaeid shrimp were placed on IBM punch cards. Summaries of length frequencies, determination of mean, standard deviation and standard error of the mean were made on the IBM 360 computer of the Data Processing Center of Texas A&M University. Portions of the data on the width/weight relations were also programmed and processed at the Center.

Two types of figures are used to present data on penaeid shrimp: the first type is a simple length frequency histogram (width frequency histogram used for blue crab data); the second type of figure employs the drafting technique used by Hubbs and Hubbs (1953) to graphically analyze a series of samples. Williams (1955) and Loesch (1962, 1965) modified this technique and applied it to samples of penaeid shrimp. Each sample in a series is represented by a diagram which shows the range, the mean, the standard deviation and the standard error of the mean ($\sigma\bar{y} = \frac{\sigma}{\sqrt{n}}$). An example of these diagrams can be seen in Figure 13.

Loesch (1962) used the mean plus and minus one standard error of the mean in his diagrams. In comparing the differences in mean length between areas, he stated that if there was overlap of the solid rectangle of one with that of any other solid rectangle among those compared, then those over-lapping could not be considered to have significantly different means.

In this study, two standard errors of the mean have been plotted in each diagram of Figures 18-22. The complete separation of the solid rectangle of one diagram from that of any of the others from the same trip may indicate differences in distribution by size.

WATER QUALITY

Salinity Values

The use of salinity values in this study may not represent accurately the total dissolved solids in the waters of the study area. The Knudsen titration involves the precipitation of silver halides, and salinity values are arrived at by use of a nomograph (Marvin, 1957). Such a conversion from the weight of a precipitated halide to total dissolved solids is possible for seawater because of the constancy of composition of the major ions. In an area such as the present study area where the chemical composition of the water is heavily influenced by river water, ionic ratios may vary from those of seawater. The chloride ion concentration in river water of the Trinity Basin is usually no greater than 0.05 o/oo in the lower part of the Trinity River Basin, thus higher values for the chloride ion usually indicate marine water intrusion. Higher values for the chloride ion in some other areas of the Trinity River Basin may be due to oil field brine (Leifeste and Hughes, 1967). Salinity is thus regarded in this study as a relative measure of the chloride ion and not of the total dissolved solids.

River Flow and Salinity

For the most part, the amount of discharge of Trinity River water regulates the hydrographic conditions of the Galveston Bay System. A salinity gradient extends from lower Galveston Bay near the tidal passes to the upper portion of Trinity Bay. This gradient results from the mixing of river water (largely from the Trinity

River) in Trinity Bay and the influx of Gulf water in the lower Galveston Bay. The salinity value at a particular site is primarily a function of river discharge which may vary greatly both seasonally and annually (Langford and Rehkemper, 1969).

The close proximity of the study area to the mouth of the Trinity River subjects it to direct effects of freshwater discharge. Table 1 shows salinity values from each station for all trips and indicates that at river discharge peaks (Figure 3) the entire study area is effectively flushed by river water. Salinities rise in times of low discharge due to the increased effect of tidal waters in the study area.

When river discharge was considerably reduced (November, December 1966; January, February 1967), salinity in the main Trinity Channel (Station T) approached 1.0 o/oo. Perhaps even more marked was the reduced river flow during August 1967, when Station T showed a salinity of 2.4 o/oo. The highest salinity recorded in the study area was 15.6 o/oo at Station A on January 29, 1967.

At times other than peak discharge, the study area is essentially two different systems: the Trinity River proper and Lake Charlotte form an essentially freshwater environment, and the portion of the study area west of the Trinity Channel is typically estuarine.

The contribution of freshwater from the Lost River and the Old River above Station L is not great. During the periods when the main Trinity River is flooding its banks, water passes from the

Trinity into the Lost River at a point above Station U. The downstream current produced during high waters flushes the Lost River and aids in reducing the salinity throughout the study area.

The Old River intermittently discharged freshwater, apparently independent of Trinity River flow. Salinities at Station L were considerably lower than those of surrounding stations on November 19 in 1966 and on January 7, February 11, April 22, June 4 and September 23 in 1967. On certain of these dates, total phosphorus levels were higher than those of surrounding stations. It is possible that discharges from rice canals on the upper reaches of the Old River would have some effect on the hydrography at Station L.

A current enters the Old River Cut from the Trinity River and flows westward. The majority of this water turns into Mud Bayou with rather turbulent mixing and eddy formation at the junction of Mud Bayou and the Old River Cut. This water from the Trinity River flows down Mud Bayou to the Bay.

Some water from the Trinity River continues west in the Old River Cut rather than flowing into Mud Bayou. Hydrographic conditions at Station H reflect the magnitude of this flow. A strong Trinity flow in the Old River Cut depresses salinity values at Station H.

When the current flowing through the Old River Cut is slow, water from the Bay is able to penetrate into Mud Bayou; high salinities at Station I reflect this penetration.

During times of reduced flow, salinity values in the Lost

River and the Old River Cut increased, but usually were not as high as those in Cross Bayou. During times of reduced flow, salinity values also tended to vary more from trip to trip at stations in the Old River Cut than at stations in the Lost River.

Water Temperatures

Water temperatures are presented in Table 2. In general, water temperatures were approximately the same at each station on any one date; the variations that did occur were due to the time of day that the stations were sampled. The Trinity River stations and Lake Charlotte (Station S) were sampled in the early morning; stations in Cross Bayou and Stations I, G and F were sampled in the late morning; Station L and the Lost River stations were sampled in the afternoon.

The lowest water temperature recorded during the study was 2.5^{o}C at Station S on February 24, 1968. Water temperatures of 35^{o}C were recorded on several occasions during the summer months.

In general, the range of water temperatures followed the same pattern through both years of the study. Water temperatures dropped below 20^{o}C in November and climbed above 20^{o}C during April. The lowest water temperatures of both years were recorded in January and February. The highest water temperatures recorded occurred in July and August in 1966 and in June and July in 1967.

Total Dissolved Organic Nitrogen

The total Kjeldahl nitrogen technique measures only dissolved organic nitrogen and ammonia and not nitrites or nitrates (American

Public Health Association *et al.*, 1965). Although this does not give a total picture of the nitrogen in the study area, it may be used to indicate industrial and domestic pollution.

The values for Kjeldahl nitrogen (Table 3) show considerable variation in levels between stations within a trip and from trip to trip. In general, water in the main channel of the Trinity River had lower levels of Kjeldahl nitrogen than did other parts of the study area. Stations in Cross Bayou, with the exception of Station A, had particularly high values, expecially during the period June 16 through November 18, 1967. Station U on the Lost River also showed high values for this period. Possibly decomposition of organic materials within the marsh produced such levels.

Total Phosphorus

Total phosphorus levels (Table 4) were highest in the main channel of the Trinity River, with peak levels occurring during times of reduced river discharge. Stations to the west of the main channel, along the Old River Cut, had relatively high phosphorus levels and suggest the extent to which Trinity River water influences the hydrology at those stations. This is illustrated by a comparison of phosphorus values for Trinity River stations from January through March of 1967 with those stations in Old River Cut. Generally lower phosphorus values were recorded for the stations in the western portion of the study area where bay water had a greater effect on the hydrology than did river water.

Salinity values were lower and total phosphorus levels were higher at Station L than at surrounding stations on several occasions (April 22, June 4 and September 23, 1967). A correlation between increased flow of water from the upper Old River and high phosphorus levels is indicated. As previously suggested, drainage from rice fields could be responsible for the low salinities and high phosphorus levels.

The Trinity River is known to carry large loads of phosphates from industrial and domestic pollution. The effects of the municipal and industrial wastes from the Ft. Worth-Dallas area are noticeable throughout the reach of the river. The waste load carried by the upper Trinity River can have significant effects on the water impounded in downstream reservoirs (Leifeste and Hughes, 1967). These latter authors quote Connell (1964) who expressed concern over the build-up of phosphates in Texas reservoirs and the potential phosphate loading of projected reservoirs. He lists the principal sources of these phosphates as municipal and industrial waste-water, surface runoff leaching mineral phosphate from soil, decay of vegetation and animal wastes and the use of phosphate fertilizers and insecticides containing phosphorus.

THE BLUE CRAB

Ecology

The blue crab, *Callinectes sapidus* Rathbun, was present throughout the study area during all months. Its relative abundance varied greatly from station to station and from trip to trip, usually with no discernible pattern.

During the study 7,511 blue crabs were collected and measured. The majority of these were immature individuals of both sexes, although males dominated most size categories. Mature males (those greater than 120 mm in carapace width) numbered 515; mature females numbered only 26.

Young crabs of 20 mm width or less were present in the study area during all months of the year. Peaks of abundance, probably indicating recruitment waves, were noted in February and December of 1967. The February 1967 peak was probably composed of young crabs spawned in late spring or early summer of 1966. The December 1967 peak probably represented young from the 1967 spring-summer period (Figures 5 and 6).

The long spawning season of the blue crab in Texas and the slow growth which occurs in winter probably accounts for the presence of small crabs during all months of the year (Gunter, 1950).

Specimens 20 mm in width and smaller were less abundant during the warmest months of the year. This was more evident during the spring, summer and early fall of 1967 than it was for the same period in 1966.

The level of abundance of small individuals was probably a function of the collecting gear used. Darnell (1959) reported that the hordes of small blue crabs observed in the shallows during the summer were unavailable to the sampling trawl. Chin (1961) found crabs of 20 mm width and less in trawl hauls from Clear Lake, Texas, during all months of the year, although scarce from May through October. Rounsefell (1964) reported the smaller crabs to be extremely scarce in trawl samples taken from June through September in Louisiana. More (1966), using seine and trawl data, showed that the maximum availability of small crabs occurred in the winter months, with relatively high numbers also reported for July, August and early fall.

In the present study, seine data were not available to supplement the trawl samples; however, six marsh net stations were sampled consistently throughout the study period. These marsh net samples were able to provide information on young blue crabs occupying edge areas not sampled by the trawl. These marsh net samples are probably more comparable from station to station and from trip to trip than seine samples would have been. As a piece of collecting gear providing comparable samples, the marsh net differs from the seine in that the marsh net has a fixed sampling aperture; it is more easily pulled at a constant speed and for a standard distance, and it can more efficiently sample a soft substrate (Pullen, Mock and Ringo, 1968). A seine would probably capture more individual specimens than would the marsh net, however.

Table 5 shows the number of individuals caught per 50-foot drag of the marsh net at each station for all trips. Marsh net catches were highest during the summer and fall of 1966 and lowest during the colder months of 1967. The February and December 1967 recruitment peaks for young blue crabs noted in trawl samples were not evident in the marsh samples for these same periods. Darnell (1959) found small crabs to be more available to the trawl during cold months, when they apparently left the shallows for refuge in deeper water.

The marsh net data indicate that small crabs were more abundant during the summer-fall period of 1966 than they were during the same period in 1967. Water temperatures for these months were much the same in both years, but the salinities were considerably lower in 1966 (Table 6).

Mating, Spawning and Adult Abundance

Darnell (1959) collected 354 adult female blue crabs out of a total adult catch of 1,016 specimens in Lake Pontchartrain, Louisiana. He also reported frequent sightings of mating crabs or "doublers". The present study area is not unlike that of Darnell's, and the sampling period in the two studies (approximately 2 years) was nearly the same. In the present study, however, the scarcity of adult females and the lack of visual sightings of mating crabs indicates that mating may take place, for the most part, outside of the study area.

One trawl collection made in May 1968 yielded only two crabs, one a male of 170 mm and the other an immature female of 131 mm. These may have been "doublers" or mating crabs. This one incident of probable mating and the occurrence of the 26 mature females have been used in this report as indicators of the mating periods for blue crabs in the upper Galveston Bay System.

The occurrence of mature females during the study period appears to follow a pattern which corresponds to the reports by Darnell (1959) and Benedict (1940) for Louisiana waters. Figures 8-10 show the frequency of male and female blue crabs in the various size groups by months for the entire study period. In 1966, the first mature females were represented by five specimens taken in June; two others were taken in July, three in September and one in November of the same year. In 1967, the first mature females (three) were collected in April; two were collected in May, four in June, one in July and three in October.

Adult female blue crabs were not collected through May of 1968, the end of the period covered in this report. Continued sampling in the study area after this date, however, showed adult blue crabs to be present during June.

Table 7 shows the collection site, water temperature and salinity where the 26 mature females were captured. These mature females were collected at various places throughout the area, at salinities ranging from 0.1 o/oo to 12.4 o/oo and at temperatures of 20^{0}C or more.

Mature females collected in June 1966 were probably part of a population which would have spawned during the late summer and early fall and whose offspring probably would have contributed to the February 1967 peak in abundance of small crabs. Females reaching maturity and mating during the late summer and fall of 1966 might migrate to higher salinities and spawn during the winter months (Daugherty, 1952). However, as was the case in Chesapeake Bay (Van Engle, 1958), they might not spawn until the following spring.

The early (April) occurrence of mature females in 1967 as compared to the later occurrence (June) in 1966 may be due to a combination of factors, including salinity and temperature. Salinities were higher during early spring 1967 than for the same period in 1966 due to reduced river flow. Although temperatures for the spring of both years were nearly the same, 1967 was slightly warmer. It is possible that temperature and salinity play a part in the maturation of female blue crabs.

The high abundance of small crabs during November and December 1967 (Figure 4) as compared to November and December 1966, may indicate a longer and more intense spawning period for Galveston Bay crabs during spring-summer 1967 than for the 1966 spawning period. During the spring of 1968, river discharge was again high, but not as high as that recorded in May 1966 (Figure 3). Temperatures in early spring 1968 were lower than for the same period in 1966 and 1967 (Table 6). The later appearance of mature females (June 1968) in samples from the study area may have been due to lower temperatures rather than to high river flow.

Figure 5 shows the sex ratios with the specimens grouped at 10 mm intervals. The number of crabs above 120 mm in width of either sex are considerably reduced from the number of individuals of smaller widths. Mortality, migration and gear selectivity may account for the smaller number of larger sizes. Chapman (1967) suggests that larger crabs are found in greater numbers in lower parts of Galveston Bay, while greater numbers of juveniles seek out the upper reaches of Trinity Bay.

The sex frequency data in Figures 8-10 reflect on the size at which female crabs undergo the terminal or maturation molt. Only two immature females were found to be over 140 mm in width. One of these collected in May 1967 was 165 mm and the other was collected in March of the same year and measured 141 mm. These two crabs seem large to still be immature, but Gunter (1950) also reported large immature females (up to 160 mm width) in his samples.

The smallest mature female collected during the study was 138 mm in width and the largest was 188 mm; the average width of the mature females was 158 mm. Gunter (1950) reported a range from 110-185 mm and an average 155 mm in width for mature females bearing eggs.

It can be seen from the above data, and it is further emphasized by Newcombe (1948), that although an individual female crab becomes sexually mature in its last instar, that stage is not reached at the same width in all crabs.

Adult male blue crabs were abundant in the spring and summer months of the study period (Figure 5), and least abundant during the colder months of January, February and March of 1967 and 1968. This low in adult male abundance occurred from 1 to 2 months after the last mature female of that year was taken. Decreasing temperature may have prompted emigration from the area or hibernation within the study area. It was noted that deep holes in parts of the Trinity Delta could offer haven for crabs and that such protective areas may be especially effective during the coldest months of the year.

The occurrence of large males in waters of low salinity has been noted by many authors. Williams (1965) claims that males may attain a carapace width of 230 mm under such conditions. Tagatz (1965) reported a male 246 mm in width from the low salinity waters of Lake George on the St. Johns River, Florida. The largest specimen taken in the present study was a male 196 mm in width. Five other males measuring from 191 mm to 195 mm in width were collected (Table 8). Van Engle (1958) reviews the concept that the amount of increase in size of a soft crab is due to water absorption and that the amount of water absorbed is a function of the salt content of the surrounding water. Hence, crabs spending their entire molting lives in low salinities should be larger in size than those who have molted in high salinity environments. It would be interesting to have the weight of very large males from very low salinities. Upper Trinity Bay is reported by local fishermen to have large crabs which yield small amounts of meat for their size. Van Engle (1958) reporting the unpublished work of Wojcik states that male blue crabs may move farther upstream after mating. It is possible that many large males encountered in low salinities are old individuals which exhibit a low weight-to-width ratio, possibly due to a low assimilation efficiency.

Distribution

The complex migratory behavior of the blue crab and its ability to cover great distances in short periods of time makes study of its distribution within a small area difficult. Although release and recovery techniques have been used to study distribution (Pullen, 1962), they were not used here. Many of Darnell's (1959) samples contained few specimens often of a wide size range, making it difficult to determine a distribution pattern. This same difficulty was encountered in the present study.

The following three divisions of the study area were recognized for the purpose of studying the distribution: Area I - the area below the proposed dam site; Area II - the area west of the main channel of the Trinity River (to be innundated by the proposed reservoir); Area III - Lake Charlotte.

Tables 9-11 show numbers of blue crabs reported for each station by trip. The samples are from the standard trawl hauls. Stations B and U are omitted due to relatively long periods when trawl samples were not taken at these stations.

Table 9 shows that more crabs were collected from Area I. Even considering the higher incidence of stations marked "No Effort" in Area II, the greater abundance of crabs in Area I appears real.

Lake Charlotte, represented by only one station, yielded a smaller total number of crabs for the study period than did any other station.

Table 10 shows the distribution of crabs 20 mm or less (carapace width) throughout the entire study area. If Areas I and II are compared by month, the total number of small crabs from each area is much the same except at apparent peak recruitment periods (i.e., April 1966, February 1967, November 1967 through January 1968, and March 1968 -- Figure 4). As Area I is closest to Trinity Bay and includes the immigration routes into the nursery area, small crabs during recruitment peaks might be concentrated in the lower areas and gradually disperse as they move deeper into the study area.

Based on the data in Table 10, it is assumed that Area I and Area II provide suitable habitat for young crabs. Though small individuals were scarce from Lake Charlotte, their presence there serves to support the notion that small crabs are widely distributed throughout the entire study area.

Data for crabs 111 mm or greater in carapace width are shown in Table 11. The monthly total numbers of crabs from Areas I and II are more nearly equal during the summer and fall of 1966 than they are for the spring-fall period of 1967. During 1967, greater numbers of blue crabs 111 mm in width or larger, are indicated for Area I than for Area II. Only 13 blue crabs of 111 mm width or greater were collected from Lake Charlotte (Station S) during the study period. Two of these were mature females (Table 7).

Individual stations in Areas I and II showed wide variation in crab catch per haul. Station C (a bayou) and Station D (a lake) in Area I consistently yielded large numbers of crabs. Currents were usually greater at Station C than at Station D, but both had soft mud bottoms. Station C resembled Station E in its physical and chemical characteristics except that Station C was closer to Trinity Bay and produced more crabs.

Stations F and G in Area II yielded the highest numbers of crabs as compared to other Area II stations, although the two situations were different. Station G was on the shallow bayou of Round Lake and Station F was an open-water station in Old River Lake.

Station L in Area II during the first year of the study was relatively productive for blue crabs. Refuse from fishermen's dwellings along the shore was a probable source of food for blue crabs and this was the only locale in the study area where crab fishing was observed. Station L was discontinued as a biological station before this study was completed, due to difficulty in obtaining a trawl sample on the extremely soft substrate.

Growth of Blue Crabs

It was not possible to determine a growth rate for blue crabs from the data recorded during this study. Burkenroad (1951) and Darnell (1959) review the difficulties involved in attempting to determine the growth rates of crustaceans from field data. The continuous recruitment of small individuals into the study area, the frequency of small sample sizes, and the apparent continuous movement of crabs through the area make it impossible to recognize a monthly progression of modal width from the data collected during this study.

Darnell (1959) stated that spring-hatched crabs probably reached 65 mm in width by September of the same year. More and Moffett (1965) suggested that blue crab juveniles of 33 mm width in March were 123 mm by August in Galveston Bay. The latter agrees closely with growth estimates made by Tagatz (1967) on penned crabs in Florida.

Width-Weight Relationship in Blue Crabs

A method of converting linear measurements of fish and crustaceans to weights is of considerable value in fisheries biology. A formula which gives the best fit of a straight line to a group of length-weight data for a particular species may be used to calculate a corresponding length or weight (Lagler, 1956). Few width-weight relationships for blue crabs have been published. Newcombe (1949) and Newcombe et al. (1949) presented width-weight curves for crabs from Chesapeake Bay. Pullen and Trent (unpublished manuscript) presented a width-weight curve for blue crabs in the Galveston Bay System. An equation for the width-weight relationship of blue crabs from the present study was determined separately for males and females. For both sexes, only specimens having all appendages and with a width of at least 40 mm were used; but in the case of females, only immature individuals were used. The weights and widths of crabs were converted to logarithms and the linear regression of the log of the weight on the log of the width was computed by the method of least squares (Campbell, 1967; Steel and Torrie, 1960). The width-weight relationship was then expressed as the logarithmic formula:

$$\text{Log } W = \log a + n \log L.$$

The equation for male crabs was determined to be:

$$\text{Log } W - 2.739756 \log \text{Width} - 3.66107$$

and the equation for female crabs was determined to be:

$$\text{Log } W = 2.618324 \log \text{Width} - 3.45805.$$

The calculations for these two equations are given in Tables 12 and 13, respectively.

Table 14 shows the t-test used to determine whether a significant difference exists between the slope of the regression line for males and females. This test shows a value of 14.54 which is significant at the 1% level. The significantly steeper regression line for male crabs indicates that males tend to be heavier than females for a given width (Figure 11).

Condition in Blue Crabs

In fisheries biology the condition, relative well-being, or robustness of an animal is expressed by the equation $K = \frac{W}{L^3}$ (Lagler, 1956). This formula implies that the weight of a fish increases as the cube of its length. Thus, in theory, the slope of the line expressing the regression of log weight on log length would equal three. Since condition coefficients have been determined for decapod crustaceans using the formula $K = \frac{W}{L^3} \times 10^5$ (Wheeler, 1967), t-tests were used to determine whether the above formula for condition could be used in the present study. Table 15 shows that there is a highly significant difference between the slope of regression line for male and female crabs and 3. As a result of the above t-tests, the formula $K = \frac{W}{L^b} \times 10^5$, where b equals the slope of the regression line was used to determine blue crab condition coefficients. Only males were used in determining the condition coefficients for blue crabs, since males were more abundant and probably would provide a more complete picture and because they probably spend their entire lives in the study area.

Temperature is considered to be an environmental factor that affects the condition of blue crabs. Temperature has been indicated as an important factor in the length of the intermolt period and the size increase per molt in blue crabs (Chruchill, 1919; Tagatz, 1967). Churchill (1919) also stated that blue crabs did not molt in water where the temperature was less than 15°C. Temperature has been thought to play an important part in the growth of other decapod crustaceans, in particular the brown shrimp. St. Amant _et al._ (1963) and Ringo (1965) noted an increase in growth rate and abundance of postlarval brown shrimp when water temperatures exceeded 20°C.

From the above observations on temperature and decapod crustaceans, it was decided that a comparison would be made of the condition between blue crabs collected at water temperatures in excess of 20°C and those at water temperatures below 20°C. Starting with April 1966 and continuing through March of 1968, four groups of male blue crabs were designated according to the above temperature criteria. The two groups with mean monthly temperatures averaging above 20°C were composed of crabs taken during the periods from April through October of 1966 and 1967, respectively. The two groups with mean monthly temperature averaging below 20^{o}C were composed of crabs taken in the periods from November through March of 1966-1967 and 1967-1968, respectively.

An individual coefficient of condition was determined for each specimen within each period and from these a mean condition was determined for each period (Table 16). The sample variance was determined for each period and it was found through F-tests of variance that non-homogeneity of variances existed between warm periods and cool periods, but that variances were homogeneous between one warm period and the other and between one cool period and the other. Valid comparisons between mean conditions could only be made between one cool period and the other and between one warm period and the other. Table 17 shows the results of t-tests for these comparisons. The tests indicate that there was no significant difference between mean condition during the cool periods, but that between warm periods (April through October of 1967) a significantly higher mean condition existed than did in the same period in 1966. The higher mean condition for the warm period of 1967 may have been caused by a greater supply of food or it may reflect the higher salinities.

Male blue crab condition was also compared between months. An individual coefficient of condition was determined for each male crab within each month of the study period, and from these a mean monthly coefficient of condition was determined. The variance for each month was also determined. As expected from the comparisons between temperature periods, a Bartlett's test of homogeneity of variances showed non-homogeneity between the monthly variances (Table 18). An analysis of variance was run on the monthly mean condition coefficients, even though due to non-homogeneity of variances, the power of the test is reduced (Table 19). A significant difference is indicated in the mean condition coefficients between months. The monthly mean condition coefficients, with their confidence limits at the 0.5 level, are plotted in Figure 12. In this figure, non-overlap of two compared samples indicates differences in mean condition. In general, this figure seems to indicate a tendency for a higher mean condition coefficient for the warmer months as compared to the cooler months.

THE WHITE AND BROWN SHRIMP

Ecology

Figures 13 and 14 are graphical presentations of the statistical analyses of data on Penaeus setiferus, the white shrimp, and Penaeus aztecus, the brown shrimp, respectively. The presentations are based on the technique of Hubbs and Hubbs (1953), as later modified and used in presenting data on penaeid shrimp by Williams (1955) and Loesch (1962, 1965). In the lower graph of each figure all shrimp from all stations and all gear are combined to present the nature of the shrimp population in the study area for each collecting trip. The upper graph in each figure depicts the shrimp taken by trawl only for each collecting trip. Both graphs, however, provide the same general picture of penaeid shrimp abundance and growth during the study period.

Histograms (Figures 15-17) are given to show the length frequency in percent of total catch from all gear for those trips in which 50 or more individuals of either of the two species of shrimp were taken.

White Shrimp

During the study period, 23,103 specimens of the white shrimp (Penaeus setiferus Linn.) were collected. A total of 5,236 white shrimp were taken from July through December 1966, and 17,867 from May through December 1967. The differences in numbers and in relative length of the white shrimp season for the 2 years may indicate a difference in ecological conditions.

Population characteristics of white shrimp - 1966

The first white shrimp collected in 1966 were two specimens of 44 mm and 46 mm total length taken at Station A on July 15. The total number of shrimp taken per trip increased rapidly during the subsequent trips reaching a peak catch of 1,328 individuals on September 24. The total number of white shrimp collected per trip remained relatively stable (605, 617, 675 for October 8, October 22 and November 19, respectively).

Water temperatures dropped considerably below 20^{0}C during November, and the continued temperature decrease through December corresponded with the disappearance of white shrimp from the study area. Chin (1961) for Clear Lake, Texas, found white shrimp abundance to decline after August and attributed it to decreasing temperatures. Trent (1967) found that the peaks of white shrimp emigration from lower Galveston Bay correlated closely with rapidly decreasing temperature, and in 1966 he found the first emigration peak of white shrimp to coincide with a temperature drop from 24^{0} to 19^{0}C.

The histogram for August 6, 1966 (Figure 15) shows that the majority of shrimp collected on this trip were in the 15-30 mm (total length) size range. The August 19 histogram appears bimodal and this may demonstrate the growth of the 15-30 mm group of August 6 and a recruitment of smaller individuals into the population. These two modes also appear to be represented in the histograms for September 2 and September 24, showing a progression attributed to growth.

The continuous recruitment of small shrimp into the study area and the emigration of larger ones from the study area would tend to lower the overall mean length of the samples depicted in Figure 13. The data shown in Figure 13 for 1966 through September 24, however, show an increasing mean length from trip to trip; this probably indicates a high growth rate which off-balances the effects of recruitment of small individuals and the emigration of large ones. A differential mortality rate, with the highest rate among the smaller sizes would also cause an increase in the mean length of a sample, but this is not indicated for the above time period. If such differential mortality did occur, however, continuous recruitment would probably mask its effects.

Emigration of large juveniles and subadults from the study area is indicated for the trip of October 8 by a reduction in total catch of white shrimp and a decrease in the sample mean length (Figure 13). The downward trend of the mean sample length throughout the remainder of the year is probably attributable to decreasing growth rate and increased emigration of large juvenile and subadult white shrimp.

Table 20 shows that for November and December there was a progressive movement of shrimp from the upper stations as temperature decreased. The majority of the shrimp taken during November and December came from Station A and these shrimp may represent individuals migrating from the study area.

Population characteristics of white shrimp - 1967

The single white shrimp reported for January 7, 1967, and the two specimens taken on February 25, 1967, were probably remnants of the previous fall population (Figure 13). The one white shrimp 127 mm total length from the April 8 collection and the two individuals of 113 and 132 mm total length from the April 22 trip are probably shrimp which had over-wintered in the Galveston Bay System. Chapman (1964), however, suggested that these large spring whites may over-winter in the shallow Gulf and re-enter the Galveston Bay System in the spring.

Two postlarvae, each 9 mm in total length, taken on May 20, were the first 1967-spawned white shrimp taken in the study area. The total number of white shrimp taken on each trip increased steadily throughout the summer, reaching a peak total catch of 4,236 individuals on September 23. The total number of white shrimp taken per trip gradually decreased after the September 23 trip, and a sharp drop was realized on November 18. The last white shrimps collected in 1967 (and for the entire study period) were 53 specimens taken on December 16.

The histograms in Figures 15 and 16 for June 26, July 8, July 22, August 5 and August 19 indicate a continuous recruitment of postlarval and small juvenile white shrimp into the study area. Large juvenile and subadult emigration from the area for the above period was probably light.

The mean length of the total sample through August 5 shows a progressive increase (Figure 13). Growth rate appears sufficiently high during this time to off-balance the depressing effects on the mean length by the continued postlarval and small juvenile recruitment and the emigration of subadults. A high level of recruitment on August 19 may have caused the decline in the mean length of the sample from the level of the previous trip. The rate of recruitment of postlarvae and small juveniles was high again on September 23, but appears to decrease on subsequent trips (Figure 16).

The temperature fell below 20^{o}C during November (Table 6) and a decrease in catch per effort was obvious on November 18th (Figure 13). The histograms show a decreasing percentage of large juveniles and subadults in the reduced catches during November and December (Figure 16).

<u>Distribution of white shrimp within the area - 1966</u>

Distribution and relative abundance of white shrimp within the study area are shown in Table 20, which gives the total number of shrimp caught by trip and station. Distribution is also shown in Figure 18, which is based on standard trawl samples of 30 or more individuals.

The first specimens of white shrimp for 1966 were taken on July 15 at Station A (Table 20). Of the 96 specimens of white shrimp taken on August 6, all but two of these came from Station A; this suggests that something was preventing the white shrimp from penetrating into the rest of the study area. Figure 3 shows that the monthly discharge of the Trinity River was considerably reduced during June and July when compared with the May level. Salinity data in Table 1 indicate, however, that relatively high runoff within the study area was preventing any measurable penetration of saline bay water during August, except at Station A. As salinities increased in late August and September there was a gradual spread of white shrimp over the study area and an overall increase in numbers (Table 20). These observations seem to agree with those of Gunter and Shell (1958), who during August in Louisiana found more white shrimp in areas with a salinity above 0.75 o/oo. The possibility should be allowed, too, that white shrimp might not swim upstream against a current of very low salinity water such as was found in Cross Bayou during July 1966. That currents play a part in white shrimp movement within the nurseries was noted by Viosca (1953). Most recently, Hughes (1969) has demonstrated the importance of changes in salinity to the rheotaxis of juvenile and postlarval pink shrimp (Penaeus duorarum Burkenroad). It would appear that once initial penetration of the study area was made by the white shrimp in 1966, salinity per se had no discernible effect on abundance.

In Figure 18, the samples appear to show that white shrimp of a particular mean length have no preference for a particular salinity. There also appears to be no meaningful or consistent pattern to the few differences in mean length of white shrimp samples between stations. What the diagrams show is the relatively continuous movement and dispersal of white shrimp throughout the study area. Continuous movement and dispersal of white shrimp may be somewhat exaggerated since Stations A, C and E are located on Cross Bayou, a major movement route.

If data for Station D (Figure 18) are followed for the trips from September 9 through October 8, a fairly constant population is recognized whose increasing mean length for each successive trip indicates growth. Emigration of this Station D population apparently took place between October 8 and 22.

The samples for 1966 indicate higher shrimp concentrations at the lower stations (those below the dam site), but these may be misleading. As alluded to above, samples from Cross Bayou may include a large percentage of immigrating and emigrating white shrimp which utilize areas above the dam site for nurseries. The apparent importance of Station D at Cotton Lake as a nursery for white shrimp can be seen by the large number of individuals taken there (Table 20).

Distribution of white shrimp within the area -- 1967

By June 26, 1967, white shrimp were spread throughout the study area (Table 20). The diagrams in Figures 19-20 show the increase and dispersion of white shrimp through the area as the season progresses. Rather than showing differences between sizes of shrimp in different parts of the study area, the diagrams seem to illustrate a continuous movement and dispersal. Two interesting exceptions are noted, however: (1) the diagram for Station E on August 19 shows a large concentration of postlarvae and small juveniles. This appears to be a major recruitment wave moving into the upper study area through Cross Bayou. (2) The diagram representing the Station L sample for September 9 shows a concentration of the smallest shrimp taken that trip; the diagram for Station L on September 23 suggests that a large number of small juveniles have moved into this area. A salinity low for the trip of September 23 of 0.74 o/oo was recorded at Station L.

The above exceptions notwithstanding, the salinities encountered during the 1967 white shrimp season do not seem to effect the abundance of these crustaceans.

Decreasing temperatures during November (Table 6) correspond with reduced total catches (Figure 13) and with the movement of most white shrimp from the upper stations.

The abundance of white shrimp during 1967 is evident by increased numbers taken at the upper stations. The lower stations, with the exception of Station A, also showed increased numbers.

The importance of the shallow lake Stations D and G as nursery areas is indicated by their total white shrimp yields for the season, as compared to the total yields of other stations (Table 20).

Marsh net data

Marsh net data for white shrimp during 1966 and 1967 are shown in Table 21. Each sample is from a standard 50-foot haul at marsh net stations (A, C, D, F, G, T). The sizes are grouped in 5 mm intervals. The marsh net is most efficient in taking postlarval shrimp.

The marsh net data of 1966 reveal a peak abundance of white shrimp on the trip of August 19 at Station D on a Rangia shell substrate. Several postlarvae were also taken at Station C and one was collected at Station A during this trip. Postlarvae taken in the marsh net samples account for the mode among the smaller sizes in the histogram for August 19, 1966 (Figure 15). Postlarvae were no longer abundant at Station D on September 2, but they were plentiful on the mud-detritus substrate of Station C.

A second peak in postlarval abundance in 1966 is indicated by the marsh net samples of October 8. Relatively high numbers were found at Station G, which had a mud substrate. After October 8, marsh net catch per unit effort declined markedly and the samples were of little significance in understanding the distribution of white shrimp.

The marsh net data are much more extensive for 1967. The wide variation in sample numbers shown for a particular station from trip to trip probably reflects recruitment of postlarvae and subsequent growth. This growth results in non-availability of shrimp to the marsh net.

On June 4, 1967, low numbers of postlarvae occurred at all marsh net stations, except D and T, but on June 24 the catch was increased at Station C. Recruitment of postlarvae in 1967, as evidenced by the marsh net samples, continued through July and August and reached a peak with the collection at Station G on September 23. After September 23, the size of marsh net samples decreased significantly, and the last white postlarva in the marsh net samples was taken on December 3 at Station C.

Williams (1958) states that both white and brown shrimp tend to avoid coarse substrate and seek cover and food by ranging over and burrowing in softer bottoms. Mock (1966) found both white and brown postlarvae to be more abundant in a nearshore environment next to an unaltered shoreline with emergent vegetation. The substrate along such a shore was found to have a high content of organic matter.

Of the six marsh net stations, a majority of the postlarvae were taken at Stations C and G during 1967. Both these stations have a soft mud substrate and plant detritus. Many grass shrimp, *Palaemonetes* sp., were usually taken at marsh net Stations C and G along with the penaeid postlarvae.

Brown Shrimp

During the study period, 27,229 specimens of the brown shrimp were collected and all but 339 were taken during 1967.

Population characteristics of brown shrimp - 1966

The first brown shrimp postlarvae (43 specimens) were collected in 1966 on April 2 (Figure 14); the distribution of 39 of these is indicated in Table 22. The catch of brown shrimp increased to 113 postlarvae on April 16, 1966 (Figure 14), at which time 94 of these were dispersed throughout the lower and middle portions of the study area (Table 22). After the trip of April 16, no additional brown shrimp were taken until August 19, 1966. The extremely high discharge of the Trinity River during May 1966 corresponded with the disappearance of brown shrimp from the area. No brown shrimp were again taken until August 19 when small numbers began to be collected.

From August 19 to December 17, the occurrence of brown shrimp was low; the highest number taken was 63 on December 3 (Figure 14).

Population characteristics of brown shrimp - 1967

The first brown shrimp taken in 1967 were two postlarvae collected in the marsh net on February 11, 1967. On February 25, one brown postlarva was collected in the marsh net, but no brown shrimp were taken on March 4. On March 18, 15 brown postlarvae were collected in the marsh net and 12 in the trawl. Those postlarvae in the trawl samples were widely dispersed throughout the study area (Table 22).

The total number of brown shrimp collected on one trip jumped to 5,016 individuals on April 8, 1967 (Figure 14). In the 3-week period between March 18 and April 8, the major recruitment of brown shrimp into the study area had begun. A peak in this recruitment was apparently realized on the trip of April 22, when a total catch of 7,044 brown shrimp was taken. A decline in the total number of brown shrimp collected occurred after April 22.

The sharp decrease in total numbers of brown shrimp taken in May, as compared to April, probably suggests a decline in the population due to intense competition for space and food. St. Amant et al. (1966) suggest that in years of high population density, crowding may result in causing the brown shrimp to leave the nursery grounds at an early date and at a smaller size. Mortality may also have contributed to the decline in brown shrimp. Major recruitment appears to have ceased after April and this would make effects of mortality more evident.

The diagrams in Figure 14 for April 8 through July 8 show an increase in mean length of the total sample for each successive trip. This suggests that rapid growth was taking place. The decline of the mean length of the total sample for July 22, from the level of July 8, may have been due to immigration of large juveniles from the study area (Figure 17). The continued reduction of the total sample mean length through August 19 is shown in Figure 14. The histograms (Figure 17) indicate that this reduction in mean length was due to the recruitment of postlarvae into the area, a process which continued through August 19, after which the mean length of the total sample increased again as recruitment slackened and the growth of the new recruits progressed.

After October 7, the number of brown shrimp decreased to very low levels. The last brown shrimp of 1967, and for the entire study period, were taken on December 16.

Distribution of brown shrimp within the study area - 1967

The widespread occurrence of brown postlarvae on March 18, 1967 has been mentioned; by April 8 the number of shrimp taken at each station was relatively high, particularly at the lower stations (Table 22).

The diagrams (Figure 21) for April 8 seem to indicate that the initial recruitment of shrimp was of rather equal-sized individuals and that they moved into the area in a short time period. Figures 21 and 22 suggest neither salinity nor area preference by a particular size group for a particular trip. As with the white shrimp, differences in mean size between stations within a trip are few, and a mixture of all sizes throughout the area is evident.

It is not likely that salinity *per se* had any effect on the abundance of brown shrimp. The highest average salinities were recorded within the area on April 8, but the largest brown shrimp collection was made on April 22 when salinities were considerably lower (Table 22). Salinities much lower than at the other stations were recorded at Station L on April 22, June 4 and September 23, 1967, however. The recorded salinity values were 0.35 o/oo, 0.37 o/oo and 0.74 o/oo, respectively. The relatively low abundance of brown shrimp at Station L on April 22 and June 4 as compared with other stations may be related to the low salinity, although the 0.74 o/oo reading on September 23 does not appear to be correlated with low abundance.

The greatest number of brown shrimp were taken below the proposed dam site (Stations A, B, C, D, R, I; Table 22) as also recorded for the white shrimp; but, as suggested above, brown shrimp might have been taken at the lower stations either because they were moving to or from upper stations or because they sought out the environment of the lower stations. Brown shrimp were more abundant than the white at the upper stations. This may be a consequence of the greater density of browns in 1967 which forced the animals to utilize more of the study area.

Marsh net data

Marsh net data on brown shrimp are sparce (Table 23), and the few postlarvae taken in the marsh net contributed little to the total picture for 1967. It is worthy to note that even when the trawl samples indicate that postlarvae are abundant in the study area (as on April 22), they appear unavailable to the marsh net. This apparent unavailability may be due to some characteristic of brown shrimp distribution such that they are not abundant in very shallow water during daylight hours.

Unidentified Postlarvae

Table 24 shows the date, place of collection and size of postlarval shrimp which were unidentified during the study. These postlarvae were grooved shrimp, according to the characters of Williams (1953, 1959) and Ringo and Zamora (1968), but whether they were brown postlarvae (Penaeus aztecus Ives) or pink postlarvae (Penaeus duorarum Burkenroad) could not be decided with certainty, since there is no practical method for identifying pink and brown postlarval shrimp in gross sample collections (K. N. Baxter, personal communication).

These unidentified postlarvae were collected during the mid-summer and fall of 1967, at a time of year during which a mixture of white, brown and pink postlarvae can be expected on certain Gulf Coast nursery grounds (Christmas, Gunter and Musgrave, 1966). The occurrence of pink postlarvae at the entrance to Galveston Bay (Bolivar Pass) is not common. Juvenile and subadult pink shrimp are occassionally found in Galveston Bay bait shrimp landings, but these may have entered the bay system at a large size rather than as postlarvae (K. N. Baxter, personal communication).

It appears logical to treat the unknown postlarvae separately and thus allow for the possibility that they are pink (P. duorarum) rather than brown (P. aztecus) shrimp. It is important to note, however, that the few unidentified postlarvae do not change the overall picture of white and brown shrimp ecology in the study area.

Growth of Penaeid Shrimp

Viosca (1920) was the first investigator to publish on the growth rate of white shrimp. He indicated that white shrimp measuring 1.25 inches in April were 6.0 inches in August, a growth rate of approximately 25-30 mm per month. Gunter (1950) suggested a growth rate for white shrimp of approximately 30 mm per month and Williams (1955) determined white shrimp growth rate to be 36 mm per month. Loesch (1965) estimated white shrimp growth to be 13-27 mm per month in winter, 18-31 mm per month in summer and 65 mm per month in spring.

For brown shrimp, Williams (1955) estimated a growth of 52 mm per month. St. Amant et al. (1963) suggested that juvenile brown shrimp grew at the rate of 1.7 mm per day, but later St. Amant and other colleagues (1966) said growth rate for brown juveniles was approximately 1.0 mm per day. Loesch (1965) found growth of brown shrimp in winter to be 12-35 mm per month, in summer to be 24-43 mm and in spring 50 mm per month.

The increase in mean length of samples collected from trip to trip during this study cannot be used as a measure of growth rate, because continuous recruitment into the population distorts any estimate of growth. Williams (1955) and Loesch (1965) have used the method of following extremes in length for successive samples. Lower extremes may give a conservative estimate of growth in winter, the upper extremes are more indicative of growth in summer (Loesch, 1962).

In this study, summer growth for white shrimp during 1966 was not estimated as there were no clear patterns of increase in the upper extremes. It also appeared from the data on white shrimp in 1966 that due to a late appearance (July), many of the larger white shrimp represented as the upper extremes in Figure 13 had attained most of their growth in an environment outside the study area. Growth of white shrimp from October to December 1966 was estimated by connecting the lower extremes of the diagrams in Figure 13. The estimated growth for the period from October 8 to December 3 is 30 mm, or approximately 0.5 mm per day. During this period the recorded salinities at the biological stations ranged from 0.6 o/oo to 9.8 o/oo, with an average of 4.1 o/oo and the recorded water temperature ranged from 15.0°C to 24.5°C, with an average of 19.5°C. A growth of 54 mm at the rate of approximately 1.0 mm per day is indicated by connecting the maximum extremes from June 26 to August 19, 1967 (Figure 13). During this period, the recorded salinities at the biological stations ranged from 1.1 o/oo to 10.4 o/oo, with an average of 4.0 o/oo and the recorded water temperatures ranged from

26.0°C to 35.0°C, with an average of 29.4°C. Connecting the lower extremes from October 21 to December 19, 1967, indicates a growth of 19 mm at the rate of 0.3 mm per day. During this period, the recorded salinities at the biological stations ranged from 0.1 o/oo to 11.7 o/oo, with an average of 3.1 o/oo, and the recorded water temperature ranged from 11.0°C to 24.0°C, with an average of 16.9°C.

A winter growth rate could not be determined for brown shrimp during 1966, as recruitment of postlarvae during November and December obscured the growth progression of the lower extremes (Figure 14). When recruitment of postlarvae is occurring, progression of the upper extremes can be used to estimate growth. The upper extremes from November 5 to December 3, 1966 indicate a growth of 20 mm at the rate of approximately 0.7 mm per day for brown shrimp. During this period, the recorded salinities at the biological stations ranged from 0.6 o/oo to 9.8 o/oo, with an average of 5.0 o/oo, and the recorded water temperatures ranged from 15.0°C to 23.5°C, with an average of 18.3°C. A growth estimate of 58 mm at the rate of approximately 1.3 mm per day was obtained for spring 1967 by following the upper extremes in the period from April 8 to May 20 (Figure 14). During this period, the recorded salinities ranged from 0.3 o/oo to 14.3 o/oo, with an average of 6.6 o/oo, and the water temperatures ranged from 21.0°C to 28.0°C, with an average of 24.7°C.

These estimates show that the growth rate for both white and brown shrimp varied between seasons, with the indication that temperature was the dominating factor. St. Amant _et al._ (1966) suggest that temperature is important to growth and report growth of brown shrimp at less than 1.0 mm per day when water temperatures are below 20°C and less than 1.5 mm per day when water temperatures are lower than 25°C. Zein-Eldin and Aldrich (1965) and Zein-Eldin and Griffith (1966) found differences in the rate of growth of postlarval brown shrimp to be more closely related to temperature than to salinity and indicated that the influence of temperature on growth is most marked in the 18°C to 25°C range.

THE GULF MENHADEN

Abundance and Distribution

It is known that *Brevoortia patronus* spawns in the open Gulf during the fall and winter months and that it utilizes estuaries during early life history stages (Gunter and Christmas, 1960). The study area was utilized by menhaden during their "growth period," but specimens were collected in each month. Of the 45,890 specimens collected, some were taken in each month during this study (Tables 25, 26, 27).

Postlarval menhaden were first recorded in the study area in December 1966, when 17 (21 to 25 mm) were collected. This "time of arrival" agrees with the findings of Gunter (1938, 1945) for Copano and Aransas Bays in Texas and for Barataria Bay in Louisiana, of Suttkus (1956) for Lake Pontchartrain in Louisiana, and Simmons and Breuer (1967) for Laguna Madre in Texas. Postlarvae continued to enter the study area through May.

Peak catches in 1967 occurred in March (3,367 specimens), April (7,983), and May (3,551), of which 33% were postlarvae. These peak catches were apparently the result of the accumulation of all postlarvae that entered the area during the period December 1966 through May 1967. Of the 19,061 specimens collected during this period, 42% were postlarvae. Catch numbers decreased to 1,765 in June, 969 in July, and 293 in August of 1967. In September the number collected increased to 711, after which a steady decrease occurred. The smallest number of specimens (43) collected during any one month was recorded in January 1969.

During the winter of 1967-1968 postlarvae were recorded in November (8 specimens), in December (199), and in January (15). Postlarvae continued to enter the area in 1968, following the pattern of 1967, with the peak catch of 6,914 occurring in March, and with 2,238 taken in April and 998 in May. However, the gradual increase in catch size recorded in 1967 was not repeated in 1968. Instead, there was a scarcity of menhaden during November through February, followed by a dramatic increase in the population in March.

Although menhaden were taken during all months, the peak catches in 1967 and 1968 occurred in March, April, and May. The two highest catches were made in May 1968 (7,998) and in April 1967 (7,983). The smallest catches were made in January (43) and July (80) of 1968. During the period May 1966 to May 1968, the study area was utilized by B. patronus throughout the entire year, with very extensive utilization from March through May. This latter period corresponds to the time of the influx of the postlarvae from the offshore spawning areas.

These observations agree with those of Gunter (1938, 1945), who reported that postlarvae first moved into the estuaries of Barataria Bay of Louisiana and Copano and Aransas Bays of Texas during January, with peak abundance in the spring months. It is clear that the study area of this project serves as an important nursery area for B. patronus, with seasonal abundance patterns closely resembling those of other areas of the Gulf Coast.

Time of Entry into the Study Area

The entrance of postlarvae into the study area during the winter of 1966-67 was first recorded in December 1966, when 16 specimens were collected (three at Station F and 13 at Station M). By the end of January 1967 the fish had dispersed throughout the study area. The January catch of 601 represented each station. Postlarvae were well established throughout the area by February. In this month all stations contributed to the catch of 2,543.

Seven were collected in November 1967 at Station F and in December 1967 six stations contributed to a collection of 196 specimens. Among the six stations was Station U, the uppermost collecting site in the study area. However, during January only 11 specimens were collected from a total of four stations, with Station G as the uppermost locality for this date from which menhaden were taken. In February 341 specimens were taken from six stations, with Station G as the upper point. The postlarvae then became well established throughout the study area, and in March 6,927 specimens were taken from nine stations. A substantial number of these specimens were taken from the upper Station U.

The mean salinities during the times of evident dispersal of postlarvae through the study area were 5.23 o/oo in January of 1967 and 0.22 o/oo in March of 1968 - the greatest variation in salinity recorded during the study. Thus, it appears that such a salinity range is not a limiting factor (Table 27).

Low temperatures may prohibit migratory movement of the menhaden. The lowest monthly mean temperature for the year was recorded one month prior to the time when the postlarvae became firmly established throughout the study area. During the winter of 1966-67, the lowest mean temperature of 11.53°C was recorded in January, when 601 postlarvae were collected. In February 1967 the catch was 2,543, at a mean temperature of 13.23°C. In February 1968 the catch was 341 at a mean temperature of 9.41°C, but in March, when the mean was 14.64°C, the catch was 6,927 specimens. These temperatures are well above the critical minimum temperature of 3.0°C for B. tyrannus, as reported by Lewis (1965).

These data suggest a relationship between the temperature and the establishment of postlarvae in the study area, but it is assumed that no correlation exists between the time of arrival of the fish and other hydrographic features (Table 27). It has been suggested that the time of arrival of menhaden to the estuary is dependent on the time of spawning and the speed of the off-shore currents (Paul L. Fore, personal communication). Fore also suggested that menhaden destined for the Trinity River area are spawned off the coast of Louisiana, with the estimated time of arrival at the study site approximately one month after spawning.

Growth

Although much has been published concerning the growth of the Atlantic menhaden (Bigelow and Welsh, 1925; Hildebrand and Schroeder, 1928; Rush, 1952; June and Reintjes, 1959, 1960; June and Roithmayr, 1960), there are few published data on the growth rate of young Gulf menhaden. Baldauf (1953, 1954) presented monthly length frequency curves for January 1952 through April 1953, based on over 10,000 specimens of Brevoortia sp. Suttkus (1956) presented meristic counts of young B. patronus and noted the changes in body shape which occur when the fish reached a length of 20 to 30 mm. Simmons and Breuer (1967) reported on the growth of small menhaden in the upper Luguna Madre of Texas during January through mid-June of 1960. Gunter (1945) reported on the growth of larger menhaden of Aransas and Copano Bays in Texas.

During the two-year period of this study, the standard length of all specimens varied from 16 to 135 mm (Table 25). The smallest specimen was collected by seine on March 18, 1967 at Station D in a salinity of 9.2 o/oo and a temperature of 17.5°C. One 135 mm specimen was collected by trawl on September 23, 1967 at Station A in a salinity of 9.7 o/oo and a temperature of 28.5°C, and another was taken at Station A by trawl on October 7, 1967 in a salinity of 8.5 o/oo and a temperature of 25.0°C. Of the fish collected during this study, over 67% were in the 20-29 mm range (Table 26).

The monthly mean standard lengths (Table 25) suggest a definite annual growth pattern. The increase in size is generally a gradual one, with the largest specimens occurring in the December-January period. This period, however, is one in which the larger fish leave and the postlarval fish enter the study area.

A comparison of the recorded sizes suggest that the rate of growth was greater in 1967 than it was in 1966. During the May-

September period of 1967 the mean standard length increased from 33.4 mm to 63.0 mm, while during the same period in 1966 the mean increased from 28.0 mm to 46.3 mm. Since the growth peak was reached two months earlier in 1967, it is not surprising to note that larger fish were leaving and postlarvae were entering the estuary one to two months earlier in that same year. Although the growing period was 60 days shorter in 1967, the peak mean standard length is over 10 mm longer than that of 1966. It would appear, then, that the 1967 growth rate was slightly greater than that of 1966, with the menhaden reaching a larger size in 1967 before moving from the estuarine environment of the study site.

The growth rates of both 1966 and 1967 are very close to those shown by Baldauf (1953, 1954) for menhaden of the lower Neches River in Texas. However, the data of Simmons and Breuer (1967) for the upper Laguna Madre of Texas show a somewhat higher growth rate, especially during the month of June. The latter authors also considered fish with a modal length of 135 mm as over one year old and those 210-225 mm slightly over two years old. The largest specimens (120-135 mm) collected during this study were taken in September and October of 1967 and are considered to be over one year and less than two years old. The rate of growth recorded here agrees favorably with the rates reported for menhaden collected from other areas of the Gulf Coast. Because of this, the lower Trinity River and associated marshes are considered important if not essential to the large population of Gulf menhaden which utilize the area.

Time of Migration from the Nursery Area

Movement of the 0-year class from the study area during the 1966-67 winter occurred in January and February. Although a large majority of the yearlings moved from the area, some remained. Specimens measuring 80 mm and longer were collected throughout the spring and summer of 1967, and specimens over 110 mm were collected during September and October 1967.

During the 1967-68 winter, migration from the study area occurred during December and January. Apparently all of the 0-year class moved out, as no fish over 53 mm were collected during the following spring. This was essentially a duplication of the summer of 1966, when no fish over 52 mm was collected, and suggests that a migration during the winter prior to this study was also made by all 0-year class fish. Therefore, it appears that a complete migration occurred during the winters of 1965-66 and 1967-68 and that not all fish moved out during the winter of 1966-67.

There apparently is a relationship between the movements of menhaden and salinities (Table 27). During the winter of 1966-67 relatively "high" salinities were recorded, ranging from 2.09 o/oo in October to 5.23 o/oo in January and 5.28 o/oo in March. These "highs" may have accounted for some of the I-year class individuals to remain in the nursery area. During the winter of 1967-68, when a complete migration occurred, the salinities were low and ranged from 1.49 o/oo in December to 0.12 o/oo in April. No I-year class individuals were taken after January 1968, when the salinity fell below

1.00 o/oo. These data agree with those of Suttkus (1956), who related the occurrence of large menhaden in Lake Pontchartrain during the winter of 1954 to the high saline waters occurring at that time.

It appears that the mass movements of *B. patronus* into and out of the estuarine areas are dependent on hydrographic features and that temperature is one of the major factors influencing the time of migration into an estuary, while salinities influence the time of movement back into the open Gulf of Mexico (Table 27).

DISCUSSION

The Galveston Bay estuarine system comprises approximately 350,000 acres of open water and an additional 230,000 acres of surrounding marsh, 20 percent (46,000 acres) of which borders Trinity Bay (R. A. Diener, personal communication). The present study area was approximately 22,000 acres (47 percent) of the marsh area surrounding Trinity Bay.

Shallow waters with muddy bottoms, low salinities and vegetated shorelines have been associated with "nurseries" or areas significant to the early life histories of commercially important decapod crustaceans (Weymouth, Lindner and Anderson, 1933; Williams, 1955, 1958; Judy and Dudley, 1966; Mock, 1967). The general physiographic characteristics of the present study area agreed with the above description of a nursery, and the study area demonstrated the capacity to sustain populations of growing juvenile brown and white shrimp and blue crabs. The extent, however, to which the above crustaceans utilized the study area during any one year was correlated with the discharge rate of the Trinity River, and Parker (1966) points out the annual and seasonal variation in the rate of freshwater flow from this river is great.

Penaeid Shrimp

Variation from year to year of such environmental factors as rainfall and riverflow may regulate penaeid shrimp populations in the Galveston Bay System. Rainfall has been implicated by various authors as regulating the abundance of penaeid shrimp on the Gulf

Coast. Viosca (1958) attributed declines in white shrimp stocks to a period of prolonged drought, and others have correlated heavy rainfalls in Texas with increased white shrimp harvests (Hildebrand and Gunter, 1953; Gunter and Hildebrand, 1954). The results of the present study agree with those of St. Amant et al. (1966) in that large portions of a nursery area may become unavailable to brown shrimp during years of high river discharge. During years of reduced flow, the previously temporarily "unavailable" nursery grounds reaffirm their importance in the production of brown shrimp.

The brown shrimp harvest in 1966 for Area 18 (the Gulf waters immediately to the west of the Galveston Bay System) was 2,814,491 pounds, whereas in 1967 it was 11,018,681 pounds (U. S. Bureau of Commercial Fisheries, 1966, 1967). The increased landings in 1967 seem to indicate that the factor or factors responsible for the low brown shrimp landings for Area 18 in 1966 had only temporary effects on brown shrimp abundance. In 1966, the high discharge of the Trinity River probably lowered the brown shrimp production of the Galveston Bay System, and this is reflected in the low brown shrimp landings for Area 18 that year. In 1967, when freshwater discharge into Galveston Bay was low, brown shrimp landings for Area 18 increased more than 8,000,000 pounds from the 1966 landings. That the cause for the differences in brown shrimp landings from Area 18 for the 2 years was freshwater discharge is not certain, but it appears that brown shrimp are able to recover rapidly from naturally caused population reductions.

Brown shrimp arrive on the nursery grounds in the early spring (usually March) in the Galveston Bay System, and increase in numbers through April, but by June are declining in abundance. White shrimp arrive in the Bay System later in the spring (usually May), increasing in abundance throughout the summer, reaching a peak in the fall (September or October). The estuarine period of the brown shrimp life history is shorter than that of the white shrimp, and the brown shrimp leaves the estuaries at a smaller size than does the white shrimp (Chin, 1961).

The arrival of brown shrimp in Galveston Bay in the early spring subjects them to severe and widely fluctuating environmental conditions. Temperatures often drop sharply with the passage of cold fronts (Pullen and Trent, 1969), and spring rains often cause high levels of freshwater discharge, particularly from the Trinity River. Although possessing certain behavioral mechanisms (such as burrowing) which possibly enable them to survive short periods of decreased water temperatures (Aldrich et al., 1968), brown shrimp postlarvae may not be able to withstand long periods of reduced salinity. Under the conditions of extremely high discharge of the Trinity River during May of 1966, brown shrimp appeared to be adversely affected, at least in areas immediately adjacent to the River. During April of 1966 brown postlarvae were taken in the study area, but during May and after the flood waters had subsided in June none were taken. This seems to indicate that shrimp present in the study area prior to peak river discharge in May either perished or were swept to the lower portions of the bay system by the flood waters. It appears that the brown shrimp did not enter the study area during the period of high Trinity River discharge during the spring of 1968. During 1968, however, unlike 1966, the Trinity discharged at a high level during March, April and May and no brown postlarvae were taken during this time period. The peak of brown shrimp recruitment into the Galveston Bay System is usually passed by the time river discharge decreases and spring flood conditions subside.

Flood conditions may decrease the rather short estuarine period of the brown shrimp life history. Berry and Baxter (1967) stated that it appeared from the spring 1966 statistics of the bait shrimp fishery in lower Galveston Bay that brown shrimp emigrated to the Gulf earlier than usual. They speculated that this might have been due to the very low salinities throughout the Bay System. Trent (1966) reported data that indicated that brown shrimp left the Bay System at a smaller size in 1966 than in other years.

The discharge of the Trinity River during the spring of 1967 was relatively low. Brown shrimp were taken in February, they increased in abundance through April, after which their numbers declined (Figure 14). The abundance of brown shrimp throughout the study area was quite high, but the period of peak utilization was short (April-May). The data on brown shrimp from 1967 indicate that the crucial time for optimum conditions on the nursery grounds occurs in early spring.

During 1966, white shrimp appeared in the study area during

July and increased in abundance through September. When compared with subsequent data on white shrimp from 1967, white shrimp appeared in the study area later in 1966 and were not as abundant. White shrimp postlarvae were first taken at the entrance to Galveston Bay during the last week of May in 1966 and during the last week of April in 1967, but peak periods of postlarval white shrimp immigration into Galveston Bay occurred during mid-summer (August-September) of both years (K. N. Baxter, personal communication). White shrimp were most abundant in the study area during September and October in both 1966 and 1967. The early appearance of white shrimp in the study area, as in 1967, may be indicative of favorable environmental conditions and a greater abundance, but it does not result in an earlier abundance peak.

The spring and summer of 1967 demonstrated that the life cycles of brown and white shrimp are such that although they utilize the same nursery grounds, the physiological and ecological requirements of the two species are different; thus the time of maximum utilization of the nursery grounds by either species does not coincide with that of the other and when brown shrimp are declining, white shrimp are increasing in numbers. As a consequence of the sequential use of the nursery grounds by the two species, the later appearance of the white shrimp in spring as compared to the brown subjects the former species to less severe environmental conditions (Aldrich et al., 1968). Peak river discharges of spring, for instance, are usually past by the time that large numbers of white shrimp are to be expected on the nursery grounds.

The estimated growth rates for white and brown shrimp within the study area varied seasonally and appeared to be related to differences in water temperature. White shrimp grew at the rate of approximately 0.3 mm per day during a period from October 21 to December 19, 1967, when the average recorded water temperature was 16.9°C and they grew at the rate of approximately 0.5 mm per day from October 8 to December 3, 1966, when the average recorded water temperature was 19.5°C. White shrimp grew at the rate of approximately 1.0 mm per day from June 26 to August 19, 1967, when the average recorded water temperature was 29.4°C. The estimated growth rate for brown shrimp is greater than that for white shrimp. Brown shrimp grew at a rate of approximately 0.7 mm per day from November 5 to December 3, 1966, when the average recorded water temperature was 18.3°C, and they grew at a rate of approximately 1.3 mm per day from April 8 to May 20, 1967, when the average recorded water temperature was 24.7°C.

The largest white shrimp taken in the study area during 1967 measured 139 mm total length and many others were greater than 120 mm total length. The largest brown shrimp taken during 1967 measured only 119 mm total length. This smaller maximum length for brown shrimp as compared to the larger maximum length for the white shrimp is indicative of the longer time a white shrimp stays on the nursery grounds. The greater maximum length recorded for a white shrimp from the study area in 1967 (139 mm), as compared to the largest white shrimp specimen taken in 1966 (119 mm), reflects the longer nursery period for white shrimp in 1967 than in 1966; in 1967 white shrimp arrived in the study area during April, whereas in 1966 they arrived in July.

The Blue Crab

Although the earlier appearance (April) of mature female blue crabs in the study area during 1967, as compared to their late appearance (June) in 1966, might be due to reduced river flow, it is more likely to be a temperature-related phenomenon. It is possible, however, that the high level of Trinity River discharge during the late spring of 1966 was detrimental to the spawning success and larval survival of the blue crab in the Galveston Bay area. In lower Galveston Bay, the salinity is usually between 20.0 o/oo and 30.0 o/oo (Chapman, 1967), the approximate range for optimum larval development of the blue crab as reported by Sandoz and Rogers (1944). In late April and May 1966, salinities in lower Galveston Bay dropped to less than 10.0 o/oo (Chapman, 1967). Pearson (1948) found that over a 15-year period in Chesapeake Bay, high discharge from the James River during May and June was associated with low annual survival of blue crabs; he attributed this low survival to below-optimum salinities on the blue crab spawning grounds. He found, however, that low discharges from the James River during May and June over the same 15-year period were associated with high annual blue crab survival, and he related this high survival to optimum salinity levels on the crab spawning grounds. In the present study area, the late spring blue crab spawning period of 1967 was longer and with a higher larval survival as compared to the late spring spawning period in 1966. This is suggested by the high abundance of small crabs from the 1967 spring spawns in collections made in November and December of 1967, whereas recruitment of small crabs from the spring 1966 spawn was not noted until February 1967. Throughout the spring of 1967, salinities in lower Galveston Bay were in the 20.0 o/oo-30.0 o/oo range, whereas during the spring of 1966 salinities dropped below 10.0 o/oo (Pullen and Trent, 1969).

The blue crab population in the study area appears to be largely composed of immature individuals, but it has been suggested that mature individuals might be more successful in evading capture and therefore are not collected. Only 26 mature female blue crabs were collected in the study area and only one incidence of probable mating of blue crabs was observed; this indicates that mating for the most part takes place outside the study area and that there is a shift of the crab population from the study area to Trinity Bay with maturity.

The width-weight relationship for male blue crabs is expressed as

$$\text{Log } W = 2.739756 \text{ Log Width} - 3.66107$$

and for female crabs as

$$\text{Log } W = 2.618324 \text{ Log Width} - 3.45805.$$

Thus, the slope of the regression line for males is steeper than it is for females, indicating that males tend to be heavier than females at a given width. These observations on the width-weight relationship agree with a similar study on this relationship for blue crabs of the Galveston Bay System conducted by the Bureau of Commercial Fisheries, Galveston (E. J. Pullen, personal communication).

There is much individual variation in the rate of increase in size per molt and in the molting interval among blue crabs under the same environmental conditions (Gray and Newcombe, 1938; Tagatz, 1967). It appears that condition is also highly variable among individual crabs. In this study, condition was determined for individual male crabs by the formula $K = \frac{W}{L^b} \times 10^5$ and a mean condition value was determined for each month. The highest mean monthly condition coefficient in 1966 was 22.7 (June) and the lowest mean monthly condition coefficient for 1966 was 20.4 (December). In 1967, the highest mean monthly condition coefficient was 24.9 (June) and the lowest mean monthly condition coefficient was 20.5 (November). Although analysis of variance showed significant differences in mean monthly condition coefficients between months, nonhomogeneity was indicated by Bartlett's test and this may reduce the power of the analysis of variance. It appears from the above condition values, however, that the relative well being or robustness of male blue crabs is greater during the warmer months of the year than during the cooler ones. Higher variance values indicated that individual condition coefficients may vary more from the mean condition coefficient during the warm months than during cool months. It is conceivable that not all individuals in a blue crab population will exhibit high condition coefficients under so-called "ideal conditions". Such individuals would affect the sample variance more during warm months, when many crabs in the population are increasing their condition, than during cool months, when condition throughout the whole population is relatively low.

In addition to attributing differences in condition to such environmental parameters as temperature, salinity, and food supply, consideration must also be given to sexual maturity. Male blue crabs were considered mature in this study if they exceeded 120 mm in carapace width. The wide variation in gonad development in "mature" crabs will influence the width-weight relationship. Male blue crabs may also shed several times after attaining sexual maturity (Van Engle, 1958), so that mature males may have a varying width-weight relationship over a relatively short time period. The extreme variations in the width-weight relationship (viz., one 195 mm male weighing 52.4 g and another 195 mm male weighing 382.6 g, (Table 8) increase sample variance and lead to non-homogeneity in variance among samples, especially if some anomalies occur more frequently than others during certain seasons.

The Gulf Menhaden

The study area is utilized by the Gulf menhaden as a nursery ground, just as has been recorded for similar estuaries in other areas of the Gulf Coast. Spawning of menhaden occurs in the Gulf, and postlarvae move into the study area during the winter and early spring months. The greatest influx of postlarvae into the nursery grounds occurs in March, April, and May. At this time most of the menhaden in the area are small (Table 25). The time of entry into the nursery area by menhaden is apparently influenced by the time of spawning in the Gulf, by the off-shore currents, and by the temperature. The condition is somewhat confused during the time of greatest influx into the area, because the I-year class fishes may still be present.

After about 12 months of growth in the study area, the menhaden move out into open Gulf waters. At this time the fishes are large and during this study reached a standard length of 135 mm. The time of ingress of postlarvae and of egress of I-year class animals occurs more or less simultaneously, the exact time of movement apparently dependent on different factors. There is no doubt that the time of movement out of the nursery area of I-year class menhaden is "timed" with the influx of fresh waters from upstream into the nursery.

The general details of movement, of growth, and other factors of the biology of the Gulf menhaden in the study area apparently duplicate those recorded for this species in other areas of the Gulf Coast. It is clear that the study area serves as a nursery ground for the Gulf menhaden.

Water Development Projects and Nurseries

Water development projects currently underway in Texas and those planned for the future will change the character of the State's major rivers and their drainages (Chapman, 1966). Rivers which normally flow directly into the estuaries of the Texas coast will be impounded and diverted by dams and man-made channels. Reduced freshwater influx into the estuaries is expected to alter the salinity regime there, resulting in higher salinities in an otherwise brackish water environment. It is expected that high salinities in estuaries will be detrimental to many important estuarine-dependent species. The diverted and impounded river water which is finally returned to the coastal areas after "multi-use" will probably be heavily loaded with domestic, industrial and agricultural pollutants which are harmful to estuarine organisms (Chapman, 1966).

The present study area is the site of the proposed Wallisville Reservoir, one of several multipurpose reservoirs planned or in operation for the water development of the Trinity River Basin. What is unique about the Wallisville Reservoir site is its close proximity to a coastal bay. The Wallisville Dam is to be located at Trinity River mile 3.9, where it will traverse an approximately 22,000 acre, low salinity, marsh which is the deltaic region of the River. The effects of impounding Trinity River in the Wallisville Reservoir and the subsequent diversion of this water from the conservation pool for domestic and industrial use is expected to alter both the character of the marsh below the dam site and of Trinity Bay. Exactly what these changes will be below the dam site and what effect they will have on organisms dependent on these areas is not known. The reservoir will probably serve as a nutrient trap, and the enrichment of areas below the dam site will be reduced. Water current patterns in the bayous below the dam site will probably be altered, as well as sedimentation patterns, and in years of low Trinity River discharge the effects of impounding the River will lead to high salinities in Trinity Bay.

What is known with certainty is the fate of the brackish marsh behind the proposed dam site, when the reservoir is completed. The Wallisville Dam will serve as an effective saltwater barrier in addition to serving as a river-water-impoundment structure, and behind the dam approximately 12,500 acres of low salinity marsh will be inundated by the conservation pool, transforming it into a freshwater environment (Figure 2). It is here demonstrated that the entire study area (approximately 22,000 acres) serves as a nursery ground for white and brown shrimp, blue crabs and menhaden, so that the loss of the marsh behind the Wallisville Dam is the loss of approximately 12,500 acres of nursery ground. Once the dam is completed, passage of penaeid shrimp, blue crabs, and menhaden behind the dam will be impossible. The construction of the dam at least 4.5 miles farther upstream from the selected site would have spared considerable nursery acreage from destruction. Data collected in this study show that in general, as distance from Trinity Bay increased, the extent of utilization of the marsh by commercially important crustaceans, and fish decreased. Costs of dam construction farther upstream may be less, due to the reduction in breadth of the Trinity River flood plain.

It is unlikely that the Wallisville Reservoir will ameliorate the effects of extremely high freshwater discharge, such as that of

May 1966, on brown shrimp. During years of high river discharge, the reservoir conservation pool would be rapidly filled and the flow of freshwater over the spillways would be almost as great as the flow of the unimpounded River.

This study shows that areas unavailable to brown shrimp because of peak freshwater discharge from the Trinity River resume their importance in brown shrimp production in years of low freshwater discharge. The Wallisville Reservoir will isolate brown shrimp from their nursery grounds and will cause permanent declines in the number of brown shrimp. This study has demonstrated that white shrimp, blue crabs, and menhaden use the same nursery grounds throughout the study area and therefore the Wallisville Reservoir will cause permanent declines in their numbers also.

SUMMARY

1. The study area serves as a nursery ground for the white shrimp (*Penaeus setiferus* Linn.), the brown shrimp (*Penaeus aztecus* Ives), the blue crab (*Callinectes sapidus* Rathbun), and the Gulf menhaden (*Brevoortia patronus* Goode).
2. The extent of utilization of the study area by brown shrimp is regulated by the flow of the Trinity River. High discharge from the Trinity River in the spring of 1966 and 1968 rendered the study area unavailable as a nursery ground for brown shrimp.
3. In the spring of 1967, when Trinity River discharge was low, brown shrimp were taken in February, increased in abundance through April, after which numbers declined. The abundance of brown shrimp was high in the study area, but the period of peak utilization was fairly short (April-May).
4. White shrimp arrived in the study area during July in 1966 and during May in 1967, when they were more abundant. White shrimp were most abundant in both years during September and October, and declined in abundance during November when water temperatures fell below $20^{o}C$.
5. The estimated growth rates for brown and white shrimp varied seasonally. White shrimp grew at the rate of approximately 0.5 mm per day during the late fall 1966 (October-December). approximately 0.3 mm per day during the late fall of 1967 (October-December) and approximately 1.0 mm per day during the summer of 1967 (June-August). Brown shrimp grew at the rate of

approximately 0.7 mm per day during late fall 1966 (November-December) and at a rate of approximately 1.3 mm per day during late spring 1967 (April-May).

6. The length of the largest white shrimp (139 mm total length) collected in the study area as compared to the largest brown shrimp (119 mm total length) is indicative of the longer time a white shrimp stays on the nursery grounds. During 1966, when white shrimp arrived late in the study area (July), the largest white shrimp taken measured only 119 mm total length, but in 1967 when white shrimp arrived early (May), the largest specimen collected was 139 mm total length.
7. The blue crab population of the study area is composed largely of immature individuals of both sexes. Crabs of 20 mm width or less were found during all months of the year, but were most abundant during winter months.
8. Male adult blue crabs (greater than 120 mm width) taken during the study numbered 515, but mature females numbered only 26.
9. The small number of mature females taken (26) and the lack of visual sightings of mating blue crabs indicate that mating, for the most part, takes place outside the study area.
10. Male blue crabs tend to be heavier than females at a given width.
11. Condition (relative well being or robustness) of male blue crabs tended to be better during spring and summer months of the study period than for fall and winter months.

12. Postlarval Gulf menhaden entered the study area during the November-May period, with the exact time of greatest influx dependent on temperature, time of spawning, and off-shore currents.
13. Gulf menhaden of the 0-year class moved from the study area and into the open Gulf during the December-February period, with the exact time of movement dependent on salinity.
14. The growth rate of postlarval Gulf menhaden in the study area agrees favorably with the rates reported for other areas of the Gulf Coast.
15. The construction of the proposed Wallisville Reservoir will destroy approximately 12,500 acres of nursery groung located behind the proposed dam-saltwater barrier. Changes in the nursery below the dam site are also likely.
16. Placing of the dam-saltwater barrier from 4.5 to 5 or more miles farther upstream would have saved much prime nursery area from direct destruction.
17. The Wallisville Reservoir will isolate brown and white shrimp, blue crabs, and Gulf menhaden from nursery areas and will cause permanent declines in the numbers of these species.

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TABLES

TABLE 1. Salinity values (‰) from all stations sampled from March 1966 through May 1968. (Note: 0.0 indicates that no sample was taken.)

Month	A	B	C	D	E	F	G	I	K	L	M	O	S	T	U	H	J	J^1	P	R	Mean
Mar.	1.3	0.4	0.5	0.0	0.3	0.2	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.0	0.4
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.4	0.2	0.3	0.0	0.0	0.0	0.0	0.3	0.2	0.2
Apr.	2.5	2.4	2.5	2.2	2.4	0.6	1.3	1.0	0.7	0.0	0.7	0.6	0.6	0.4	0.0	0.8	0.4	0.0	0.3	0.2	1.1
	1.4	0.9	1.1	0.8	0.0	0.1	0.6	0.3	0.5	0.3	0.5	0.9	0.0	0.1	0.0	0.4	0.1	0.0	0.6	0.3	0.5
May	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0
	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.1
	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	0.3	0.3	0.3	0.2	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1
July	0.5	0.4	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.2	0.3	0.2	0.0	0.2	0.1	0.0	0.1	0.2	0.2
	0.6	0.2	0.2	0.2	0.2	0.2	0.4	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.0	0.1	0.1	0.0	0.3	0.1	0.2
Aug.	1.1	0.7	0.5	0.5	0.4	0.2	0.2	0.4	0.1	0.1	0.2	0.4	0.3	0.2	0.0	0.2	0.2	0.0	0.2	0.2	0.3
	2.4	1.2	0.8	0.8	0.5	0.3	0.4	0.1	0.4	0.4	0.4	0.4	0.2	0.2	0.0	0.2	0.2	0.0	0.2	0.3	0.5
Sept.	1.5	1.0	0.9	0.7	0.8	0.6	0.5	0.6	0.5	0.5	0.7	0.4	0.4	0.4	0.0	0.6	0.4	0.0	0.4	0.4	0.6
	5.3	5.3	5.5	1.7	1.2	0.4	0.3	0.5	0.5	0.2	0.5	0.5	0.2	0.2	0.0	0.4	0.3	0.0	0.2	0.2	1.3
Oct.	6.5	7.4	7.0	3.0	1.9	3.4	2.5	5.7	1.4	1.2	1.1	1.1	0.1	0.2	0.6	4.4	0.2	0.0	0.3	0.2	2.5
	4.2	5.3	3.3	3.6	0.9	1.8	0.7	2.6	0.7	0.7	0.9	1.0	0.2	0.5	0.5	1.7	0.2	0.0	0.2	0.1	1.5
Nov.	9.6	9.8	9.7	8.9	8.3	7.6	8.0	7.7	6.9	4.2	3.9	3.5	0.5	0.8	1.5	5.0	0.8	0.0	0.9	0.8	5.2
	6.7	4.3	3.3	3.5	3.3	2.4	2.1	5.7	2.6	0.6	2.1	1.6	0.3	0.6	0.8	2.3	0.7	0.0	0.3	0.3	2.3
Dec.	8.4	7.0	6.9	6.8	6.7	6.7	6.4	4.0	4.3	3.4	3.7	2.9	0.7	0.7	1.5	5.7	0.0	1.0	0.6	0.8	4.1
	7.1	7.1	6.5	6.3	6.7	7.3	5.5	6.8	3.4	0.0	3.3	2.6	0.4	0.6	1.5	7.9	1.5	0.0	0.9	0.7	4.2
Jan.	8.4	7.8	8.0	8.0	8.0	4.9	4.1	6.6	3.7	0.9	3.8	3.4	0.6	0.7	2.3	7.2	0.8	0.0	0.4	0.5	4.3
	15.6	14.2	12.1	9.5	7.3	10.2	5.9	10.6	5.9	3.0	4.4	2.9	0.5	0.5	2.2	8.1	0.5	0.0	0.7	0.6	6.1
Feb.	11.2	7.1	5.1	5.9	5.3	4.8	4.0	3.4	2.7	0.6	2.7	2.5	0.5	0.7	1.3	1.1	0.6	0.0	0.9	0.4	3.2
	7.6	8.3	6.1	7.2	7.0	4.4	4.5	2.1	3.7	0.0	3.1	2.5	0.5	0.3	1.7	1.5	0.3	0.3	0.3	0.4	3.3
Mar.	6.1	6.7	6.6	6.5	6.8	4.0	3.8	6.5	3.5	0.0	3.4	2.9	0.5	0.3	2.1	4.2	0.3	0.4	0.0	0.3	3.6
	10.5	9.0	9.0	9.2	8.9	6.8	5.9	9.3	5.3	5.3	4.6	4.0	0.4	0.6	2.9	7.9	0.6	0.8	0.0	0.3	5.3
Apr.	12.7	14.3	12.5	12.8	10.2	9.6	9.0	11.0	8.7	7.8	8.5	7.5	0.6	0.4	6.2	8.3	2.0	2.0	0.0	0.4	7.6
	5.2	6.1	6.0	5.3	5.5	2.4	2.0	1.5	4.1	0.3	4.9	4.4	0.2	0.2	5.2	0.8	0.1	0.2	0.0	0.2	2.9
May	6.0	6.4	6.5	6.1	5.9	3.4	2.8	3.1	3.7	1.3	2.8	3.7	0.5	0.5	4.5	2.9	0.5	0.5	0.0	0.5	3.2
	9.7	12.2	12.9	7.6	7.3	8.7	8.3	8.5	7.4	6.4	7.0	5.6	0.4	0.5	4.6	8.5	1.1	1.0	0.0	0.6	6.2
June	6.4	6.3	5.0	4.0	2.4	0.8	1.2	1.6	2.5	0.3	2.8	2.6	0.3	0.2	2.1	1.3	0.2	0.2	0.0	0.2	2.1
	7.6	5.8	5.7	6.0	6.6	1.7	1.1	1.6	1.8	1.2	0.0	2.5	0.5	0.2	3.5	1.8	0.6	0.6	0.0	0.1	2.7
July	3.8	6.4	5.6	5.2	3.8	1.7	1.4	1.7	2.1	2.8	2.1	2.5	0.3	0.6	2.8	0.6	0.3	0.2	0.0	0.1	2.3
	2.9	2.8	2.5	2.4	2.3	1.6	1.5	1.9	1.9	1.6	2.0	2.3	0.4	0.6	2.5	1.9	0.4	0.7	0.0	0.4	1.7
Aug.	10.4	9.5	6.5	5.2	4.4	3.5	3.6	4.4	3.3	2.6	2.4	2.3	0.4	0.7	2.5	4.4	1.1	3.9	0.0	0.7	3.8
	9.4	9.2	7.9	7.5	6.5	7.4	7.3	7.6	4.9	3.9	3.7	2.3	1.3	2.4	2.8	7.9	4.2	4.5	0.0	2.4	5.4
Sept.	13.1	11.5	8.4	8.0	6.7	9.3	7.2	10.4	4.7	4.6	4.4	3.8	1.1	2.2	3.2	6.7	4.2	4.3	0.0	1.7	6.1
	9.7	9.4	9.2	9.1	9.0	7.3	9.6	4.2	6.2	0.7	6.0	6.3	0.2	0.2	6.5	6.0	0.2	0.2	0.0	0.3	5.3
Oct.	8.5	8.9	7.7	7.8	6.8	5.7	4.1	6.2	5.1	4.6	5.0	5.0	0.2	0.2	5.8	2.6	0.2	0.2	0.0	0.2	4.4
	11.7	8.6	9.0	9.4	8.9	5.6	3.9	4.0	3.7	2.2	3.9	4.9	0.4	0.2	5.6	6.2	0.3	0.4	0.0	0.2	4.7
Nov.	6.6	6.4	6.7	7.2	6.5	3.2	2.4	1.8	3.1	0.0	2.9	4.2	0.4	0.2	5.0	1.0	0.2	0.2	0.0	0.2	3.2
	1.5	1.7	1.9	1.8	0.2	0.2	0.3	0.1	0.6	0.1	0.4	0.5	0.1	0.1	0.5	0.2	0.1	0.1	0.0	0.1	0.5
Dec.	1.9	1.8	1.6	1.7	1.5	3.8	1.9	3.3	0.0	0.3	0.0	0.0	0.1	0.2	0.0	5.0	0.1	0.1	0.0	0.1	1.5
	5.6	3.0	3.0	3.1	3.0	0.5	0.3	1.4	0.9	0.2	0.9	0.9	0.3	0.2	0.9	1.5	0.2	0.2	0.0	0.2	1.4
Jan.	1.7	1.3	1.2	1.2	0.8	0.5	0.5	0.4	0.3	0.1	0.4	0.4	0.1	0.3	0.5	0.9	0.2	0.1	0.0	0.1	0.6
	0.2	0.4	0.1	1.0	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.2
Feb.	0.2	0.2	0.2	0.5	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1
	0.3	1.3	1.4	1.7	0.1	0.2	0.3	0.3	0.2	0.2	0.2	0.4	0.1	0.2	0.3	0.2	0.2	0.2	0.0	0.2	0.4
Mar.	0.4	0.3	0.7	0.4	0.1	0.1	0.2	0.1	0.1	0.1	0.4	0.7	0.1	0.1	0.4	0.1	0.1	0.1	0.0	0.1	0.2
	0.2	0.2	0.1	0.9	0.1	0.1	0.3	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1
Apr.	0.2	0.3	0.2	0.3	0.1	0.0	0.3	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1
	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0
May	0.2	0.2	0.2	0.3	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.0	0.1	0.1
	0.2	0.1	0.1	0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1
Mean	5.0	4.8	4.2	3.9	3.4	2.7	2.4	2.9	2.2	1.3	2.1	2.0	0.3	0.4	2.2	2.4	0.5	0.7	0.4	0.3	2.3

TABLE 2. Temperature values (°C) from all stations sampled from March 1966 through May 1968. (Note: 0.0 indicates that no sample was taken.)

Month	A	B	C	D	E	F	G	I	K	L	M	O	S	T	U	H	J	J[1]	P	R	Mean
Mar.	17.0	18.0	18.0	18.0	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	23.0	24.0	21.0	21.0	20.0	0.0	0.0	0.0	0.0	20.0	20.0	21.6
Apr.	21.0	21.0	22.5	24.0	23.5	22.0	21.0	18.5	21.0	0.0	24.0	23.0	17.5	19.0	0.0	19.0	19.0	0.0	19.0	18.0	20.7
	22.0	23.0	23.0	22.0	23.0	21.0	21.0	21.0	23.0	22.0	24.0	22.0	18.5	20.0	0.0	20.0	20.0	0.0	20.0	20.0	21.4
May	22.0	0.0	23.0	0.0	22.0	21.0	21.0	21.0	21.0	22.0	21.0	0.0	20.0	20.0	0.0	21.0	21.0	0.0	21.0	21.0	21.2
	0.0	0.0	27.0	27.0	27.0	26.0	26.0	26.0	26.0	27.0	27.0	0.0	25.0	26.0	0.0	26.0	25.0	0.0	0.0	25.0	26.1
June	0.0	0.0	0.0	0.0	0.0	28.0	28.0	29.0	28.0	28.0	28.0	0.0	26.0	27.0	0.0	28.0	27.0	0.0	27.0	27.0	27.5
	28.0	27.0	20.0	28.0	28.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.8
	28.0	27.0	21.0	27.0	27.0	30.0	31.0	0.0	27.0	27.0	27.0	26.0	27.0	28.0	0.0	31.0	29.0	0.0	29.0	28.0	27.6
July	32.0	31.0	31.0	29.0	27.0	31.0	30.0	30.0	27.0	30.0	27.0	28.0	30.0	29.0	0.0	30.0	29.0	0.0	29.0	29.0	29.2
	33.0	33.0	33.0	35.5	32.0	33.0	33.0	31.0	33.0	32.0	33.0	32.0	30.0	31.0	0.0	31.0	30.0	0.0	31.0	30.0	32.0
Aug.	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	28.0	28.0	28.0	29.0	29.0	30.0	0.0	27.0	23.0	0.0	29.0	28.0	27.8
	29.0	30.0	30.5	30.0	30.0	29.5	29.5	30.0	31.0	31.0	31.0	31.0	29.0	30.0	0.0	30.0	30.5	0.0	30.5	31.0	30.1
Sept.	32.0	31.5	30.0	31.5	30.0	29.0	29.5	29.0	31.5	32.5	31.5	32.0	27.0	28.5	0.0	28.5	28.5	0.0	28.5	28.5	29.9
	27.5	26.5	28.0	29.0	27.5	26.5	26.0	25.5	28.0	27.0	28.0	27.0	24.5	25.0	0.0	25.5	25.5	0.0	25.0	25.0	26.4
Oct.	23.5	21.0	22.0	23.0	24.0	22.0	22.5	21.0	24.5	23.0	23.5	23.0	24.5	24.5	24.0	21.5	24.5	0.0	24.5	24.5	23.3
	19.0	19.0	20.0	20.5	20.0	19.0	20.0	18.5	20.0	21.0	21.5	21.0	18.0	18.0	20.5	18.0	18.0	0.0	18.0	18.0	19.3
Nov.	16.0	16.0	16.0	19.5	17.0	15.5	16.0	16.5	15.0	17.0	18.5	16.5	17.0	17.0	17.5	16.0	16.5	0.0	17.0	16.5	16.6
	21.5	22.5	22.5	23.0	22.5	21.5	21.0	21.0	22.0	22.5	23.5	22.0	21.0	19.5	22.0	20.0	13.0	0.0	19.5	19.5	21.3
Dec.	17.0	17.0	17.0	16.5	16.5	17.5	17.0	17.5	16.5	16.5	16.5	16.5	17.5	17.5	16.5	17.5	0.0	17.5	17.5	17.5	17.0
	13.5	12.0	12.0	11.5	12.0	12.0	11.5	12.5	12.0	12.5	12.5	12.5	11.5	12.0	12.5	12.5	12.5	0.0	12.5	12.0	12.2
Jan.	11.0	10.0	10.0	10.0	10.0	10.5	9.0	10.0	9.5	10.0	8.5	9.5	8.0	10.0	9.5	10.5	10.0	0.0	10.0	10.0	9.7
	11.5	11.5	12.5	14.5	13.0	12.0	12.5	11.5	14.0	14.0	13.5	13.0	13.5	15.0	13.5	12.0	14.5	0.0	15.0	15.0	13.2
Feb.	14.5	14.5	15.5	17.0	16.5	14.5	15.0	13.5	15.5	17.5	16.5	15.5	12.0	11.5	16.0	12.0	11.5	0.0	11.5	11.5	14.3
	12.0	12.0	11.5	13.0	12.0	10.0	10.0	10.5	12.5	0.0	14.0	12.0	5.0	13.5	12.5	14.0	14.5	14.5	13.5	13.5	12.1
Mar.	21.0	19.5	21.0	22.5	22.5	20.0	20.0	19.0	20.5	0.0	21.5	20.5	19.0	15.5	21.5	19.0	15.5	15.5	0.0	15.5	19.4
	17.0	17.0	16.0	17.5	17.5	17.0	14.5	15.5	19.0	23.0	19.0	18.5	14.0	21.5	20.5	16.0	21.0	21.0	0.0	21.5	18.2
Apr.	24.5	24.5	25.0	27.0	25.0	23.5	25.0	23.0	25.5	27.0	26.5	26.5	22.0	25.0	26.5	23.0	24.5	24.5	0.0	25.0	24.9
	26.0	26.0	27.5	27.0	27.0	25.0	25.0	25.0	27.5	27.0	28.0	27.5	25.0	25.0	27.5	25.0	25.0	25.0	0.0	25.0	26.1
May	24.0	23.0	23.0	24.0	24.0	22.0	22.0	22.0	24.0	25.0	24.0	24.0	21.5	21.0	24.5	21.5	21.0	21.0	0.0	21.0	22.7
	23.5	24.0	25.0	24.5	24.5	26.0	24.5	25.0	25.0	24.5	25.0	26.0	25.0	27.0	25.5	25.0	26.0	26.0	0.0	27.0	25.2
June	28.0	26.0	28.0	28.0	29.0	26.0	26.0	27.0	29.5	29.5	30.5	29.5	25.0	26.0	30.5	26.0	25.5	25.5	0.0	26.0	27.4
	34.0	31.5	31.0	31.0	34.0	32.5	30.0	29.5	33.0	34.0	33.0	33.0	29.5	31.0	35.0	29.0	31.0	31.0	0.0	30.5	31.7
July	33.0	30.5	30.5	31.0	32.5	30.0	30.0	30.0	32.5	33.0	32.0	32.0	29.0	31.5	33.0	30.0	31.5	31.5	0.0	31.5	31.3
	26.5	26.0	27.0	27.0	28.0	26.5	26.0	26.0	28.5	28.0	28.5	28.5	25.5	28.0	28.0	26.0	28.0	28.0	0.0	28.0	27.2
Aug.	31.0	30.5	31.0	31.0	33.0	29.5	29.5	29.5	32.5	32.0	32.5	31.5	29.0	31.0	31.5	30.0	30.5	30.5	0.0	31.5	30.9
	26.0	26.0	27.0	26.5	26.0	27.0	27.0	27.0	26.5	26.5	27.0	27.0	26.0	29.0	27.0	27.0	28.0	28.0	0.0	29.0	27.0
Sept.	27.0	28.0	29.0	31.0	29.0	28.0	26.5	26.0	28.0	30.0	30.0	29.5	25.0	27.0	30.5	27.0	27.0	27.0	0.0	27.5	28.0
	28.5	29.0	29.0	30.0	29.5	27.0	27.0	26.0	29.5	29.0	30.0	27.5	26.5	27.0	27.5	27.0	27.0	27.0	0.0	27.0	27.8
Oct.	25.0	25.5	26.0	26.5	27.0	25.4	25.0	24.5	27.0	27.0	27.5	27.5	25.0	25.0	27.0	25.0	25.0	25.0	0.0	25.0	25.8
	22.0	20.5	22.5	22.0	23.0	21.0	20.0	20.0	21.5	23.5	24.0	20.0	20.0	20.0	20.0	20.0	20.5	20.5	0.0	20.0	21.1
Nov.	14.0	12.0	14.0	16.0	15.0	12.0	11.0	11.5	14.0	0.0	16.0	15.0	9.0	15.0	16.0	14.0	15.0	15.0	0.0	15.0	13.8
	20.0	20.0	21.0	21.5	19.0	18.0	18.5	17.0	20.0	17.5	20.5	20.5	15.0	15.0	20.0	17.0	15.0	15.0	0.0	15.0	18.1
Dec.	20.0	19.5	19.5	19.5	19.0	19.5	19.5	19.5	0.0	19.5	0.0	0.0	17.5	17.5	0.0	19.5	17.5	17.5	0.0	17.5	18.8
	12.0	11.5	12.0	12.0	11.5	14.0	11.5	13.5	13.0	13.0	12.0	13.5	11.0	14.5	12.0	13.0	14.5	14.5	0.0	15.0	12.8
Jan.	10.0	10.0	10.0	11.5	11.0	9.5	10.0	9.5	10.0	10.5	11.0	10.5	9.0	9.0	11.0	9.5	9.0	9.0	0.0	9.0	9.9
	12.0	12.0	11.5	13.5	11.5	12.5	13.5	12.0	12.0	10.5	12.0	11.0	11.5	8.5	11.0	12.5	8.5	8.5	0.0	8.0	11.1
Feb.	11.0	11.5	11.5	12.0	12.0	11.5	11.0	11.0	12.0	12.0	12.5	12.5	11.0	12.0	12.5	11.5	12.0	12.0	0.0	12.0	11.7
	6.0	6.0	7.5	9.0	9.5	4.5	3.0	5.0	7.5	13.0	10.0	8.0	2.5	7.5	8.0	4.0	7.5	7.5	0.0	8.0	7.0
Mar.	16.5	17.5	19.0	19.0	18.5	15.0	15.5	13.0	19.5	15.0	20.0	18.5	11.5	12.0	19.5	12.0	10.5	10.5	0.0	12.0	15.5
	13.2	13.0	14.0	14.0	14.0	13.0	10.0	13.0	16.0	14.0	16.0	16.0	12.0	13.0	17.0	12.0	14.0	14.0	0.0	13.0	13.7
Apr.	18.0	18.5	19.0	20.0	21.0	17.0	16.0	17.0	20.0	19.5	20.0	21.5	18.0	18.0	21.5	17.0	18.0	18.0	0.0	18.5	18.7
	26.0	26.5	25.5	25.5	26.0	23.0	23.5	24.0	25.0	25.0	0.0	0.0	24.0	22.5	24.5	24.0	22.5	22.5	0.0	22.5	21.2
May	24.0	24.0	25.5	26.5	26.0	24.5	22.5	22.5	26.0	26.5	27.5	26.0	23.5	22.5	27.5	23.0	22.5	22.5	0.0	23.0	24.5
	23.5	24.0	24.5	24.5	25.5	23.5	24.0	24.0	25.0	26.0	25.0	26.0	26.0	24.0	25.0	24.0	24.0	24.0	0.0	0.0	24.5
Mean	21.5	21.2	21.7	22.4	22.1	21.2	20.8	20.5	22.3	22.9	22.8	22.0	20.0	21.0	21.1	20.7	21.0	20.2	21.2	20.9	21.4

TABLE 3. Total Kjeldahl nitrogen values (µg at/l) from all stations sampled from March 1966 through May 1968. (Note: 0.0 indicates that no sample was taken.)

Month	A	B	C	D	E	F	G	I	K	L	M	O	S	T	U	H	J	J^1	P	R	Mean
Mar.	73.5	42.9	50.9	50.5	36.0	46.2	60.5	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.7	49.1	0.0	0.0	0.0	47.5
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.2	41.0	45.1	37.0	51.0	03.1	0.0	0.0	0.0	0.0	33.8	43.5	39.8
Apr.	44.2	45.0	48.1	48.7	49.6	38.1	47.3	56.3	37.2	0.0	35.7	32.2	80.7	70.4	0.0	36.1	45.2	0.0	56.1	61.5	48.9
	54.5	25.0	39.5	43.0	52.5	0.0	27.0	37.0	0.0	43.5	26.0	39.5	34.5	45.0	0.0	44.5	27.5	0.0	0.0	30.5	37.9
May	0.0	0.0	55.5	0.0	78.0	61.5	63.0	0.0	75.5	55.0	57.5	0.0	71.5	96.5	0.0	51.0	51.0	0.0	60.0	0.0	64.6
	0.0	0.0	34.0	117.5	32.5	23.0	39.0	34.0	37.5	34.5	0.0	0.0	58.5	0.0	0.0	45.5	25.5	0.0	0.0	44.0	43.7
June	0.0	0.0	0.0	0.0	0.0	0.0	51.0	26.5	44.0	13.0	40.5	0.0	40.5	31.5	0.0	47.5	50.0	0.0	34.5	39.0	38.0
	47.5	37.0	0.0	43.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.6
	63.0	38.0	46.0	37.0	31.5	29.5	24.0	06.5	54.5	0.0	21.0	39.5	0.0	27.0	0.0	21.5	26.0	0.0	30.5	15.7	31.9
July	48.5	40.0	54.0	35.0	33.5	18.0	33.5	28.5	65.0	21.0	47.0	44.5	47.5	22.5	0.0	25.5	22.5	0.0	26.5	21.5	35.2
	37.5	0.0	53.6	44.5	45.5	38.5	51.0	0.0	46.2	39.5	33.2	65.0	63.5	06.0	0.0	0.0	23.0	0.0	07.5	28.0	38.8
Aug.	44.0	0.0	65.0	63.0	0.0	56.0	0.0	51.0	59.0	0.0	50.0	0.0	78.0	53.0	0.0	0.0	0.0	0.0	64.0	54.0	57.9
	52.2	0.0	0.0	0.0	57.0	37.0	33.0	53.0	50.0	52.0	0.0	0.0	0.0	42.0	0.0	0.0	0.0	0.0	05.0	36.0	41.7
Sept.	0.0	55.5	0.0	56.0	0.0	0.0	0.0	0.0	47.5	0.0	0.0	0.0	91.8	0.0	0.0	0.0	0.0	0.0	54.8	0.0	61.1
	69.1	62.7	64.8	70.0	72.9	58.4	39.2	47.5	58.4	46.1	59.6	64.6	84.7	45.2	0.0	35.5	34.9	0.0	35.0	110.0	58.2
Oct.	84.5	65.0	86.5	92.5	72.0	69.7	71.5	63.2	81.5	71.7	69.8	74.6	60.3	49.5	73.5	40.9	16.3	0.0	41.9	40.8	64.5
	71.8	63.0	61.4	70.6	61.0	47.7	51.5	69.5	51.5	0.0	0.0	0.0	0.0	44.5	35.5	49.8	39.0	0.0	34.5	34.5	52.3
Nov.	107.0	89.0	83.5	80.5	55.0	53.5	66.0	76.5	61.0	78.5	63.0	54.5	0.0	101.0	0.0	47.5	0.0	0.0	0.0	0.0	72.6
	63.0	77.0	52.5	61.0	40.5	11.5	0.0	41.0	57.5	45.5	23.5	32.5	0.0	0.0	0.0	45.5	60.0	0.0	12.5	64.5	45.8
Dec.	50.0	75.5	110.5	91.5	83.0	64.5	0.0	119.0	63.5	53.5	45.0	44.0	88.5	108.5	0.0	115.5	108.5	0.0	118.0	94.5	84.3
	69.0	67.0	54.5	100.0	54.0	66.5	49.5	40.0	72.0	58.0	53.5	65.5	113.0	64.0	41.5	67.0	59.0	0.0	0.0	62.0	64.2
Jan.	67.5	51.5	113.5	106.0	91.0	70.0	75.5	69.5	70.0	70.0	74.5	49.5	82.5	72.0	48.0	75.5	84.5	0.0	87.5	79.0	75.6
	42.0	60.0	66.5	66.0	104.5	96.0	58.0	82.0	75.0	66.0	65.5	57.0	118.5	97.5	0.0	76.5	102.0	0.0	0.0	101.0	78.4
Feb.	90.0	79.5	74.0	85.5	105.5	66.0	97.5	64.0	69.0	59.5	88.0	63.5	78.5	74.0	42.0	109.0	80.0	0.0	73.0	94.5	78.5
	87.2	77.8	62.4	81.8	72.1	79.8	76.3	64.0	55.8	0.0	65.3	47.0	61.0	86.6	43.9	52.9	66.9	0.0	89.2	86.2	69.7
Mar.	78.1	77.7	86.2	70.9	64.6	61.8	57.0	86.8	60.0	0.0	88.0	58.0	65.9	72.9	50.8	69.4	91.8	67.9	0.0	69.5	70.9
	77.9	80.7	89.7	87.7	83.1	69.7	46.7	86.5	84.7	86.8	79.0	83.1	96.0	79.4	71.7	83.9	63.5	76.1	0.0	73.5	78.9
Apr.	84.8	68.3	87.2	115.5	88.7	71.0	93.2	68.5	105.0	98.8	112.1	93.3	138.1	0.0	94.0	0.0	106.8	116.5	0.0	128.2	98.2
	59.6	56.8	62.6	80.2	64.7	68.7	116.2	48.1	51.3	49.1	51.4	79.0	115.0	0.0	70.2	44.4	49.8	93.0	0.0	74.2	68.5
May	61.8	64.6	70.1	53.8	94.0	54.9	53.6	53.0	95.8	69.2	63.8	143.2	86.0	53.0	94.5	49.7	36.5	40.1	0.0	50.0	67.7
	60.9	71.0	71.3	76.3	63.1	52.3	74.8	61.9	61.4	77.1	74.5	73.5	81.3	64.6	74.1	90.5	70.5	0.0	0.0	61.0	70.0
June	85.7	67.0	86.1	83.3	61.6	62.1	66.1	74.2	102.9	60.5	81.5	99.8	86.3	78.9	81.9	90.1	54.1	90.1	0.0	54.8	77.2
	96.7	117.0	110.9	124.2	102.8	99.8	52.1	59.9	69.0	76.0	70.8	100.1	70.0	59.6	109.8	52.5	30.0	58.8	0.0	42.9	79.1
July	87.2	81.9	116.7	105.4	41.7	90.2	63.1	76.3	67.6	110.0	82.0	96.3	95.0	53.1	101.8	59.5	64.7	57.3	0.0	88.2	80.9
	64.6	71.2	49.6	61.4	63.6	103.7	58.9	69.7	70.0	0.0	0.0	44.8	84.2	0.0	50.4	69.1	78.1	63.3	0.0	69.4	67.0
Aug.	86.5	112.5	115.2	133.7	103.9	110.7	82.5	72.3	109.5	101.8	136.2	93.5	116.2	64.8	116.6	83.5	60.7	105.2	0.0	49.3	97.6
	92.8	129.2	110.2	163.0	102.2	98.1	118.2	78.6	112.1	101.9	116.5	0.0	84.8	94.1	125.5	97.6	75.0	90.2	0.0	89.0	104.3
Sept.	71.6	89.6	154.7	114.0	169.2	85.3	88.1	90.0	128.1	119.2	79.8	129.5	77.8	93.5	177.5	73.3	91.0	79.6	0.0	107.5	106.2
	93.2	107.5	124.6	110.7	122.4	110.6	86.7	83.8	95.9	62.3	106.7	98.1	79.6	77.3	100.8	92.2	71.2	90.9	0.0	74.3	94.1
Oct.	96.2	102.7	107.6	119.5	121.7	62.4	103.2	80.2	92.0	89.8	106.8	112.3	65.4	54.5	113.2	54.2	54.6	52.2	0.0	51.1	86.2
	88.9	131.2	189.8	192.7	177.0	79.2	82.6	85.0	108.7	74.3	113.5	145.0	101.8	85.1	0.0	79.8	40.0	71.1	0.0	92.5	107.6
Nov.	143.0	142.2	129.6	173.1	162.1	96.1	85.0	79.4	85.5	0.0	73.4	125.0	133.0	62.8	122.5	73.0	71.5	55.9	0.0	66.4	104.4
	50.2	56.0	61.1	64.1	[illegible]	13.9	12.4	12.2	45.5	52.1	41.7	47.7	44.3	37.5	51.8	18.0	49.2	40.5	0.0	17.0	45.9
Dec.	43.0	52.6	46.0	73.3	51.4	43.7	68.2	56.7	0.0	40.8	0.0	0.0	67.2	44.4	0.0	67.2	47.4	56.0	0.0	48.3	54.5
	76.4	0.0	80.4	96.0	71.9	45.7	41.1	0.0	0.0	46.0	59.5	49.3	0.0	73.5	45.5	45.9	0.0	0.0	0.0	0.0	61.3
Jan.	44.4	108.2	60.1	115.9	17.1	48.9	39.3	15.6	48.9	57.6	50.6	21.5	47.5	53.2	51.3	0.0	55.6	56.0	0.0	46.3	54.3
	37.4	0.0	0.0	45.0	12.0	0.0	55.4	63.2	0.0	50.0	59.0	0.0	0.0	0.0	41.1	0.0	48.4	0.0	0.0	46.2	48.7
Feb.	47.0	50.6	40.2	65.1	50.7	42.0	59.5	92.5	30.3	39.9	43.9	39.9	57.2	47.5	44.3	51.6	43.2	51.0	0.0	36.9	49.1
	48.4	79.9	80.5	86.0	37.3	54.1	58.6	48.7	51.2	53.6	49.1	49.7	43.5	48.7	47.8	39.8	51.0	57.2	0.0	52.0	54.5
Mar.	49.8	83.5	56.0	39.2	43.5	41.1	50.5	42.7	51.5	67.3	54.4	54.7	50.1	42.2	41.5	50.3	61.0	46.5	0.0	53.1	51.5
	89.4	51.5	98.2	59.6	50.8	0.0	61.2	56.6	43.8	0.0	50.0	38.1	58.1	43.8	42.4	0.0	47.9	32.1	0.0	0.0	54.9
Apr.	46.5	62.2	48.8	78.6	0.0	47.3	63.5	46.5	78.4	53.2	57.0	57.2	54.0	45.3	56.3	0.0	54.5	44.3	0.0	0.0	55.8
	55.4	49.9	47.1	52.6	54.2	50.7	48.7	52.2	61.3	42.5	0.0	0.0	98.6	42.6	45.9	56.1	34.1	50.0	0.0	83.1	53.8
May	47.2	43.9	58.2	60.5	33.9	45.6	46.2	30.7	35.6	36.3	35.7	44.5	55.9	34.0	0.0	46.3	33.5	30.4	0.0	32.2	42.1
	45.4	42.7	0.0	41.3	50.9	46.1	40.0	43.8	35.0	50.5	47.6	39.2	46.0	39.1	55.5	42.2	34.7	33.3	0.0	0.0	43.1
Mean	67.7	61.8	77.2	82.1	71.7	60.7	61.6	59.6	66.8	60.8	64.0	67.3	76.1	50.3	61.6	59.1	53.8	64.7	48.0	61.2	65.8

TABLE 4. Total phosphorus values (μg at/l) from all stations sampled from March 1966 through May 1968. (Note: 0.0 indicates that no sample was taken.)

Month	A	B	C	D	E	F	G	I	K	L	M	O	S	T	U	H	J	J[1]	P	R	Mean
Mar.	3.6	4.0	3.5	2.9	4.1	4.4	4.6	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0	0.0	0.0	4.1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	3.9	2.4	2.8	3.2	10.9	0.0	0.0	0.0	0.0	11.2	11.3	6.1
Apr.	2.1	1.6	1.4	1.4	1.8	3.3	2.7	7.7	2.3	0.0	2.2	6.0	3.3	15.4	0.0	3.5	14.0	0.0	17.4	14.9	5.9
	3.0	1.5	1.1	1.9	0.0	3.0	2.2	2.3	2.1	1.3	2.9	3.9	2.2	6.1	0.0	1.8	6.0	0.0	5.7	6.0	3.1
May	0.0	0.0	3.8	0.0	3.8	3.9	8.3	3.5	0.0	6.6	5.7	0.0	0.0	3.3	0.0	3.1	3.6	0.0	2.9	3.5	4.3
	0.0	0.0	3.2	3.2	3.5	2.9	3.4	3.2	2.3	3.5	0.0	0.0	0.0	0.0	0.0	3.0	3.0	0.0	0.0	0.0	3.1
June	0.0	0.0	0.0	0.0	0.0	2.9	2.6	3.0	2.8	0.0	3.3	0.0	1.4	3.0	0.0	3.0	3.2	0.0	0.0	2.8	2.8
	3.7	0.0	3.2	2.9	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2
	3.7	3.1	3.1	2.9	3.6	4.1	3.6	2.9	4.2	3.3	3.3	2.4	3.1	3.8	0.0	2.1	3.8	0.0	3.8	3.7	3.3
July	5.4	5.4	11.6	5.8	5.0	5.9	5.9	5.4	0.0	4.9	5.9	5.0	5.8	6.0	0.0	0.0	5.8	0.0	6.4	9.5	6.2
	2.0	2.1	1.2	1.5	1.5	2.1	2.8	2.9	2.8	2.2	2.8	2.0	5.9	3.6	0.0	3.0	3.3	0.0	0.0	3.1	2.6
Aug.	14.2	10.4	5.5	6.0	9.3	7.2	8.0	8.0	4.9	5.4	5.3	6.0	13.6	3.7	0.0	6.9	14.0	0.0	12.6	7.4	8.2
	5.5	6.2	5.1	6.0	5.9	7.0	6.3	6.8	0.0	7.0	6.5	4.8	9.4	0.0	0.0	6.3	6.3	0.0	5.9	5.9	6.3
Sept.	0.0	5.8	5.1	5.0	5.8	0.0	0.0	0.0	6.7	7.4	6.4	7.0	7.9	10.1	0.0	0.0	10.1	0.0	0.0	9.4	7.2
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct.	50.0	15.6	15.5	14.5	14.0	15.7	0.0	14.7	13.8	11.0	14.2	11.9	18.2	17.8	7.0	16.5	18.2	0.0	18.7	12.8	16.7
	9.4	8.8	8.9	4.1	10.3	10.5	10.6	10.7	9.3	8.1	8.2	6.1	4.9	9.7	2.0	10.2	9.4	0.0	9.6	10.5	8.5
Nov.	11.0	9.9	9.1	9.7	9.8	9.6	9.9	10.6	9.6	5.0	7.1	6.5	7.6	0.0	0.0	9.4	6.0	0.0	0.0	8.3	8.7
	7.5	4.2	3.7	4.0	3.4	4.8	4.2	6.7	3.0	3.4	3.0	2.3	0.0	7.9	1.6	7.5	8.4	0.0	8.4	9.2	5.2
Dec.	7.8	5.6	5.0	4.0	5.2	8.3	7.0	8.6	2.5	3.0	3.5	2.8	16.2	17.0	2.9	12.9	0.0	17.2	18.1	17.8	8.7
	7.1	6.1	6.1	4.5	7.2	16.5	13.1	20.5	4.7	3.8	4.6	2.6	20.9	26.5	2.2	15.9	23.5	0.0	23.3	21.1	12.1
Jan.	21.4	14.8	12.0	9.7	17.4	24.5	21.6	21.2	10.3	24.0	7.4	5.0	24.6	26.8	2.5	22.9	25.8	0.0	27.0	26.0	18.1
	12.4	13.7	10.4	10.1	15.0	15.8	20.8	12.7	14.6	10.5	12.9	8.0	0.0	0.0	4.4	19.1	0.0	0.0	0.0	0.0	12.9
Feb.	13.3	7.0	11.9	6.1	12.1	18.7	17.7	23.8	11.6	0.0	10.9	7.6	29.4	31.2	2.6	29.5	31.7	0.0	0.0	32.5	17.5
	11.2	9.5	8.5	6.1	7.7	11.9	13.0	20.5	9.1	0.0	5.6	4.6	3.7	29.5	2.9	21.8	35.6	30.4	26.4	25.2	14.9
Mar.	12.9	9.9	7.3	9.6	9.0	11.1	12.1	21.0	9.4	0.0	7.7	5.8	4.0	35.0	4.9	16.3	35.0	35.0	0.0	35.0	15.6
	16.0	11.9	10.5	10.0	10.3	10.5	12.0	15.9	10.4	10.4	8.4	6.7	14.8	20.5	5.0	13.2	23.1	24.2	0.0	23.7	13.5
Apr.	9.5	8.3	6.4	6.1	6.2	11.4	7.0	12.0	5.9	4.8	5.8	5.8	12.1	27.8	5.7	14.1	23.2	22.8	0.0	27.3	11.6
	8.1	7.0	6.6	7.8	5.2	8.6	10.3	11.3	3.8	11.5	3.9	4.2	13.5	15.3	4.5	14.1	15.0	15.5	0.0	15.1	9.5
May	9.0	6.9	4.4	3.0	3.0	8.0	7.7	9.8	5.1	11.5	7.9	5.6	5.2	9.4	2.9	9.2	9.4	8.3	0.0	8.2	7.1
	0.0	7.8	8.0	4.8	4.7	5.8	4.4	8.4	4.8	5.4	5.0	4.2	5.8	15.5	3.4	9.2	12.4	12.4	0.0	15.7	7.7
June	7.6	7.3	5.4	5.6	10.1	23.8	21.1	17.7	5.4	17.6	5.8	4.8	7.6	23.4	3.9	20.8	27.2	23.8	0.0	22.4	13.7
	6.5	5.5	5.5	5.1	5.5	3.8	5.3	0.0	3.7	3.4	3.9	3.3	10.8	7.3	2.7	4.2	6.3	5.6	0.0	6.8	5.3
July	8.2	9.8	6.4	7.0	7.5	6.6	7.0	8.4	0.0	6.1	6.6	5.4	16.6	10.1	5.2	9.0	10.1	9.3	0.0	8.5	8.2
	8.3	7.2	6.5	7.9	5.8	7.4	6.9	8.0	5.2	5.5	5.7	4.2	13.0	9.4	2.3	7.8	8.9	9.9	0.0	10.8	7.4
Aug.	10.7	9.8	8.8	7.4	9.1	11.0	11.1	13.9	0.0	10.5	8.4	8.8	17.8	11.0	10.6	11.2	12.4	9.6	0.0	13.8	10.8
	7.6	9.2	8.9	11.2	10.5	11.0	9.7	10.3	13.1	7.8	8.7	9.7	13.3	7.1	8.6	13.0	10.0	10.4	0.0	9.0	9.9
Sept.	12.0	12.8	11.5	10.1	10.6	11.3	10.2	14.1	9.4	9.4	9.4	9.2	7.1	16.3	7.8	9.2	12.7	11.3	0.0	14.9	11.0
	9.8	10.2	11.2	10.0	10.0	9.4	6.0	17.0	8.1	28.7	7.5	6.4	48.7	50.7	5.8	12.9	48.4	46.2	0.0	49.6	20.8
Oct.	20.9	15.9	15.2	14.4	13.5	16.8	17.6	18.8	13.3	10.6	14.2	10.2	20.6	25.8	7.3	24.7	23.0	24.2	0.0	22.8	17.3
	17.1	12.8	11.2	12.8	13.3	16.5	15.4	19.7	11.4	5.6	10.5	8.1	16.4	22.0	5.1	17.6	24.4	24.3	0.0	23.0	15.1
Nov.	6.9	9.7	9.0	8.5	9.9	7.8	9.0	10.0	7.9	0.0	5.6	5.5	7.0	14.0	5.6	10.9	11.5	9.2	0.0	8.7	8.7
	6.9	7.1	6.2	7.9	9.7	7.1	8.2	8.5	6.8	9.3	5.3	4.7	0.0	6.1	4.4	8.5	0.0	6.9	0.0	8.6	7.2
Dec.	7.4	9.0	9.8	7.9	11.0	10.6	0.0	13.6	0.0	6.9	0.0	0.0	15.0	16.0	0.0	11.2	16.2	15.8	0.0	14.7	11.7
	11.5	8.1	6.7	6.2	4.9	15.2	10.1	20.8	6.7	11.9	5.2	4.3	3.3	0.0	3.1	17.9	0.0	0.0	0.0	0.0	9.5
Jan.	10.4	8.7	8.7	9.1	10.2	10.3	10.6	0.0	9.4	12.0	8.5	7.0	12.1	0.0	4.0	10.8	11.4	11.8	0.0	12.9	9.8
	6.3	6.7	7.1	3.8	6.8	6.3	6.8	7.0	6.3	6.7	6.7	7.7	2.9	6.6	0.0	7.5	7.0	7.2	0.0	7.9	6.5
Feb.	6.6	6.2	6.4	4.9	6.8	0.0	6.2	6.2	0.0	6.7	6.0	6.6	3.5	6.6	8.5	6.7	6.4	9.1	0.0	6.4	6.4
	8.7	5.4	1.9	3.3	10.3	7.3	5.2	11.9	5.3	9.1	4.4	3.5	0.0	0.0	3.0	8.2	0.0	0.0	0.0	0.0	6.4
Mar.	9.0	8.8	5.9	8.0	9.4	8.8	7.2	9.3	7.9	9.4	4.6	2.6	8.3	9.6	2.6	9.0	9.2	9.3	0.0	9.4	7.8
	6.5	6.1	5.6	4.4	6.3	6.0	7.4	6.6	5.7	7.1	6.1	5.4	4.4	5.3	5.3	6.2	5.6	5.7	0.0	6.3	5.8
Apr.	4.9	4.3	5.0	2.2	5.3	4.0	5.7	4.3	4.0	4.3	3.5	4.2	7.5	4.2	3.9	4.3	4.3	5.2	0.0	4.5	4.2
	4.9	5.8	0.0	5.9	5.9	5.2	5.4	4.7	5.4	5.9	0.0	0.0	4.1	4.2	5.1	4.7	4.0	0.0	0.0	3.8	5.0
May	6.0	4.6	5.1	5.4	5.2	4.8	5.3	4.8	5.6	5.2	4.9	4.7	4.0	5.9	4.7	5.5	7.4	6.4	0.0	6.9	5.1
	6.3	6.7	6.7	4.9	7.2	6.4	5.6	5.7	5.8	7.0	6.3	5.7	4.7	5.9	6.3	6.3	5.7	6.1	0.0	0.0	[illegible]
Mean	9.6	7.8	7.0	6.4	7.7	9.1	8.8	10.6	6.8	7.9	6.3	5.5	10.4	13.8	4.6	10.5	13.5	14.9	13.1	13.5	[illegible]

TABLE 5. Number of blue crabs 20 mm in width or less taken in semimonthly marsh net samples.

Year	Station	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Annual Total
1966	A							5	9	0	0	0	0	0	3	1	0	13	0	1	0	3	2	2	3	42
	C							3	0	0	2	0	0	6	26	8	4	5	7	0	3	10	4	7	3	83
	D							0	1	0	0	0	0	0	0	1	5	12	12	0	1	0	0	0	0	32
	F							0	0	0	0	0	0	2	5	0	3	3	6	1	0	0	1	0	0	21
	G							0	3	0	0	0	0	5	0	0	7	11	10	2	1	0	3	1	0	43
	T							0	3	0	0	0	0	0	0	0	2	0	1	1	0	0	1	0	1	9
Totals								8	16	0	2			13	34	10	21	44	36	5	5	13	10	10	7	235
1967	A	1	1	1	1	2	0	2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	9	9	1	29
	C	0	0	0	14	1	5	7	1	0	0	0	1	0	0	4	3	5	0	2	15	1	0	1	0	60
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4	2	7
	F	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	4
	G	0	0	0	1	3	8	0	0	0	1	0	0	1	1	3	12	4	3	1	2	2	2	0	0	44
	T	1	0	0	0	0	0	0	1	0	0	0	0	0	3	3	1	0	0	0	0	0	0	0	0	9
Totals		2	1	1	16	6	13	9	3	0	1	0	2	1	6	11	18	9	3	3	17	3	11	14	3	152
1968	A	0	0	1	0	0	0	0	6	6	0															13
	C	1	1	3	1	1	1	2	6	2	4															22
	D	0	0	0	0	0	0	0	0	0	0															0
	F	0	0	1	0	3	0	0	1	1	0															6
	G	1	4	0	0	1	1	2	0	0	5															14
	T	0	0	0	0	0	0	0	0	0	0															0
Totals		2	5	5	1	5	2	4	13	9	9															55

TABLE 6. Semimonthly mean salinity at biological stations and semimonthly mean temperature at all stations.

Month	Mean Salinity (o/oo) Biological Stations		Mean Temperature (^{o}C) All Stations	
1966				
April	1.58	0.70	20.7	21.4
May	0.07	0.15	21.2	26.1
June	0.10	0.19	27.6	27.6
July	0.27	0.24	29.2	32.0
Aug.	0.44	0.72	27.8	30.1
Sept.	0.76	1.85	29.9	26.4
Oct.	3.33	2.07	23.3	19.3
Nov.	6.93	3.03	16.6	21.3
Dec.	5.33	5.39	17.0	12.2
1967				
Jan.	5.56	8.04	9.7	13.2
Feb.	4.37	4.89	14.3	12.1
Mar.	4.96	7.02	19.4	18.2
April	10.10	4.11	24.9	26.1
May	4.34	8.21	22.7	25.2
June	2.97	3.8	27.4	31.7
July	3.26	2.16	31.3	27.2
Aug.	4.69	6.18	30.9	27.0
Sept.	7.37	7.21	28.0	27.8
Oct.	6.29	6.30	25.8	21.1
Nov.	4.71	0.7	13.8	18.1
Dec.	1.97	1.87	18.8	12.8
1968				
Jan.	0.75	0.26	9.9	11.1
Feb.	0.16	0.53	11.7	7.0
Mar.	0.30	0.22	15.5	13.7
Apr.	0.18	0.07	18.7	24.2
May	0.15	0.10	24.5	24.5

TABLE 7. Data on all mature female blue crabs.

Date	Station	Size (mm)	Salinity (o/oo)	Temp. (°C)
1966				
June 4	F	151	0.09	28.0
June 18	K	168	0.12	27.0
June 18	K	180	0.12	27.0
June 18	M	141	0.14	27.0
June 18	M	161	0.14	27.0
July 1	E	156	0.22	27.0
July 1	G	158	0.21	30.0
July 15	S	188	0.20	30.0
Sept. 24	D	169	1.70	28.0
Sept. 24	D	175	1.70	28.0
Sept. 24	F	152	0.40	26.5
Nov. 19	E	156	3.30	22.5
1967				
April 8	C	171	12.40	25.0
April 22	K	169	4.19	27.5
April 22	L	140	0.35	27.0
May 6	F	138	3.43	22.0
May 20	A	159	9.77	23.5
May 20	D	153	7.60	24.5
June 4	A	150	6.49	28.0
June 4	K	163	2.58	29.5
June 4	L	151	0.37	29.5
June 4	O	140	2.65	29.5
July 8	S	171	0.33	29.0
Oct. 7	C	147	7.73	26.0
Oct. 21	C	146	9.08	22.5
Oct. 21	I	155	4.05	20.0

TABLE 8. Data on all male blue crabs larger than 190 mm in width.

Date	Size (mm)	Weight (g)	Station	Salinity (o/oo)
1966				
Aug. 19	195	52.4	K	0.4
Aug. 19	192	330.8	M	0.5
Oct. 22	192	218.7*	M	0.9
1967				
April 8	196	59.0	L	7.8
Oct. 7	191	375.8	D	7.8
Oct. 21	195	382.6	C	9.1

*no claws

TABLE 9. Number of blue crabs taken in semimonthly trawl samples.

Month	Area I											Area II											Area III		
	Stations											Stations											Station		
	A		C		D		E		I		Total	F		G		K		L		O		Total	S		Total
1966																									
Apr.	20	42	64	0	8	22	24	35	15	8	238	14	8	34	6	13	7	0	4	12	2	100	3	0	3
May										---FLOOD---															
June	1	12	NE	55	3	16	7	0	11	1	108	18	5	5	27	6	11	23	16	0	14	125	3	7	10
July	10	19	63	55	51	NE	24	23	23	8	276	6	18	64	6	6	8	6	6	7	5	132	1	5	6
Aug.	11	8	39	15	15	29	14	7	54	31	223	8	3	14	16	6	3	10	11	3	0	74	4	1	5
Sept.	3	0	27	5	23	13	7	2	0	0	80	6	8	5	16	4	4	9	10	0	3	70	0	0	0
Oct.	1	0	1	37	9	3	2	13	8	5	79	3	2	2	2	3	2	11	7	3	2	37	1	0	1
Nov.	5	2	30	5	22	13	7	3	17	13	117	8	5	7	8	4	4	32	10	3	2	83	0	2	2
Dec.	2	0	42	21	39	13	5	6	38	8	174	18	12	9	5	4	3	40	30	3	1	125	0	15	15
1967																									
Jan.	2	6	54	58	17	13	0	0	32	5	187	0	5	36	7	9	10	0	14	0	2	83	8	13	21
Feb.	5	6	248	6	60	30	4	5	3	6	373	36	8	15	19	7	3	28	NE	6	2	124	5	2	7
Mar.	2	0	52	27	13	8	13	0	3	7	125	7	6	12	12	4	1	NE	NE	2	0	44	3	2	5
Apr.	4	1	50	30	1	0	1	11	13	20	131	6	5	5	4	0	2	4	2	0	16	44	2	0	2
May	15	18	40	31	1	17	8	6	14	13	163	13	12	11	19	1	4	5	4	0	1	70	0	5	5
June	11	7	17	10	25	18	13	4	30	56	191	6	11	21	45	2	7	8	14	4	11	129	1	1	2
July	5	8	19	3	33	34	10	4	35	24	175	22	11	19	11	7	5	5	8	6	4	98	1	0	1
Aug.	11	0	18	5	5	6	14	6	18	6	89	25	3	8	5	10	1	0	4	6	3	65	3	2	5
Sept.	5	1	11	16	1	6	2	3	0	8	53	0	5	0	7	4	4	7	8	0	NE	35	NE	1	1
Oct.	4	0	36	14	20	19	3	4	6	19	125	14	10	13	2	1	4	9	NE	3	8	64	0	2	2
Nov.	20	16	43	41	52	28	0	17	29	7	253	19	4	3	10	13	11	NE	6	4	9	79	1	2	3
Dec.	6	1	75	18	153	25	24	18	6	7	333	15	9	14	8	NE	0	4	NE	NE	0	50	0	0	0
1968																									
Jan.	3	3	15	89	54	81	4	5	11	6	271	13	14	8	8	0	5	NE	NE	1	2	51	0	1	0
Feb.	8	8	12	8	23	21	1	3	3	0	87	1	2	4	2	6	0	NE	NE	1	0	16	0	0	0
Mar.	19	10	50	36	25	21	10	3	5	1	180	5	2	4	2	10	0	NE	NE	0	1	24	0	0	0
Apr.	11	NE	13	6	30	15	0	1	9	0	85	0	0	3	0	3	0	NE	NE	0	0	6	0	0	0
May	8	10	28	26	21	35	18	2	13	2	163	4	4	20	13	6	5	NE	NE	0	1	53	0	0	0
Total	192	178	1047	617	704	488	215	181	396	261		267	172	336	260	129	104	201	154	64	94		36	61	
										G	4279										G	1789		G	97

NE = no effort

TABLE 10. Number of blue crabs 20 mm or less taken in semimonthly trawl samples.

Month	Area I Stations A		C		D		E		I		Total	Area II Stations F		G		K		L		O		Total	Area III Station S		Total
1966																									
Apr.	2	16	43	NE	6	7	13	17	0	2	106	6	1	25	3	6	0	0	0	3	2	46	0	0	0
May										- - - F L O O D - - -															
June	0	0	NE	6	0	1	0	0	0	1	8	0	0	0	0	0	0	1	0	0	0	1	0	0	0
July	0	3	0	0	3	0	10	6	0	2	24	0	2	2	0	1	3	1	2	0	2	13	0	0	0
Aug.	0	1	0	0	0	3	0	1	6	18	29	4	1	6	7	0	0	1	4	0	0	23	0	0	0
Sept.	0	0	2	0	0	1	2	1	0	0	6	1	0	3	6	3	2	4	3	0	1	23	0	0	0
Oct.	1	0	1	1	0	0	1	0	0	0	4	1	0	1	1	0	0	2	2	1	1	9	0	0	0
Nov.	1	0	0	0	2	1	1	0	1	4	10	1	0	1	0	0	2	0	5	1	1	11	0	0	0
Dec.	0	0	12	2	8	1	1	0	5	1	30	9	3	1	2	1	0	25	4	3	1	49	0	2	2
1967																									
Jan.	0	3	33	19	11	1	0	0	2	1	70	0	2	5	3	7	10	0	3	0	1	31	4	0	4
Feb.	4	4	218	5	29	21	3	2	2	2	289	20	4	7	3	6	0	15	NE	3	2	60	1	1	2
Mar.	0	0	4	16	7	0	3	0	0	0	30	4	0	2	4	1	0	NE	NE	0	0	11	0	0	0
Apr.	0	2	0	0	0	0	0	1	0	3	6	0	1	0	2	0	0	0	0	0	1	4	0	0	0
May	0	0	2	0	0	0	0	0	0	0	2	0	0	1	1	0	0	0	0	0	0	2	0	0	0
June	0	0	0	1	0	0	0	0	0	12	13	0	6	0	11	1	2	0	6	0	1	27	0	0	0
July	0	3	0	2	0	3	2	0	5	1	16	1	6	4	5	0	1	0	4	0	2	23	0	0	0
Aug.	3	0	3	0	4	1	0	1	6	0	18	12	1	7	0	3	1	0	0	2	2	28	1	0	1
Sept.	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	2	2	5	6	0	NE	15	NE	0	0
Oct.	0	0	0	4	4	9	0	1	0	1	19	2	5	5	1	1	3	2	NE	1	8	28	0	0	0
Nov.	10	14	34	22	44	9	0	15	8	2	158	13	3	0	5	10	9	NE	5	1	7	53	0	0	0
Dec.	5	0	67	18	136	18	19	17	3	2	285	12	4	10	2	NE	0	1	NE	NE	0	29	0	0	0
1968																									
Jan.	2	0	7	75	11	63	2	3	2	0	165	11	10	6	6	0	1	NE	NE	0	1	35	0	0	0
Feb.	6	5	6	3	13	1	0	1	0	0	35	1	2	1	0	2	0	NE	NE	1	0	7	0	0	0
Mar.	18	9	29	30	17	19	6	0	1	1	130	2	1	3	2	3	0	NE	NE	0	1	12	0	0	0
Apr.	10	0	4	0	17	6	0	1	0	0	38	0	0	3	0	2	0	NE	NE	0	0	5	0	0	0
May	4	5	7	8	8	22	1	2	0	0	57	0	2	3	10	1	1	NE	NE	0	1	18	0	0	0
Total	66	65	472	212	320	187	62	69	41	55		100	54	96	74	50	37	57	44	16	35		6	3	

NE = no effort

TABLE 11. Number of blue crabs larger than 110 mm taken in semimonthly trawl samples.

Month	Area I Stations											Area II Stations											Area III Station		
	A		C		D		E		I		Total	F		G		K		L		O		Total	S		Total
1966																									
Apr.	6	2	2	NE	2	3	2	3	1	1	22	2	0	3	0	2	3	0	1	0	0	11	0	0	0
May											- - - F L O O D - - -														
June	0	1	NE	11	0	1	1	0	4	0	18	3	0	0	6	0	4	2	4	0	5	24	0	2	2
July	0	0	7	3	4	0	6	3	1	3	27	1	3	11	2	0	3	2	3	3	1	29	0	0	0
Aug.	5	3	7	1	4	7	4	4	2	3	40	0	2	2	3	0	2	3	3	0	0	15	2	0	2
Sept.	1	0	4	1	6	4	2	0	0	0	18	1	3	0	4	0	0	3	2	0	2	15	0	0	0
Oct.	0	0	0	5	5	1	1	3	0	0	15	0	1	1	0	1	2	4	2	1	1	13	0	0	0
Nov.	1	1	1	0	7	5	0	1	1	0	17	3	3	4	2	2	0	3	1	0	0	18	0	0	0
Dec.	0	0	7	2	3	0	3	0	6	0	21	0	2	0	0	0	0	1	0	0	0	3	0	0	0
1967																									
Jan.	1	0	1	1	1	1	0	0	2	0	7	0	0	0	0	0	0	0	1	0	0	1	0	1	1
Feb.	0	0	0	0	3	0	0	1	0	0	4	4	0	0	0	0	1	0	0	1	NE	6	1	0	1
Mar.	1	0	2	0	0	1	2	0	0	2	8	0	1	0	0	1	1	0	0	NE	NE	3	0	1	1
Apr.	3	1	7	3	1	0	0	0	4	4	23	0	0	1	1	0	1	2	2	0	2	9	0	0	0
May	0	4	0	9	0	3	5	0	1	3	25	2	2	1	0	0	3	3	1	0	0	12	0	2	2
June	4	2	1	2	4	3	4	0	10	6	36	2	2	2	7	1	1	1	0	3	5	24	0	0	0
July	2	2	1	1	6	4	1	0	10	4	31	9	0	0	3	2	1	2	0	1	0	18	1	0	1
Aug.	4	0	1	3	0	3	4	3	5	1	24	7	1	0	3	0	0	0	2	1	0	14	1	1	2
Sept.	2	0	0	6	0	2	0	1	0	5	16	0	1	0	1	0	0	1	0	0	NE	3	NE	0	0
Oct.	0	0	6	5	5	5	0	1	1	6	29	1	1	1	0	0	0	1	0	0	0	4	0	1	1
Nov.	0	0	4	4	3	3	0	0	2	0	16	0	0	1	0	1	1	0	1	1	0	5	0	0	0
Dec.	0	1	1	0	3	0	3	0	0	0	8	0	2	0	0	0	0	NE	NE	0	0	2	0	0	0
1968																									
Jan.	1	0	0	0	2	2	1	0	0	0	6	1	0	0	0	0	1	NE	NE	1	0	3	0	0	0
Feb.	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	1	0	NE	NE	0	0	1	0	0	0
Mar.	0	0	1	0	2	0	0	0	0	0	3	1	1	1	0	1	0	NE	NE	0	0	4	0	0	0
Apr.	0	0	3	2	1	4	0	0	0	0	10	0	0	0	0	0	0	NE	NE	0	0	0	0	0	0
May	0	3	6	6	0	1	0	2	2	0	20	2	2	1	2	1	2	NE	NE	0	0	10	0	0	0
Total	31	20	62	55	65	54	40	22	52	38		39	27	29	34	13	26	28	23	12	16		5	8	

NE = no effort

TABLE 12. <u>The estimation of the linear regression line relating the log width of male blue crabs to their log weight</u>.

Number of observations = 2142

Mean of the log widths ($\bar{x}$) = 1.90260

Mean of the log weights ($\bar{y}$) = 1.55157

Point estimate of b = $\frac{SP}{SS_x} = \frac{170.29114}{62.15558} = 2.739756$

a (y-intercept) = $\bar{y} - b\bar{x} = -3.66107$

Point estimate of residual variance:

$$s^2 = (SSy - \frac{(SP)^2}{SS_x}) \frac{1}{(n-2)}$$

$$= \frac{12.96949}{2140} = .00606$$

Estimate of the variance of b = $\frac{s^2}{SS_x} = .00009$

Interval estimate of b = $\frac{SP}{SS_x} \pm t_{.05} \sqrt{\frac{s^2}{SS_x}}$

$$= 2.739756 \pm .0186$$

TABLE 13. The estimation of the linear regression line relating the log width of female blue crabs to their log weight.

Number of observations = 948

Mean of the log widths ($\bar{x}$) = 1.90260

Mean of the log weights ($\bar{y}$) = 1.55157

Point estimate of b = $\frac{SP}{SS_x} = \frac{44.99934}{17.18631}$

= 2.618324

a (y-intercept) = $\bar{y} - b\bar{x}$ = -3.45805

Point estimate of residual variance:

$$S^2 = (SSy - \frac{(SP)^2}{SS_x}\frac{1}{(n-2)}$$

$$S^2 = \frac{4.66610}{946} = .00492$$

Estimate of the variance of b = $\frac{S^2}{SS_x}$ = .00286

Internal estimate of b = $\frac{SP}{SS_x} \pm t_{.05}\sqrt{\frac{S^2}{SS_x}}$

= 2.618324 ± .03312

TABLE 14. T-test for a significant difference between the slopes of the width/weight lines of male and female blue crabs.

$$t_{n_1+n_2-4} = \frac{b_1 - b_2}{\sqrt{S^2P\ (1/SS_{x_1} + 1/SS_{x_2}}}$$

$$t_{3086} = \frac{2.739756 - 2.618324}{\sqrt{\frac{.005535}{79.34189}}}$$

$$t_{3086} = \frac{.121432}{.00835}$$

$$= 14.54^{**}$$

** significant at 1% level.

TABLE 15. T-test for significant difference between the slopes (b) of the male and female blue crab width-weight regression line and 3.

For male blue crabs

$b = 2.739756$

$$t_{2140} = \frac{3 - 2.739756}{\sqrt{S^2/SS_X}}$$

$$t_{2140} = \frac{.260244}{.00948}$$

$$t_{2140} = 27.45^{**}$$

For female blue crabs

$b = 2.618324$

$$t_{946} = \frac{3 - 2.618324}{\sqrt{S^2/SS_X}}$$

$$= \frac{.381676}{.01691}$$

$$t_{2140} = 22.57^{**}$$

**significant at 1% level.

TABLE 16. Mean condition coefficients and variances of samples of male blue crabs for warm and cool periods.

Warm Period I -- April through October, 1966

N = 650

Mean condition coefficient ($\overline{KB}$) = 22.04981

Variance = 10.84

Warm Period II -- April through October, 1967

N = 636

$\overline{KB}$ = 23.71307

Variance = 12.85

Cool Period I -- November 1966 through March 1967

N = 450

$\overline{KB}$ = 21.0692

Variance = 8.1540

Cool Period II -- November 1967 through March 1968

N = 241

$\overline{KB}$ = 20.66686

Variance = 7.106

TABLE 17. Test for significant differences between mean condition coefficients of male blue crabs for warm and cool periods.

F test of variances between warm periods:

$$F_{635,649} = \frac{12.85}{10.84} = 1.18$$ No significance at 1% level

F test of variances between cool periods:

$$F_{449,240} = \frac{8.15}{7.10} = 1.14$$ No significance at 1% level

F test of variances between warm and cool periods:

$$F_{635,449} = \frac{12.85}{8.15} = 1.57^{**}$$

$$F_{635,240} = \frac{12.85}{7.10} = 1.80^{**}$$

$$F_{649,449} = \frac{10.84}{8.15} = 1.33^{**}$$

$$F_{649,240} = \frac{10.84}{7.10} = 1.52^{**}$$

t-test for a significant difference between mean coefficients of condition for warm periods

$$t_{1284} = \frac{\overline{KB_1} - \overline{KB_2}}{\sqrt{\frac{S_1^2 + S_2^2}{n_1 + n_2}}} = \frac{1.6632}{.190} = 8.75^{**}$$

t-test for a significant difference between mean coefficients of condition for cool periods

$$t_{689} = \frac{\overline{KB_1} - \overline{KB_2}}{\sqrt{\frac{S_1^2 + S_2^2}{n_1 + n_2}}} = \frac{.04024}{.221} = .182$$

Not significant at any level.

** signigicant at 1% level.

TABLE 18. Bartlett's test of the homogeneity of variances for the variance of samples used in calculating the mean monthly condition coefficient of male blue crabs.

Month	d.f. N-1	S^2 variance	Log S^2 Log of variance	Month	d.f. N-1	S^2 variance	Log S^2 Log of variance
1966							
Mar.	59	7.353	0.86646	May	99	11.363	1.05537
Apr.	122	10.861	1.03583	June	151	9.128	0.96042
May	-	-	-	July	137	11.758	1.07040
June	100	13.327	1.12483	Aug.	61	14.808	1.17055
July	157	8.083	0.90757	Sept.	36	16.556	1.21906
Aug.	127	9.937	0.99725	Oct.	67	12.858	1.10924
Sept.	70	10.912	1.03782	Nov.	71	7.112	0.85199
Oct.	53	12.308	1.09025	Dec.	39	5.949	0.77451
Nov.	85	8.435	0.92608				
Dec.	128	7.912	0.89834	1968			
1967				Jan.	62	8.255	0.91677
				Feb.	35	4.094	0.61214
Jan.	101	7.941	0.89993	Mar.	29	10.600	1.02530
Feb.	71	8.452	0.92695	Apr.	33	3.534	0.54838
Mar.	60	6.745	0.82904	May	60	9.437	0.97488
Apr.	78	9.814	0.99189				

$$(n_1-1)\ \log S_1^{\,2} = 2028.10931$$

(Log of the pooled variance) $\log \overline{S^2} = 0.98524$

$$(N_1-1)\ \log \overline{S^2} = 2060.13684$$

$$x^2 = 2.3026 \quad (N_1-1)\ \log S^2 - (n_1-1)\ \log S_1^{\,2}$$
$$= 2.3026\ (2060.13684 - 2028.10931)$$
$$= 2.3026\ (\ 32.02753)$$
$$= 73.74659^{**}$$

** significance at 1% level.

TABLE 19. Analysis of variance for mean monthly condition coefficients of male blue crabs.

Source of Variation	Sum of Squares	D.F.	Mean Squares	F
Between levels	3,923.68402	25	156.94736	16.23755**
Residual	20,210.98023	2091	9.6657	
Total	24,134.66425	2116		

**significance at the 1% level.

TABLE 20. Numbers of white shrimp in semimonthly trawl samples.

Month	Stations													
	A	B	C	D	E	F	G	I	K	L	M	O	U	S
1966														
July	2	NE	0	0	0	0	0	0	0	0	0	0	NE	0
Aug.	94	NE	2	0	0	0	0	0	0	0	0	0	NE	0
	54	NE	189	67	32	0	6	0	0	0	0	0	NE	0
Sept.	3	NE	92	493	222	68	47	1	0	7	6	0	NE	0
	351	NE	277	323	48	56	0	0	82	54	101	0	NE	0
Oct.	6	NE	30	193	36	24	68	65	34	50	10	0	0	1
	193	NE	86	2	100	21	34	73	56	6	28	0	0	0
Nov.	522	NE	26	13	5	4	12	84	3	0	2	0	0	0
	135	NE	12	23	45	2	11	49	0	0	1	0	0	0
Dec.	83	NE	44	15	7	0	0	32	0	0	0	0	0	0
	8	NE	1	3	0	0	1	3	0	0	0	0	0	0
Total	1451	-	719	1132	495	175	179	307	175	117	148	8	0	1
1967														
Jan.	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	NE	0	0	0
Feb.	0	0	0	0	0	0	0	0	0	0	NE	0	0	0
	1	0	1	0	0	0	0	0	0	0	NE	0	0	0
Mar.	0	0	0	0	0	0	0	0	0	0	NE	0	0	0
	0	0	0	0	0	0	0	0	0	0	NE	0	0	0

TABLE 20. (continued)

Month	A	B	C	D	E	F	G	I	K	L	M	O	U	S
	Stations													
Apr.	0	0	0	0	0	1	0	0	0	0	NE	0	0	0
	0	0	0	0	1	0	0	0	1	0	NE	0	0	0
May	0	0	0	0	0	0	0	0	0	0	NE	0	0	0
	0	NE	0	0	0	0	0	0	0	0	NE	0	0	0
June	1	NE	0	0	0	0	0	0	1	4	NE	0	0	0
	11	NE	184	23	86	17	16	80	0	12	NE	0	0	0
July	9	NE	77	57	55	17	16	108	2	14	NE	0	1	0
	22	NE	12	84	53	105	68	261	28	46	NE	0	1	0
Aug.	5	118	89	30	32	83	196	143	29	1	NE	9	1	0
	7	12	94	58	27	32	57	66	67	9	NE	12	1	0
Sept.	67	104	386	241	41	15	0	7	113	58	NE	36	12	2
	48	468	446	753	123	207	547	269	230	407	NE	6	8	0
Oct.	181	164	1097	737	307	93	555	242	128	272	NE	0	5	0
	495	487	64	578	434	147	144	241	85	0	NE	39	6	0
Nov.	86	76	23	59	500	79	202	863	81	0	NE	46	26	4
	22	26	2	190	0	0	0	0	6	0	NE	57	22	0
Dec.	0	0	0	106	0	2	1	0	0	0	NE	3	0	0
	32	5	3	2	2	3	0	0	2	0	NE	0	0	0
Total	986	1460	2477	2818	1960	800	1802	2280	772	623	-	211	84	6

NE = no effort

TABLE 21. White shrimp taken in marsh net samples (length in mm).

Date	Station	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90
1966																		
Aug. 19	A	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	2	2	4	4	1	0	0	0	0	0	0	0	0	0	0	0
	D	8	54	60	17	2	0	0	0	0	0	0	0	0	0	0	0	0
Sept. 2	C	2	9	6	6	1	3	0	0	0	0	0	0	0	0	0	0	0
	D	0	3	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Sept. 24	A	0	0	0	0	2	0	1	0	0	0	0	1	0	0	0	0	0
	C	0	2	2	2	6	1	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	1	1	2	0	2	0	1	0	0	0	0	0	1	0
	G	0	0	1	3	3	1	0	0	0	0	0	0	0	0	0	0	0
Oct. 8	C	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0
	F	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
	G	8	30	1	0	3	10	7	0	2	0	1	0	0	0	0	0	0
Oct. 22	C	0	1	0	1	2	0	2	3	1	0	0	0	0	0	0	0	0
	D	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
	G	0	1	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Nov. 5	C	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1967																		
May 20	G	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June 4	A	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June 26	A	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	13	22	18	17	12	4	0	0	0	0	0	0	0	0	0	0	0
	D	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
July 8	C	16	25	27	25	6	0	0	0	0	0	0	0	0	0	0	0	0
	G	5	21	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July 22	C	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	20	35	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 21. (continued)

Date	Station	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90
July 22	F	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug. 5	A	12	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	C	25	23	10	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	G	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug. 19	A	0	2	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	2	30	6	5	1	0	0	0	0	0	0	0	0	0	0	0	0
	D	4	14	6	2	3	0	0	0	0	0	0	0	0	0	0	0	0
	F	0	5	17	13	2	1	0	0	0	0	0	0	0	0	0	0	0
	G	4	27	55	40	0	0	0	0	0	0	0	0	0	0	0	0	0
	T	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept. 19	A	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	3	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	3	4	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	G	5	20	8	3	0	0	1	0	0	0	0	0	0	0	0	0	0
Sept. 23	A	7	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	4	49	27	4	3	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	1	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0
	F	8	14	7	6	3	5	0	1	0	0	0	0	0	0	0	0	0
	G	36	130	212	102	23	4	1	0	0	0	0	0	0	0	0	0	0
Oct. 7	A	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	19	19	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	F	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	3	4	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0
Oct. 21	C	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	2	6	6	5	4	0	1	0	0	0	1
	F	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	2	7	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Nov. 4	A	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	D	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	G	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov. 18	G	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec. 2	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 22. Numbers of brown shrimp in semimonthly trawl samples.

Month	Stations													
	A	B	C	D	E	F	G	I	K	L	M	O	U	S
1966														
Apr.	7	10	21	0	1	0	0	0	0	0	0	0	NE	0
	55	2	1	4	20	1	3	8	0	0	0	0	NE	0
May	0	0	0	0	0	0	0	0	0	0	0	0	NE	0
	0	0	0	0	0	0	0	0	0	0	0	0	NE	0
June	0	0	0	0	0	0	0	0	0	0	0	0	NE	0
	0	NE	0	0	0	0	0	0	0	0	0	0	NE	0
July	0	NE	0	0	0	0	0	0	0	0	0	0	NE	0
	0	NE	0	0	0	0	0	0	0	0	0	0	NE	0
Aug.	0	NE	0	0	0	0	0	0	0	0	0	0	NE	0
	2	NE	2	0	0	0	0	0	0	0	0	0	NE	0
Sept.	0	NE	0	1	0	0	0	0	0	0	0	0	NE	0
	0	NE	0	1	0	0	0	0	0	0	0	0	NE	0
Oct.	1	NE	0	4	1	1	0	0	0	0	0	0	0	0
	7	NE	13	1	1	0	0	0	0	0	0	0	0	0
Nov.	1	NE	7	12	1	0	1	4	0	0	1	0	0	0
	0	NE	5	7	0	0	0	2	0	1	2	1	0	0
Dec.	2	NE	20	15	7	0	1	10	1	2	2	0	0	0
	4	NE	3	7	2	1	5	3	1	0	5	1	0	0
Total	79	12	72	52	33	3	10	27	2	3	10	2	0	0

TABLE 22. (continued)

Month	Stations													
	A	B	C	D	E	F	G	I	K	L	M	O	U	S
1967														
Jan.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	NE	0	0	0
Feb.	0	0	0	0	0	0	0	0	0	0	NE	0	0	0
	0	0	0	0	0	0	0	0	0	0	NE	0	0	0
Mar.	0	0	0	0	0	0	0	0	0	0	NE	0	0	0
	1	0	2	0	1	1	1	1	1	0	NE	3	1	0
Apr.	281	36*	1040	494*	411	609	412	667	224	229	NE	321	128	0
	837	224*	1710	490*	232	312	171	1603	441	159	NE	522	258	0
May	512	73*	890	316*	NE	447	288	327	36	85	NE	39	NE	0
	357	NE	1030	1375	93	410	187	180	197	185	NE	181	347	0
June	174	NE	362	801	94	612	166	193	160	44	NE	76	190	0
	64	NE	207	252	55	84	182	87	53	33	NE	132	261	0
July	75	NE	181	317	50	74	32	44	35	24	NE	46	105	0
	29	NE	38	67	1	16	13	8	19	9	NE	52	40	0
Aug.	10	10	42	19	22	36	11	25	10	2	NE	17	26	0
	0	1	9	11	14	12	10	10	30	4	NE	23	12	0
Sept.	2	8	36	8	7	7	0	0	10	23	NE	7	17	0
	7	39	59	55	12	9	9	16	13	62	NE	0	3	0
Oct.	5	30	141	12	24	4	0	2	6	2	NE	1	3	0
	6	4	23 1	14	0	0	3	1	2	0	NE	1	2	0

TABLE 22. (continued)

Month	A	B	C	D	E	F	G	I	K	L	M	O	U	S
Nov.	3	7	8	13	2	0	9		2	0	NE	1	1	0
	0	1	0	8	0	0	4	1	0	0	NE	2	0	0
Dec.	0	0	0	33	0	0	1	0	0	0	NE	0	0	0
	1	0	0	6	0	0	0	0	0	0	NE	0	0	0
Total	2364	253	5778	4291	1018	2633	1499	3165	1039	861	-	1424	1394	0

NE = no effort
* = 6-ft. trawl

TABLE 23. Brown shrimp taken in marsh net samples (length in mm).

Date	Station	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95
1966																			
Apr. 2	A	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr. 16	A	0	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept. 24	C	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Oct. 8	D	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Oct. 22	D	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Dec. 3	G	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1967																			
Feb. 11	A	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb. 25	C	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar. 8	C	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	11	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr. 8	A	0	10	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	1	3	8	6	8	3	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	1	1	3	17	7	3	0	0	0	0	0	0	0	0	0
	F	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	9	11	17	23	13	3	0	0	0	0	0	0	0	0	0	0	0
Apr. 22	A	0	1	1	0	1	2	3	5	5	1	0	0	0	0	0	0	0	0
	C	0	0	4	1	1	0	0	0	0	3	0	0	0	0	0	0	0	0
	D	0	0	1	0	0	0	1	3	6	3	2	1	0	0	0	0	0	0
	G	0	0	7	2	0	1	1	2	2	3	2	0	0	0	0	0	0	0
May 6	A	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
	C	0	0	0	0	1	0	2	0	3	1	0	0	0	1	0	0	0	0
	D	0	1	0	0	1	0	1	1	1	5	2	2	1	0	0	0	0	0
	F	0	6	1	1	1	0	1	0	0	0	0	1	0	1	0	0	0	0
	G	0	0	0	0	1	1	1	0	1	2	2	0	1	0	0	0	0	0

TABLE 23. (continued)

Date	Station	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95
May 20	A	0	0	0	0	0	1	3	2	3	1	0	0	0	0	0	0	0	0
	C	0	0	0	0	1	0	1	2	1	1	0	0	0	0	0	0	0	0
	D	0	0	1	0	0	0	0	1	0	2	3	3	0	1	0	0	0	0
	G	1	1	1	1	6	1	1	4	0	0	2	1	0	0	0	0	0	0
June 4	A	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0
	F	1	0	0	0	0	0	0	0	1	1	2	4	1	0	0	0	0	0
	G	0	0	2	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
June 26	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	C	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	1	0	0	0	0	0	0	2	1	1	0	0	0
July 8	D	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	0
July 22	D	1	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
	F	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug. 5	D	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Aug. 19	D	0	2	2	1	0	0	1	0	0	0	1	1	0	0	1	0	0	0
	F	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	1	0	1	3	2	0	0	0	0	0	0	0	0	0	0	0	0
	T	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept. 9	D	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	0
	G	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Sept. 23	C	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	D	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	F	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Oct. 7	C	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct. 21	C	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov. 18	A	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 24. Unidentified penaeid postlarvae.

Date 1967	Station	Number	Size Group	Gear
July 22	I	1	11-15	Trawl
Aug. 5	F	4	11-15	Trawl
	F	2	16-20	Trawl
	K	1	6-10	Trawl
	K	15	11-15	Trawl
Aug. 19	G	1	11-15	Trawl
	E	2	11-15	Trawl
	E	2	16-20	Trawl
	E	1	21-25	Trawl
	T	1	11-15	Marsh
Oct. 7	E	1	11-15	Trawl
	K	1	11-15	Trawl
	A	1	6-10	Trawl
	A	3	11-15	Trawl
	A	2	16-20	Trawl
	D	4	11-15	Trawl
	D	3	16-20	Trawl
Oct. 21	C	1	11-15	Marsh
Nov. 4	E	1	11-15	Trawl
Nov. 18	C	1	16-20	Trawl
	D	1	26-30	Trawl

TABLE 25. Numbers and the ranges and means of standard lengths of Gulf menhaden.

Date	Number	Ranges In Standard Length (mm)	Mean Standard Length (mm)
1966			
May	1980	17-42	28.0
June	304	16-49	30.0
July	80	40-53	42.7
August	108	36-55	45.7
September	290	32-60	46.3
October	1376	33-113	49.5
November	532	40-92	52.8
December	642	21-71	52.2
1967			
January	691	19-98	24.1
February	2827	19-70	23.3
March	3367	16-92	37.2
April	7983	18-81	24.5
May	3551	17-81	33.4
June	1765	23-54	36.2
July	969	31-91	40.3
August	293	36-73	47.3
September	711	35-135	63.0
October	556	40-135	59.2
November	104	18-85	40.3
December	227	19-68	30.4
1968			
January	43	20-113	43.1
February	342	19-30	22.1
March	6914	18-34	22.8
April	2238	20-43	24.4
May	7998	18-53	24.9

TABLE 26. Size groups of Gulf menhaden.

Standard Length (mm)	Number	Per cent
10-19	320	0.73
20-29	29,782	67.82
30-39	6,300	14.35
40-49	3,574	8.14
50-59	2,802	6.38
60-69	738	1.67
70-69	250	0.57
80-89	58	0.13
90-99	44	0.10
100-109	25	0.06
111-119	13	0.03
120-129	1	0.01
130-139	4	0.01

TABLE 27. Catches of postlarval menhaden and mean salinities and temperatures.

Month	Mean Salinity (o/oo)	Mean Temperature (^{o}C)	Number Postlarvae Collected
December, 1966	4.21	14.67	16
January, 1967	5.23	11.53	601
February, 1967	3.26	13.23	2,543
November, 1967	1.94	16.02	7
December, 1967	1.49	15.83	196
January, 1968	0.42	10.51	11
February, 1968	0.29	9.41	341
March, 1968	0.22	14.64	6,927

FIGURES

FIGURE 1.--The Galveston Bay Estuarine System. Inset indicates the study area.

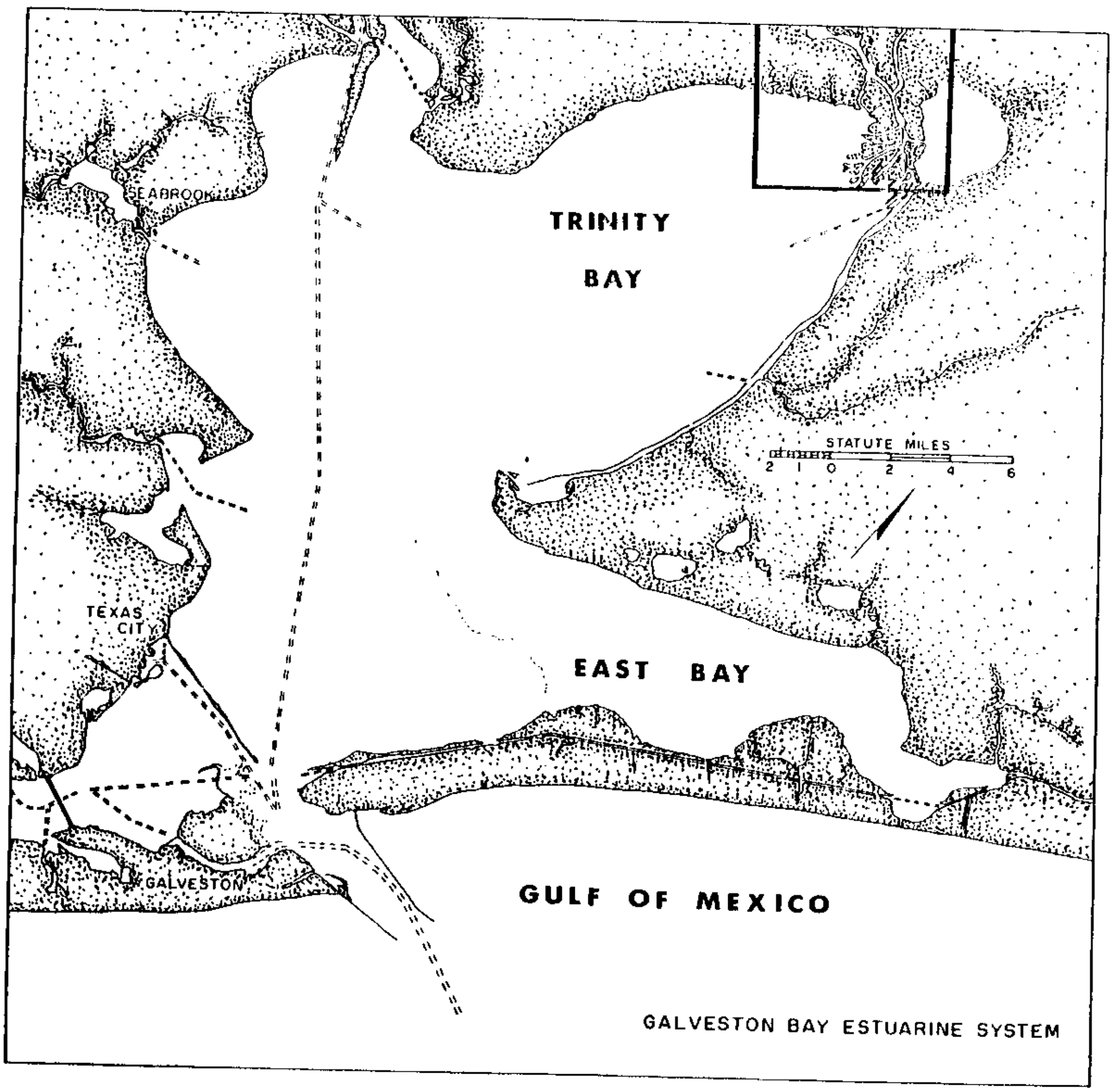

SEABROOK
TRINITY
BAY
STATUTE MILES
2 1 0 2 4 6
TEXAS CITY
EAST BAY
GALVESTON
GULF OF MEXICO
GALVESTON BAY ESTUARINE SYSTEM

FIGURE 1

FIGURE 2.--The study area showing the sampling stations and the proposed Wallisville Reservoir.

———	=	salt water barrier
::::	=	conservation pool of the reservoir
letters	=	stations
numbers	=	geographic features
1.	=	Trinity Bay
2.	=	Red Bayou
3.	=	Cross Bayou
4.	=	Mud Bayou
5.	=	Cotton Lake
6.	=	Lake Anahuac
7.	=	Old River Cut
8.	=	Old River Lake
9.	=	Round Lake
10.	=	Trinity River
11.	=	Interstate Highway 10
12.	=	Lost River
13.	=	Old River
14.	=	Lost Lake
15.	=	Lake Charlotte

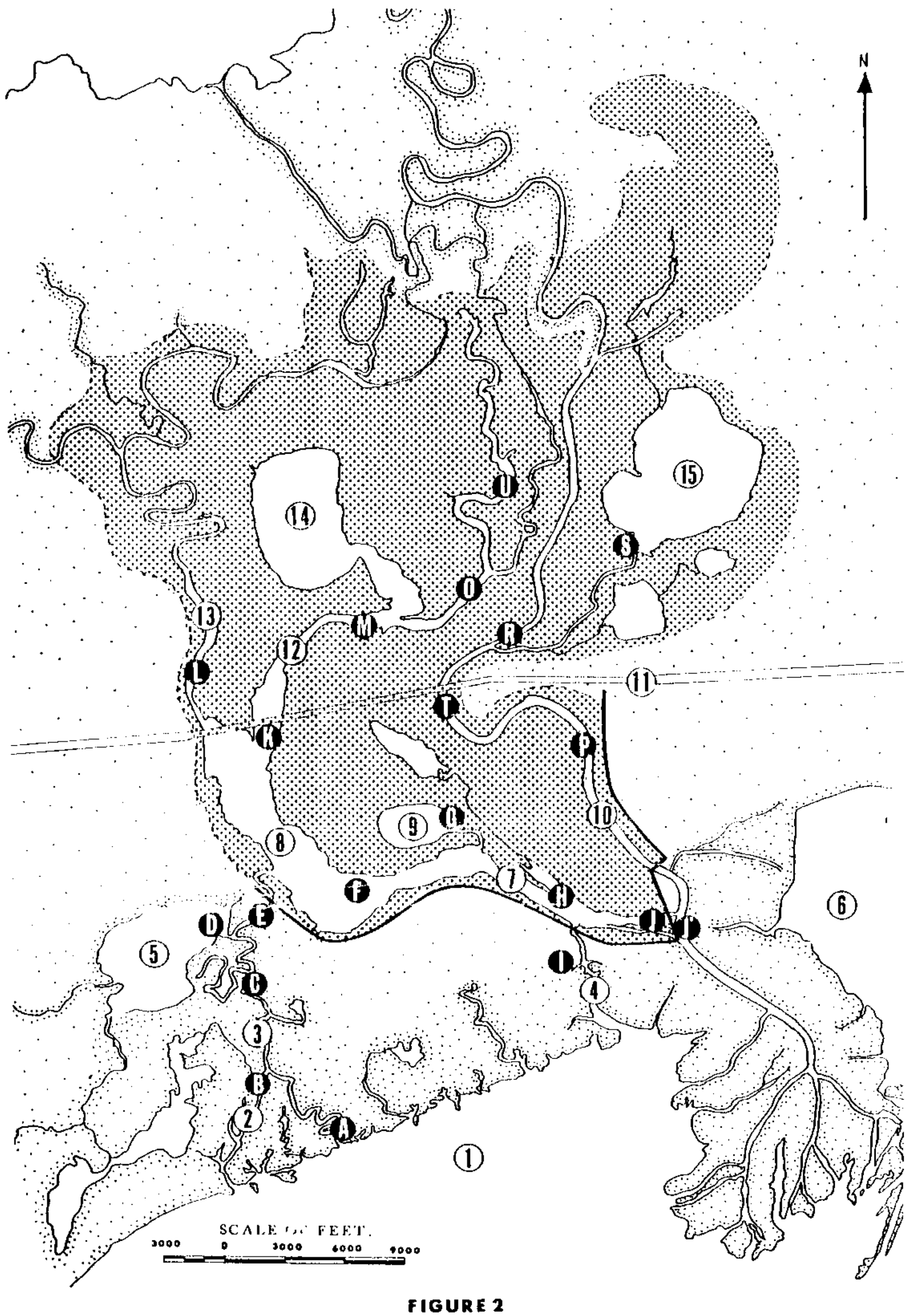
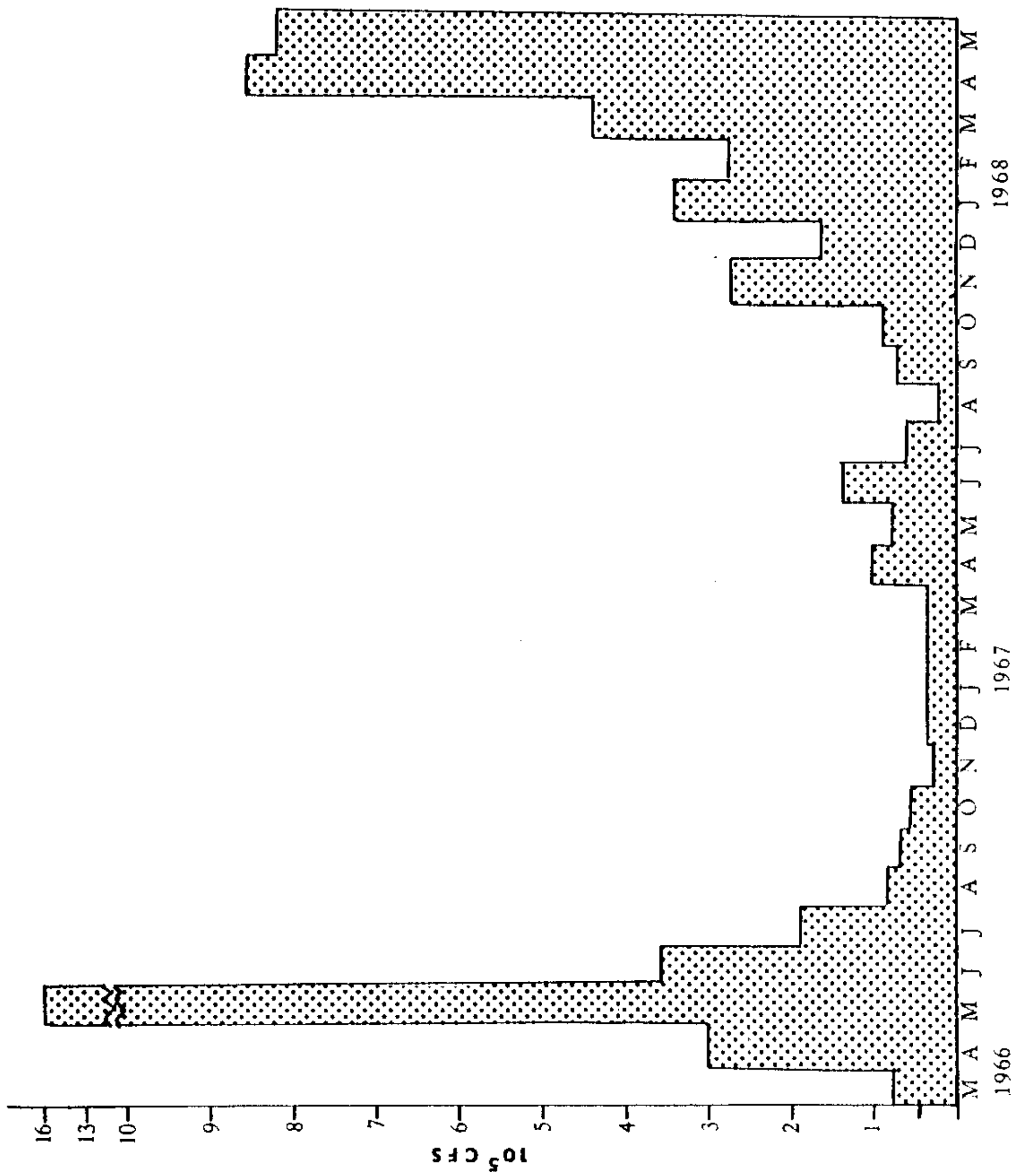

N
A
B
C
D
E
F
G
H
I
J
K
L
M
O
P
R
S
T
U
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
SCALE OF FEET
3000 0 3000 6000 9000

FIGURE 2

FIGURE 3.--Total monthly Trinity River discharge in cubic feet per second, March 1966 through May 1968. (Recorded by the U. S. Department of the Interior Geological Survey flow gauge at Romayor, Texas.)



16
13
10
9
8
7
6
5
4
3
2
1
10^5 CFS
M A M J J A S O N D J F M A M J J A S O N D J F M A M
1966
1967
1968

FIGURE 3

FIGURE 4.--Width frequency of the total catch of blue crabs from all gear April 1966 through January 1967.

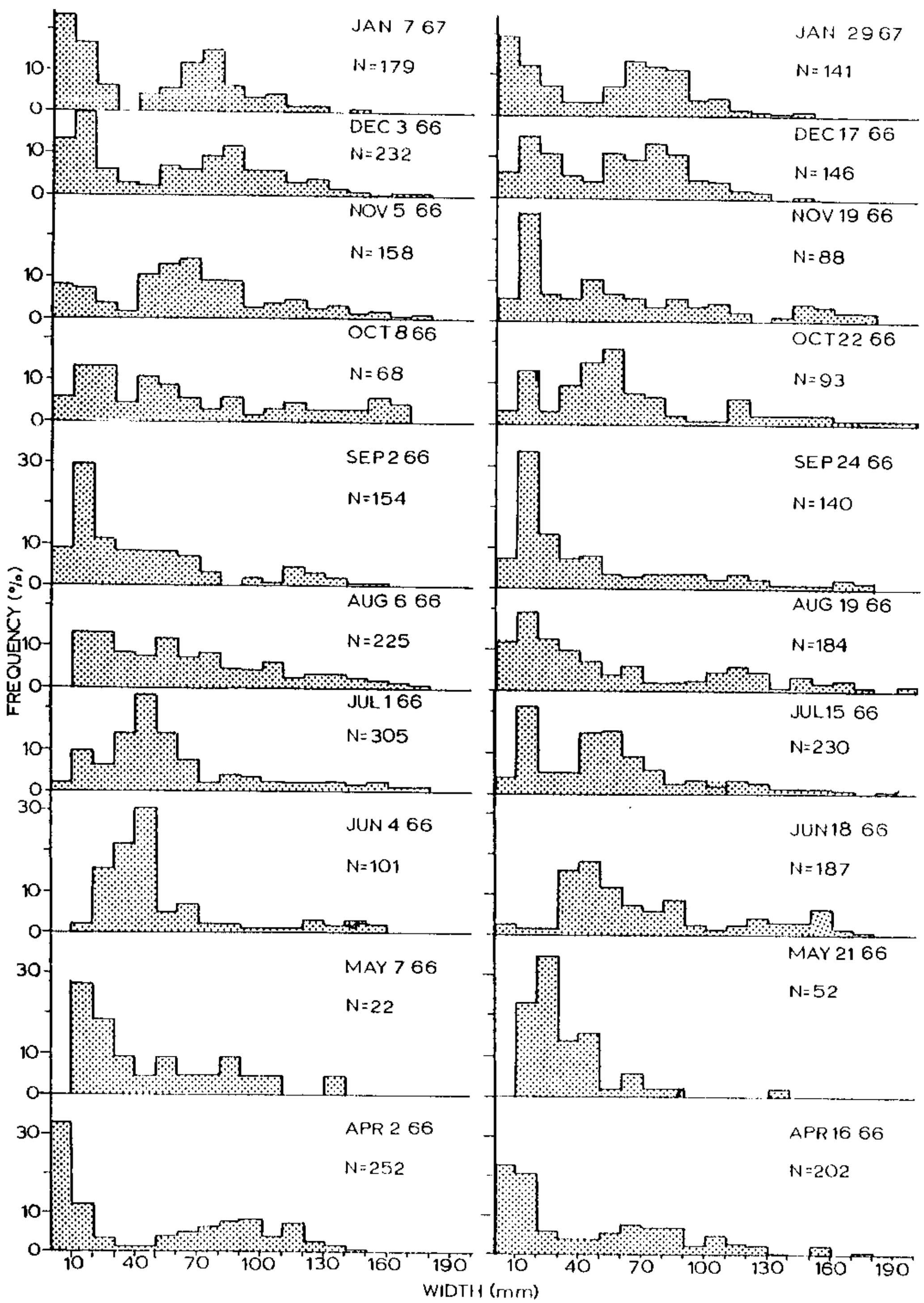

JAN 7 67
N=179
JAN 29 67
N=141
DEC 3 66
N=232
DEC 17 66
N=146
NOV 5 66
N=158
NOV 19 66
N=88
OCT 8 66
N=68
OCT 22 66
N=93
SEP 2 66
N=154
SEP 24 66
N=140
AUG 6 66
N=225
AUG 19 66
N=184
JUL 1 66
N=305
JUL 15 66
N=230
JUN 4 66
N=101
JUN 18 66
N=187
MAY 7 66
N=22
MAY 21 66
N=52
APR 2 66
N=252
APR 16 66
N=202
FREQUENCY (%)
WIDTH (mm)

FIGURE 4

FIGURE 5.--Width frequency of the total catch of blue crabs from all gear from February 1967 through October 1967.

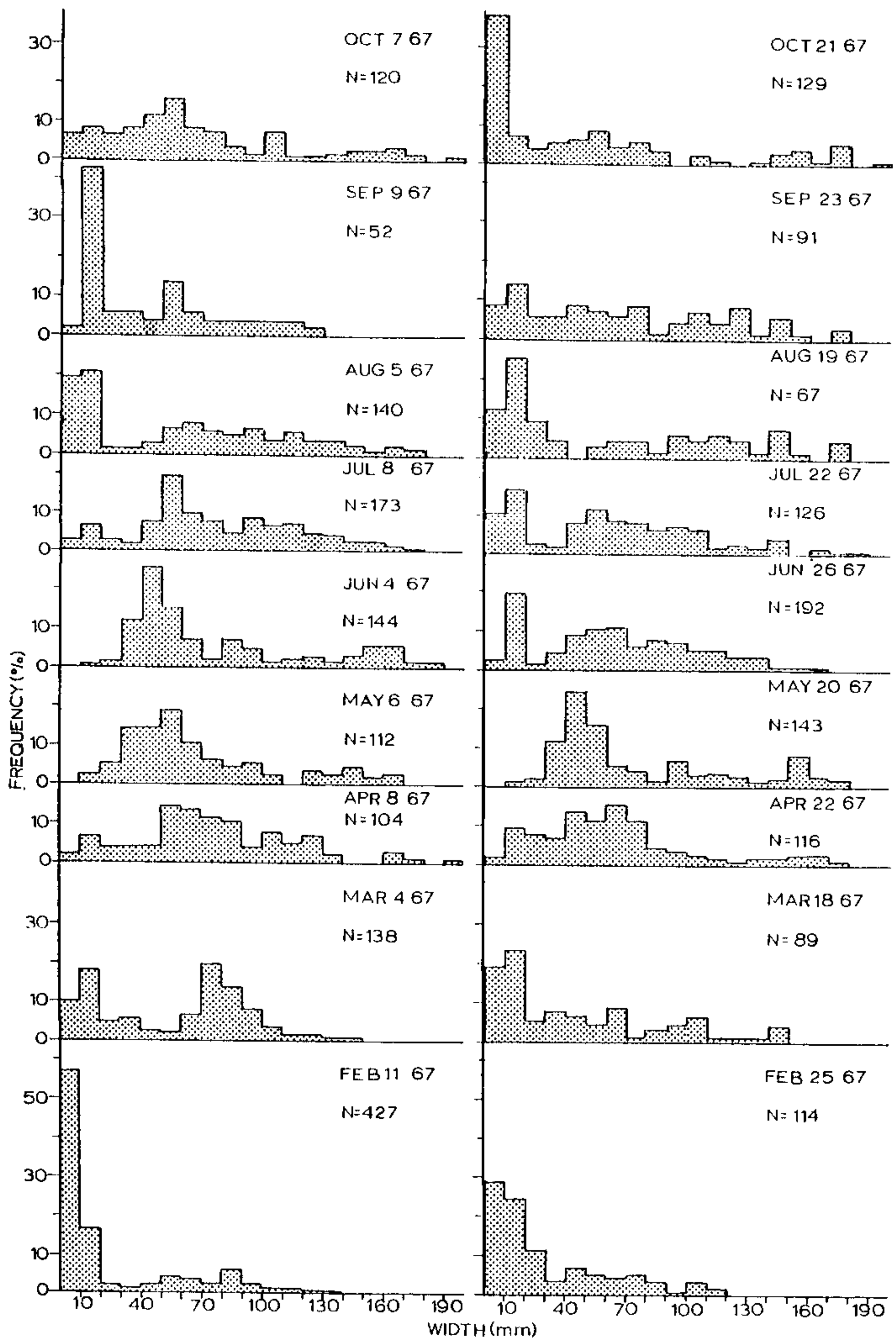

OCT 7 67
N=120
OCT 21 67
N=129
SEP 9 67
N=52
SEP 23 67
N=91
AUG 5 67
N=140
AUG 19 67
N=67
JUL 8 67
N=173
JUL 22 67
N=126
JUN 4 67
N=144
JUN 26 67
N=192
MAY 6 67
N=112
MAY 20 67
N=143
APR 8 67
N=104
APR 22 67
N=116
MAR 4 67
N=138
MAR 18 67
N=89
FEB 11 67
N=427
FEB 25 67
N=114
FREQUENCY (%)
WIDTH (mm)

FIGURE 5

FIGURE 6.--Width frequency of the total catch of blue crabs from all gear, November 1967 through April 1968.

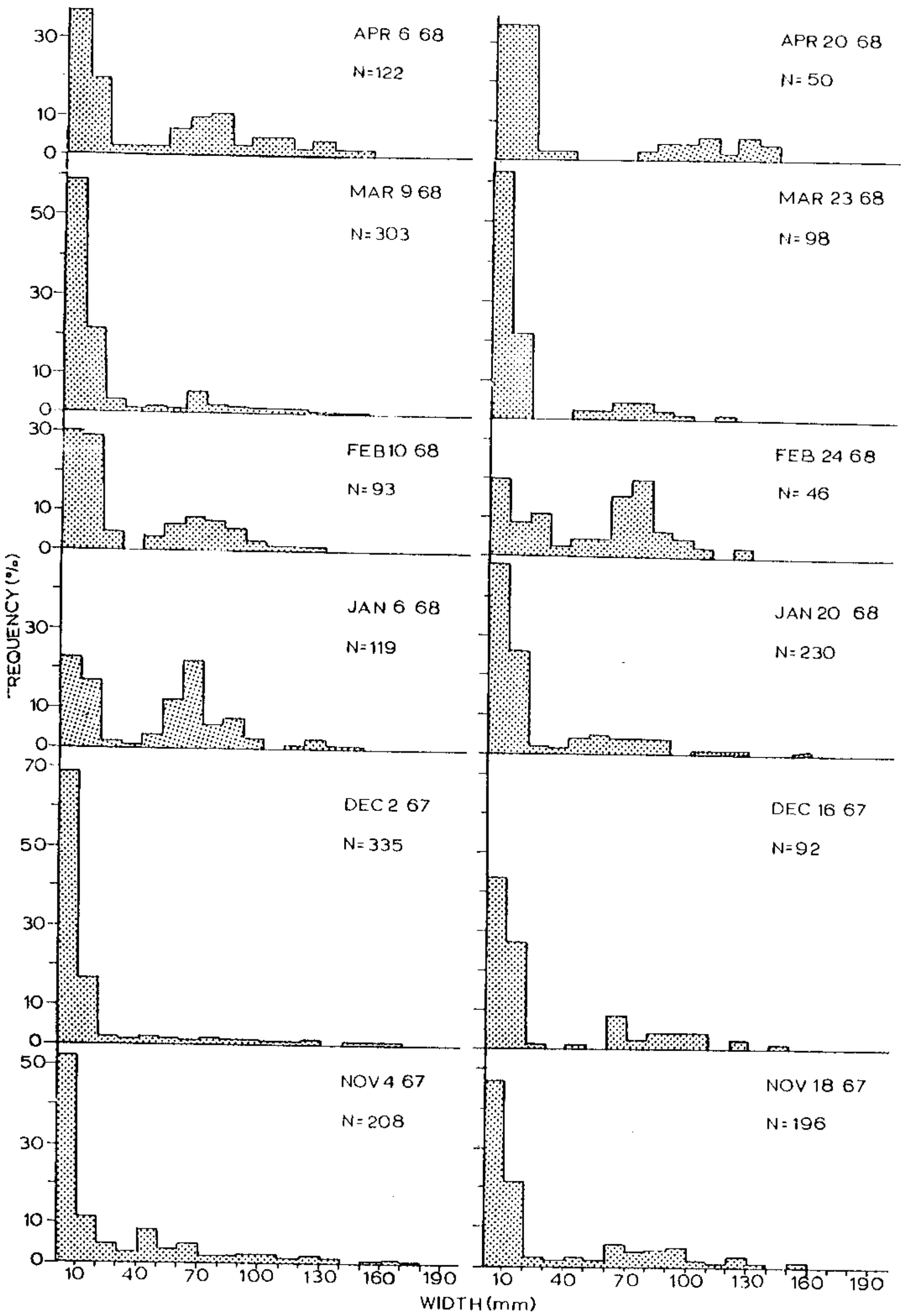

APR 6 68
N=122
APR 20 68
N= 50
MAR 9 68
N= 303
MAR 23 68
N= 98
FEB10 68
N= 93
FEB 24 68
N= 46
JAN 6 68
N=119
JAN 20 68
N= 230
DEC 2 67
N= 335
DEC 16 67
N=92
NOV 4 67
N= 208
NOV 18 67
N= 196
FREQUENCY (%)
WIDTH (mm)
0
10
30
50
70
40
100
130
160
190

FIGURE 6

FIGURE 7.--Width frequency of the total catch of blue crabs from all gear, May 1968.

FIGURE 8.--Width frequency of male, immature female and mature female blue crabs from all gear, April 1966 through October 1966.

= males

= immature females

= mature females

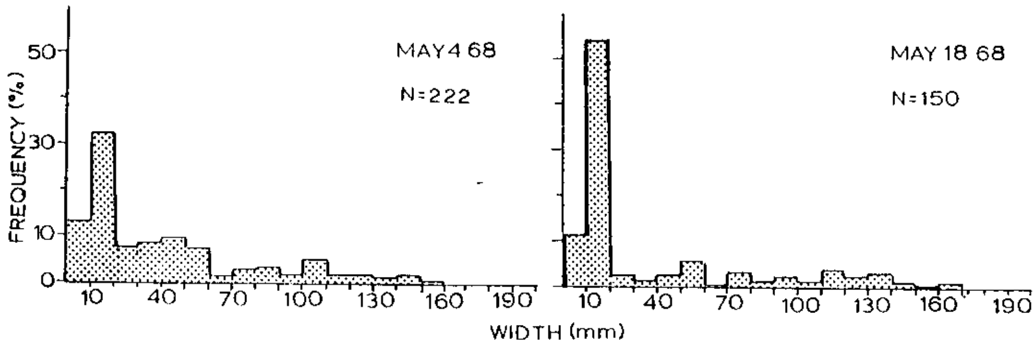


FIGURE 7

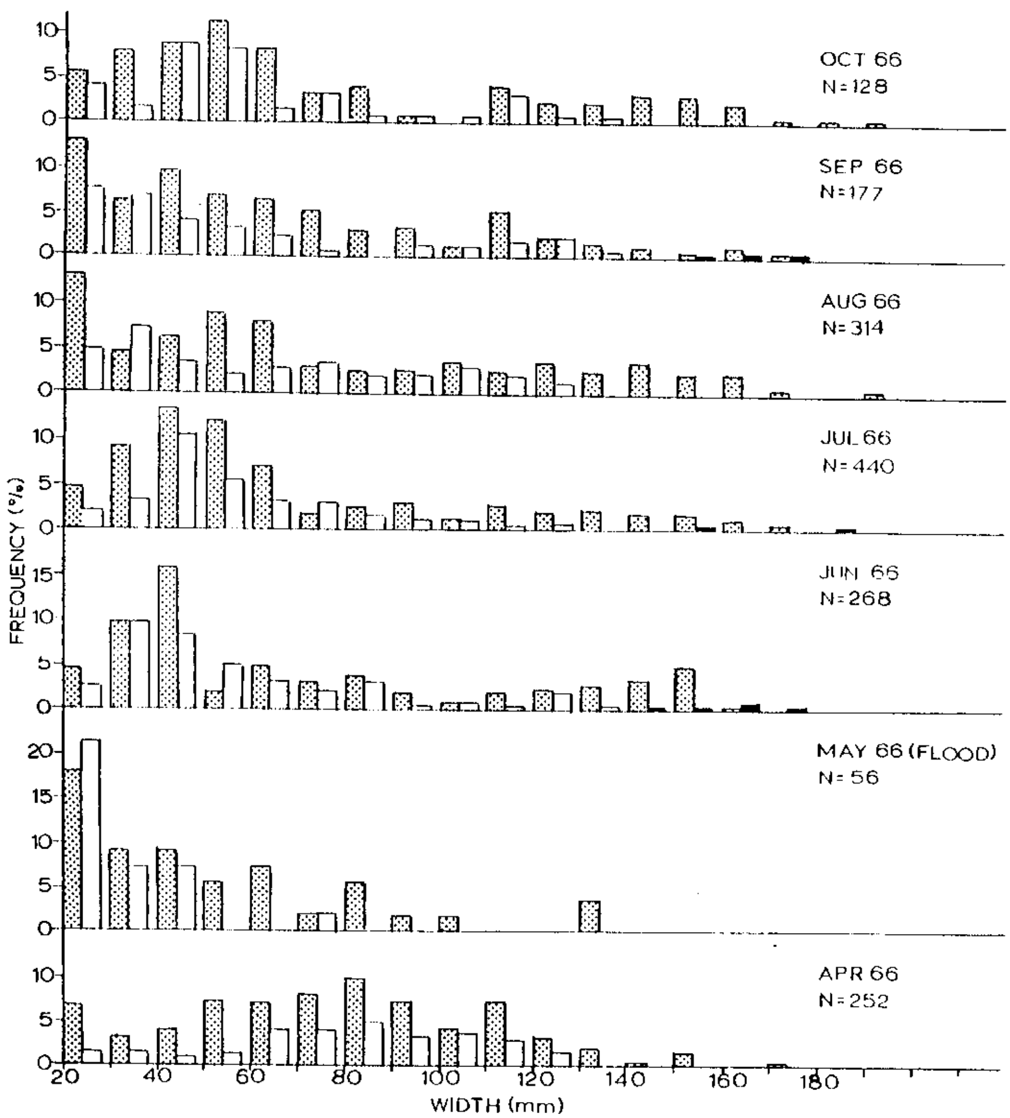


FIGURE 8

FIGURE 9.--Width frequency of male, immature female and mature female blue crabs from all gear, November 1966 through October 1967.

⁙ = males

□ = immature females

■ = mature females

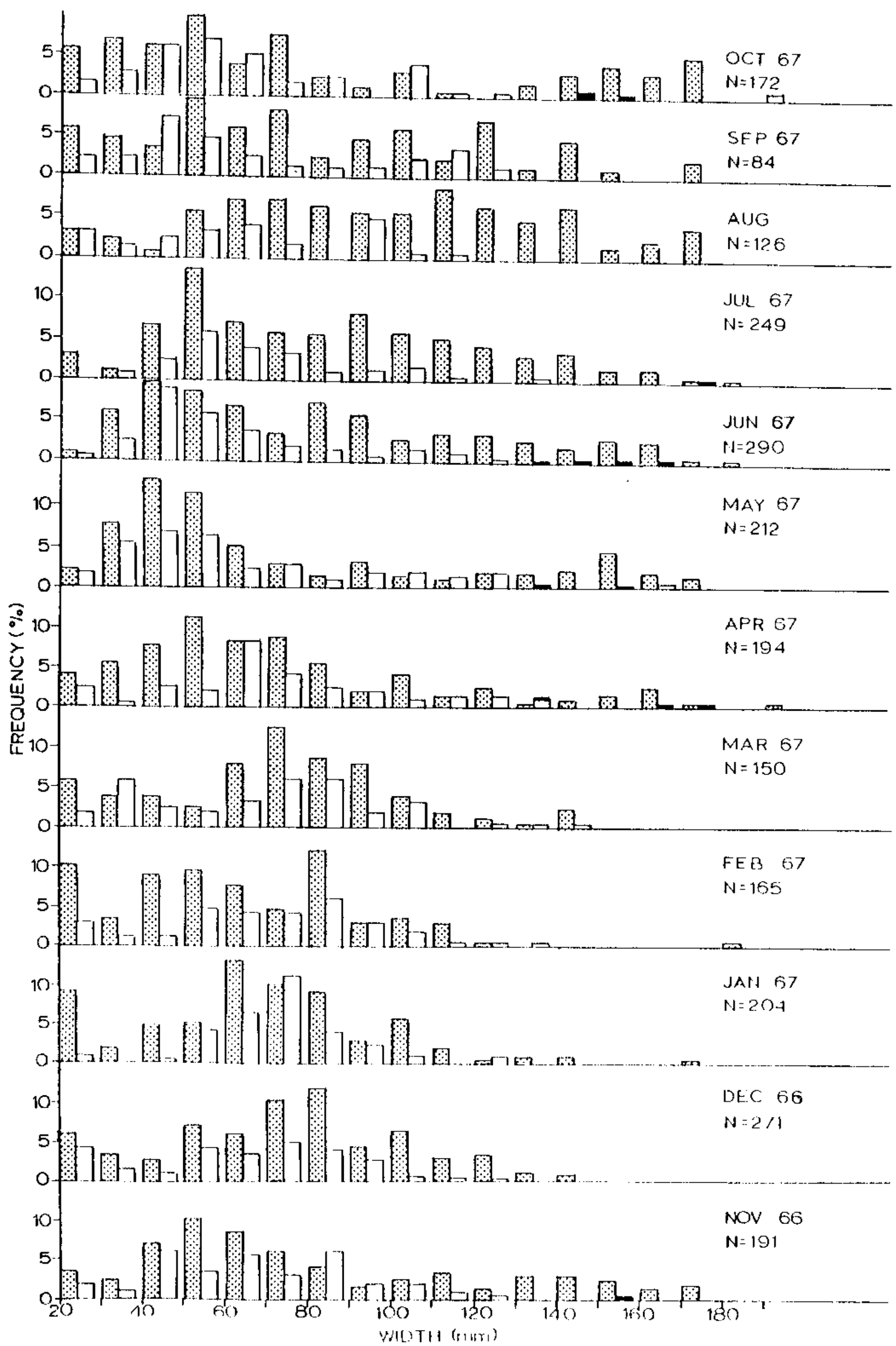

OCT 67
N=172
SEP 67
N=84
AUG
N=126
JUL 67
N=249
JUN 67
N=290
MAY 67
N=212
APR 67
N=194
MAR 67
N=150
FEB 67
N=165
JAN 67
N=204
DEC 66
N=271
NOV 66
N=191
FREQUENCY (%)
20
40
60
80
100
120
140
160
180
WIDTH (mm)

FIGURE 9

FIGURE 10.--Width frequency of male, immature female and mature female blue crabs from all gear, November 1967 through May 1968.

⁝⁝⁝ = males

☐ = immature females

■ = mature females

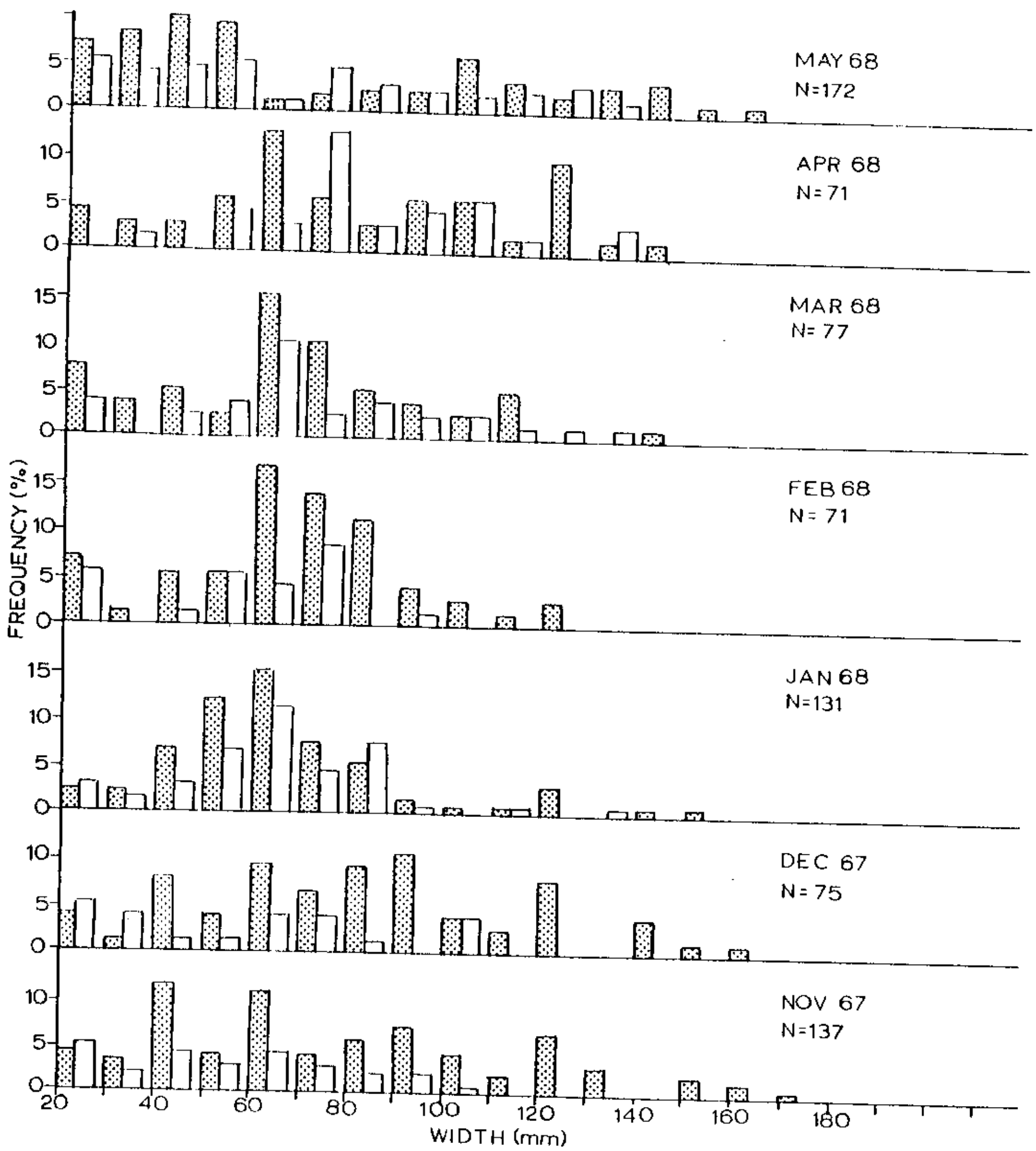

MAY 68
N=172
APR 68
N=71
MAR 68
N=77
FEB 68
N=71
JAN 68
N=131
DEC 67
N=75
NOV 67
N=137
FREQUENCY (%)
WIDTH (mm)
20
40
60
80
100
120
140
160
180

FIGURE 10

FIGURE 11.--The width-weight relationship of male and female blue crabs. The longer line represents the males; the shorter line represents the females.

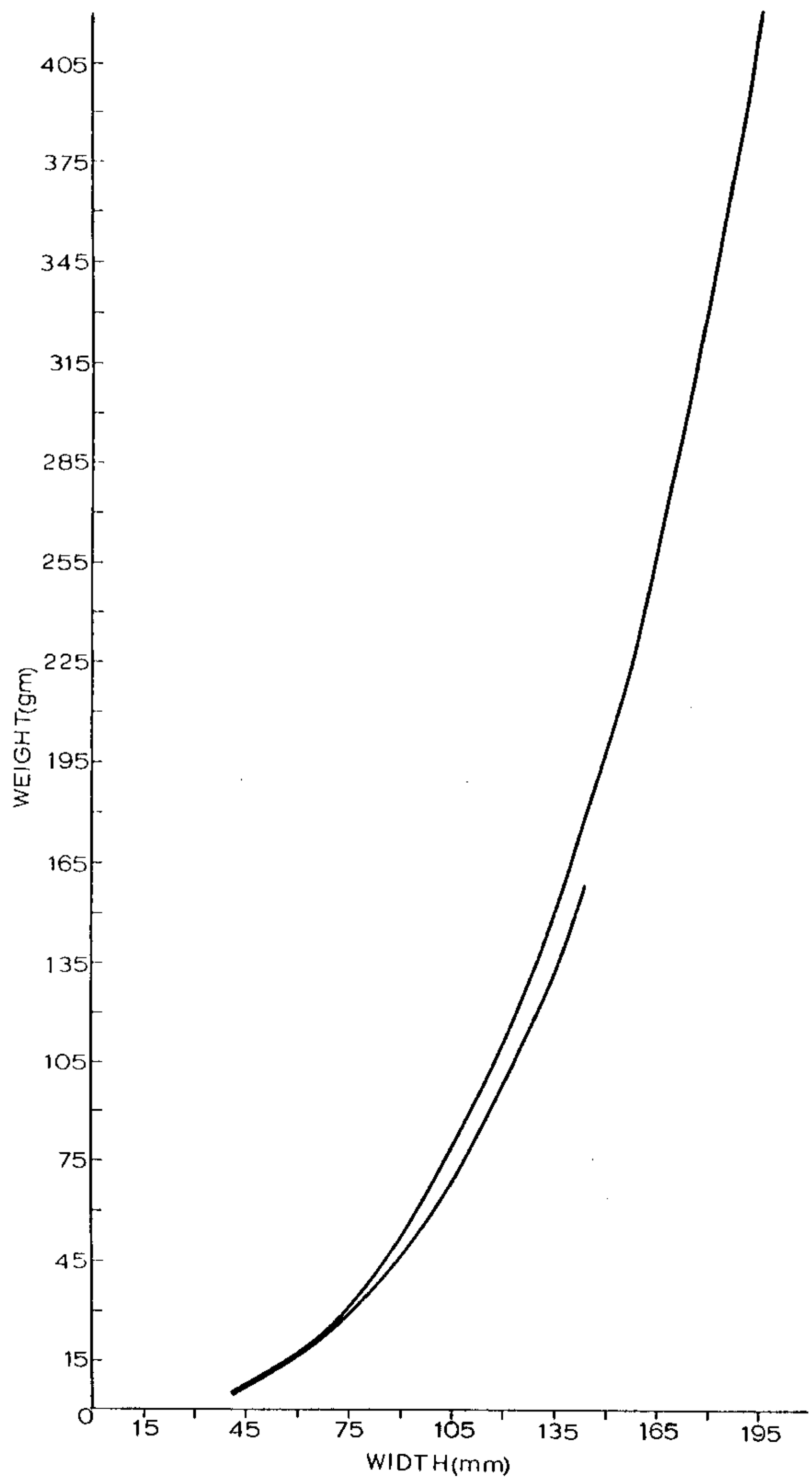
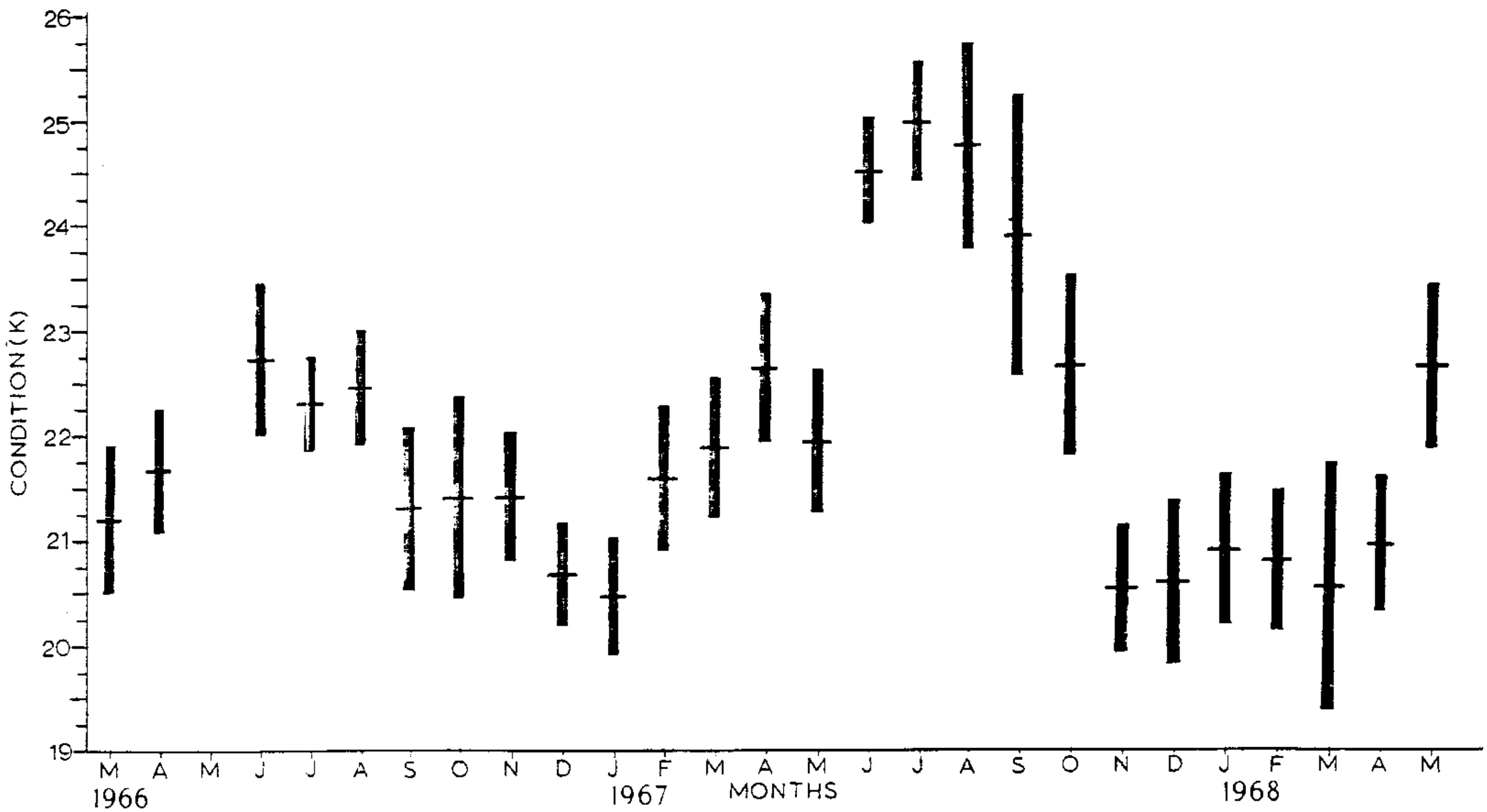

405
375
345
315
285
255
225
195
165
135
105
75
45
15
0
WEIGHT(gm)
15
45
75
105
135
165
195
WIDTH(mm)

FIGURE 11

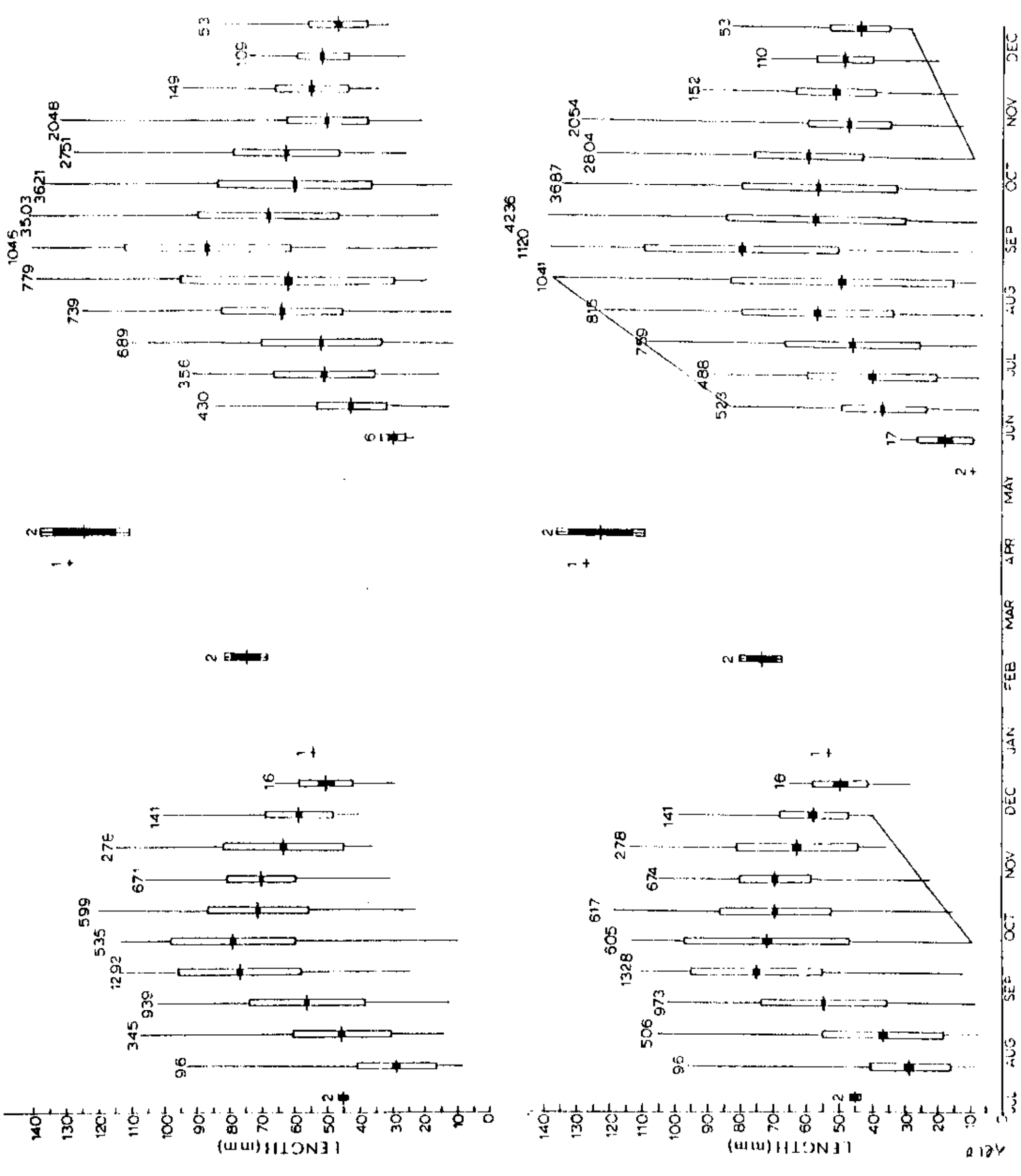
FIGURE 12.--Mean monthly condition coefficients of male blue crabs. The horizontal bar in each diagram represents the mean monthly condition coefficient; the solid black rectangle represents the 5 percent confidence limits on the mean value.



26
25
24
23
22
21
20
19
CONDITION (K)
M A M J J A S O N D J F M A M J J A S O N D J F M A M
1966
1967
1968
MONTHS

FIGURE 12

FIGURE 13.--Total semimonthly catch of white shrimp. In each diagram the vertical line represents the sample range of total lèngths; the short horizontal line represents the mean total length of the sample; the solid black rectangle represents one standard error of the mean on each side of the mean; the white rectangle plus the black rectangle represents one standard deviation on each side of the mean and the number at the top of each diagram gives the sample size. The diagrams in the lower half of the figure represent total catch from all gear; the diagrams in the upper half represent total catch from the trawl only. Lines connecting extremes in length may indicate growth.



LENGTH (mm)
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1966
1967

FIGURE 13

FIGURE 14.--Total semimonthly catch of brown shrimp. In each diagram the vertical line represents the sample range of total lengths; the short horizontal line represents the mean total length of the sample; the solid black rectangle represents one standard error of the mean on each side of the mean; the white rectangle plus the black rectangle represent one standard deviation on each side of the mean and the number at the top of each diagram give the sample size. The diagrams in the lower half of the figure represent total catch from all gear; the diagrams in the upper half represent total catch from the trawl only. No brown shrimp were taken during May, June and July 1966 nor during January 1967. Line connecting extremes in length may indicate growth.

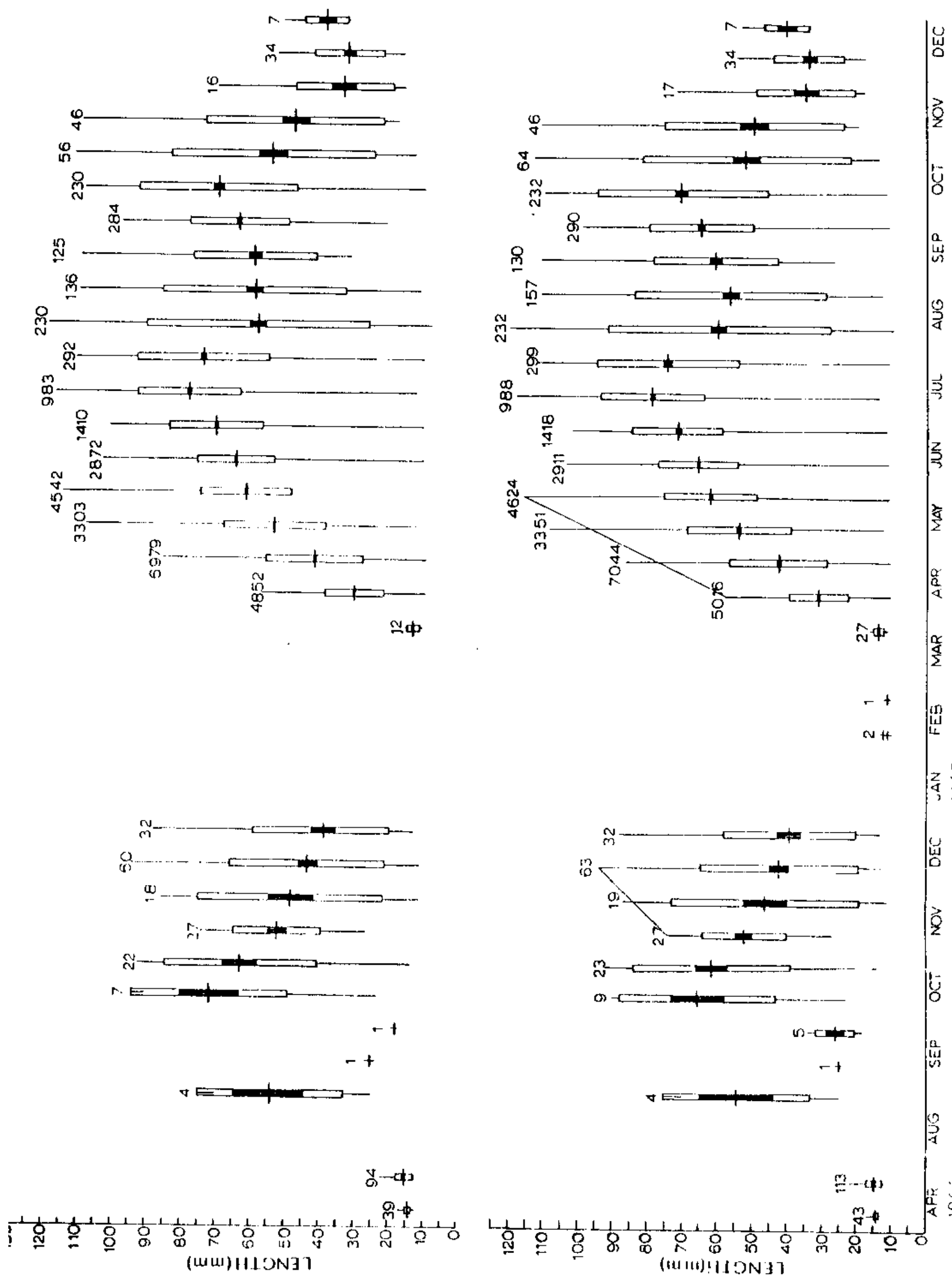

LENGTH (mm)
APR AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1966
1967

FIGURE 14

FIGURE 15.--Length frequency of white shrimp from all gear for a trip in which 50 or more specimens were taken, August 6, 1966 through July 8, 1967.

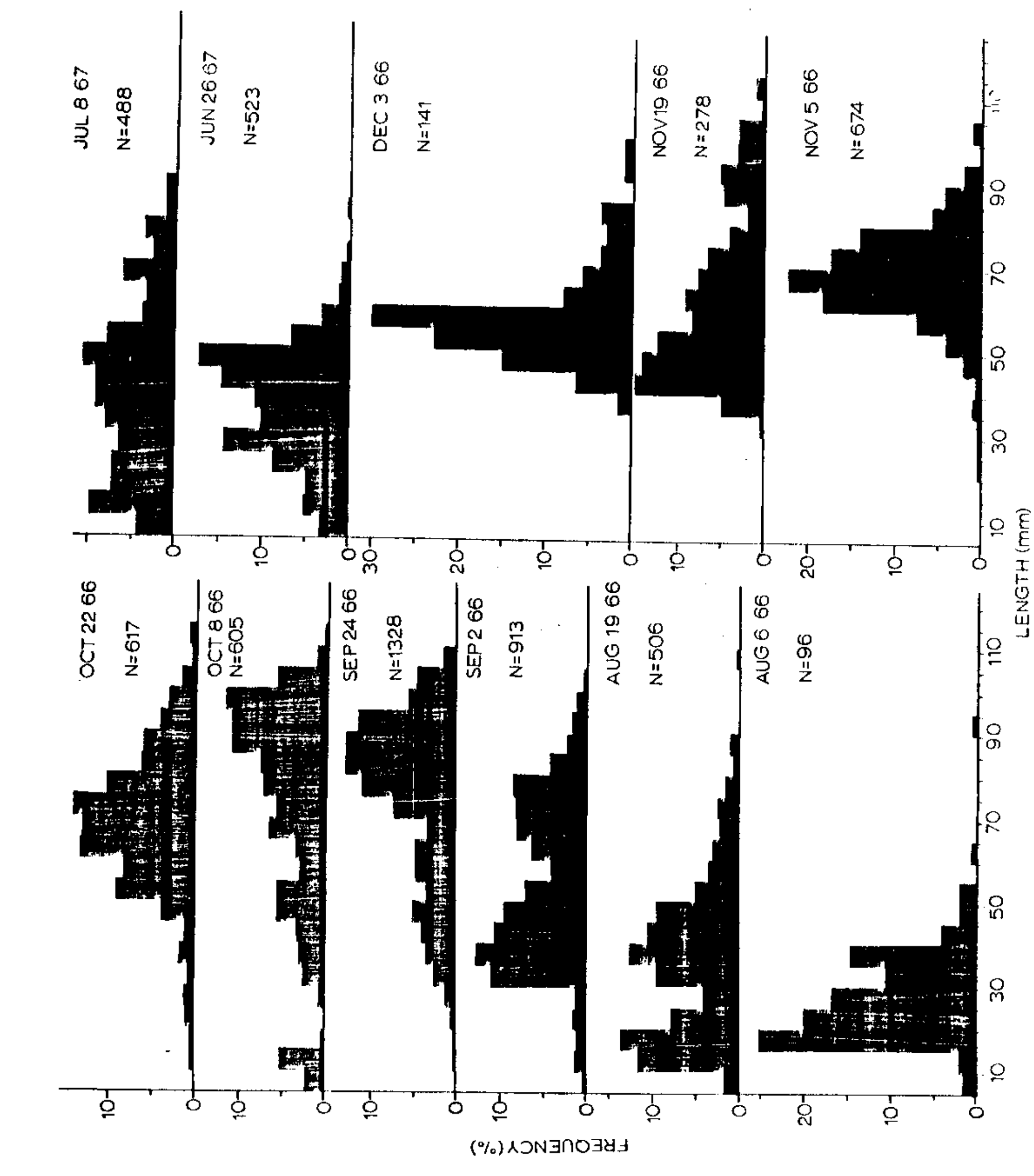

OCT 22 66
N=617
OCT 8 66
N=605
SEP 24 66
N=1328
SEP 2 66
N=913
AUG 19 66
N=506
AUG 6 66
N=96
JUL 8 67
N=488
JUN 26 67
N=523
DEC 3 66
N=141
NOV19 66
N=278
NOV 5 66
N=674
FREQUENCY (%)
LENGTH (mm)

FIGURE 15

FIGURE 16.--Length frequency of white shrimp from all gear for a trip in which 50 or more specimens were taken, July 22, 1967 through December 16, 1967.

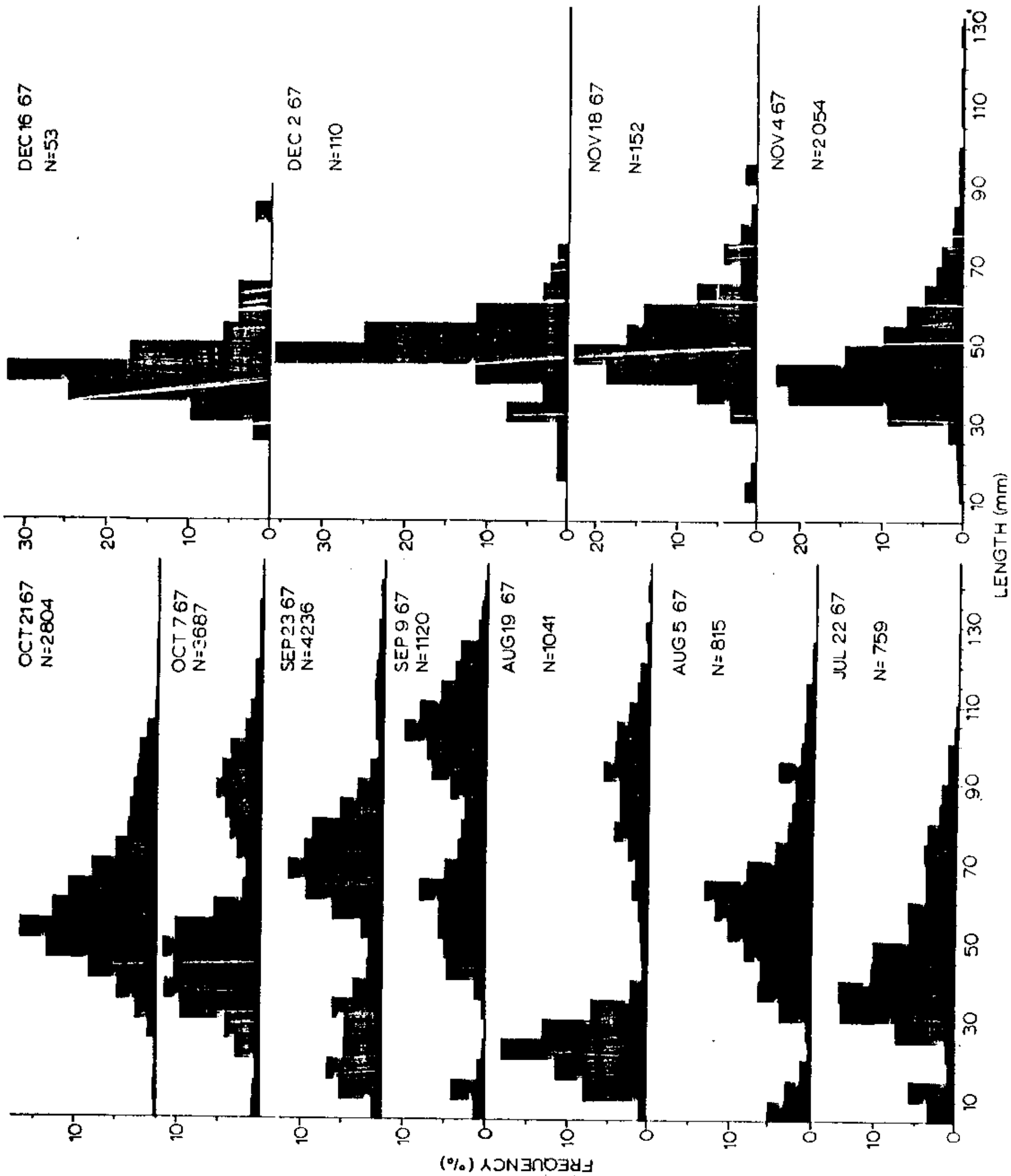

OCT 21 67
N=2804
OCT 7 67
N=3687
SEP 23 67
N=4236
SEP 9 67
N=1120
AUG 19 67
N=1041
AUG 5 67
N=815
JUL 22 67
N=759
DEC 16 67
N=53
DEC 2 67
N=110
NOV 18 67
N=152
NOV 4 67
N=2054
FREQUENCY (%)
LENGTH (mm)

FIGURE 16

FIGURE 17.--Length frequency of brown shrimp from all gear for a trip in which 50 or more specimens were taken, December 3, 1966 through October 21, 1967.

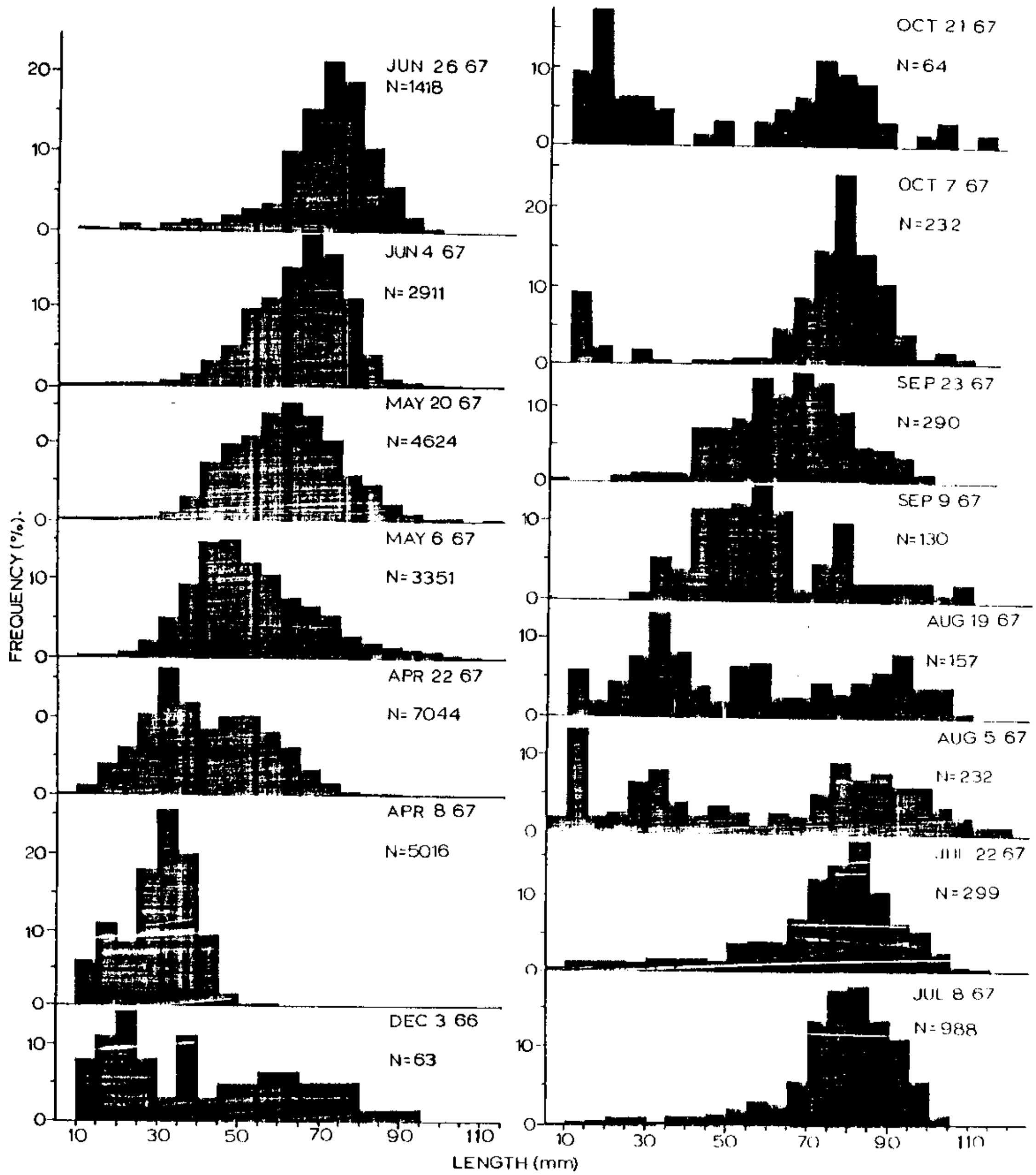

JUN 26 67
N=1418
JUN 4 67
N=2911
MAY 20 67
N=4624
MAY 6 67
N=3351
APR 22 67
N=7044
APR 8 67
N=5016
DEC 3 66
N=63
OCT 21 67
N=64
OCT 7 67
N=232
SEP 23 67
N=290
SEP 9 67
N=130
AUG 19 67
N=157
AUG 5 67
N=232
JUL 22 67
N=299
JUL 8 67
N=988
FREQUENCY (%)
LENGTH (mm)

FIGURE 17

FIGURE 18.--Distribution of white shrimp within the study area from trawl samples containing 30 or more specimens, August 6, 1966 through December 3, 1966. In each diagram, the long horizontal line represents the sample range of total lengths; the number at the right of the horizontal line gives the sample size; to the left of the horizontal line the number in parenthesis gives the salinity in parts per thousand and the letter designates the station. The short vertical line represents the mean total of the sample; the black rectangle represents two standard errors of the mean on each side of the mean and the white rectangle plus the black rectangle represent one standard deviation on each side of the mean.

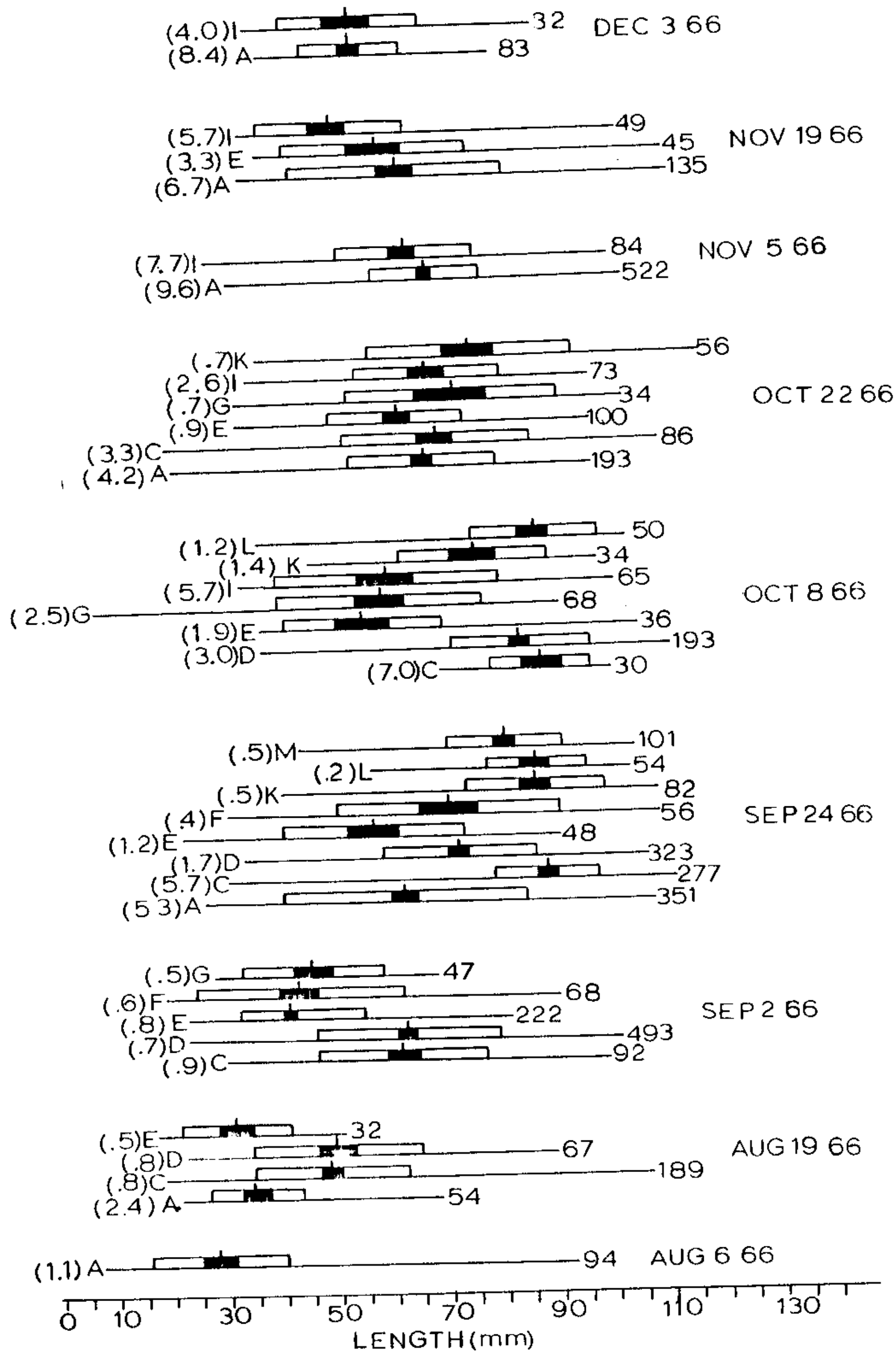

DEC 3 66
(4.0)I 32
(8.4) A 83
NOV 19 66
(5.7)I 49
(3.3) E 45
(6.7)A 135
NOV 5 66
(7.7)I 84
(9.6)A 522
OCT 22 66
(.7)K 56
(2.6)I 73
(.7)G 34
(.9)E 100
(3.3)C 86
(4.2) A 193
OCT 8 66
(1.2)L 50
(1.4) K 34
(5.7)I 65
(2.5)G 68
(1.9)E 36
(3.0)D 193
(7.0)C 30
SEP 24 66
(.5)M 101
(.2)L 54
(.5)K 82
(.4)F 56
(1.2)E 48
(1.7)D 323
(5.7)C 277
(5.3)A 351
SEP 2 66
(.5)G 47
(.6)F 68
(.8)E 222
(.7)D 493
(.9)C 92
AUG 19 66
(.5)E 32
(.8)D 67
(.8)C 189
(2.4) A 54
AUG 6 66
(1.1) A 94
0 10 30 50 70 90 110 130
LENGTH (mm)

FIGURE 18

FIGURE 19.--Distribution of white shrimp within the study area from trawl samples containing 30 or more specimens, June 26, 1967 through September 23, 1967. In each diagram the long horizontal line represents the sample range of total lengths; the number ot the right of the horizontal line gives the sample size; to the left of the horizontal line the number in parenthesis gives the salinity in parts per thousand and the letter designates the station. The short vertical line represents the mean total length of the sample; the black rectangle represents two standard errors of the mean on each side of the mean and the white rectangle plus the black rectangle represent one standard deviation on each side of the mean.

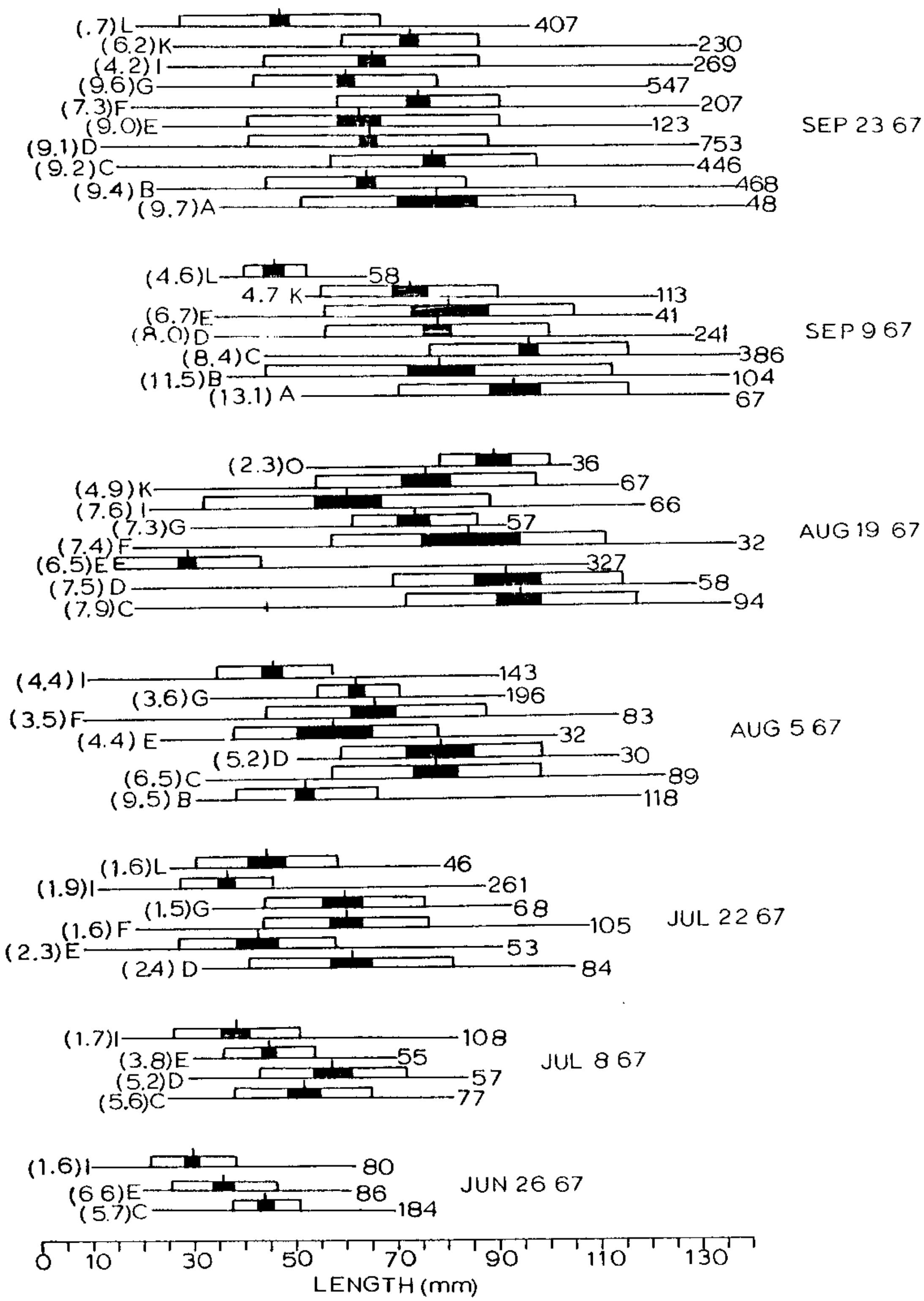

(.7)L 407
(6.2)K 230
(4.2)I 269
(9.6)G 547
(7.3)F 207
(9.0)E 123
(9.1)D 753
(9.2)C 446
(9.4)B 468
(9.7)A 48
SEP 23 67
(4.6)L 58
4.7 K 113
(6.7)E 41
(8.0)D 241
(8.4)C 386
(11.5)B 104
(13.1) A 67
SEP 9 67
(2.3)O 36
(4.9)K 67
(7.6)I 66
(7.3)G 57
(7.4)F 32
(6.5)E 327
(7.5) D 58
(7.9)C 94
AUG 19 67
(4.4)I 143
(3.6)G 196
(3.5)F 83
(4.4) E 32
(5.2)D 30
(6.5)C 89
(9.5) B 118
AUG 5 67
(1.6)L 46
(1.9)I 261
(1.5)G 68
(1.6) F 105
(2.3)E 53
(2.4) D 84
JUL 22 67
(1.7)I 108
(3.8)E 55
(5.2)D 57
(5.6)C 77
JUL 8 67
(1.6)I 80
(6.6)E 86
(5.7)C 184
JUN 26 67
0 10 30 50 70 90 110 130
LENGTH (mm)

FIGURE 19

FIGURE 20.--Distribution of white shrimp within the study area from trawl samples containing 30 or more specimens, October 7, 1967 through December 18, 1967. In each diagram the long horizontal line represents the sample range of total lengths; the number at the right of the horizontal line gives the sample size; to the left of the horizontal line the number in parenthesis give the salinity in parts per thousand and the letter designates the station. The short vertical line represents the mean total length of the sample; the black rectangle represents two standard errors of the mean on each side of the mean and the white rectangle plus the black rectangle represent one standard deviation on each side of the mean.

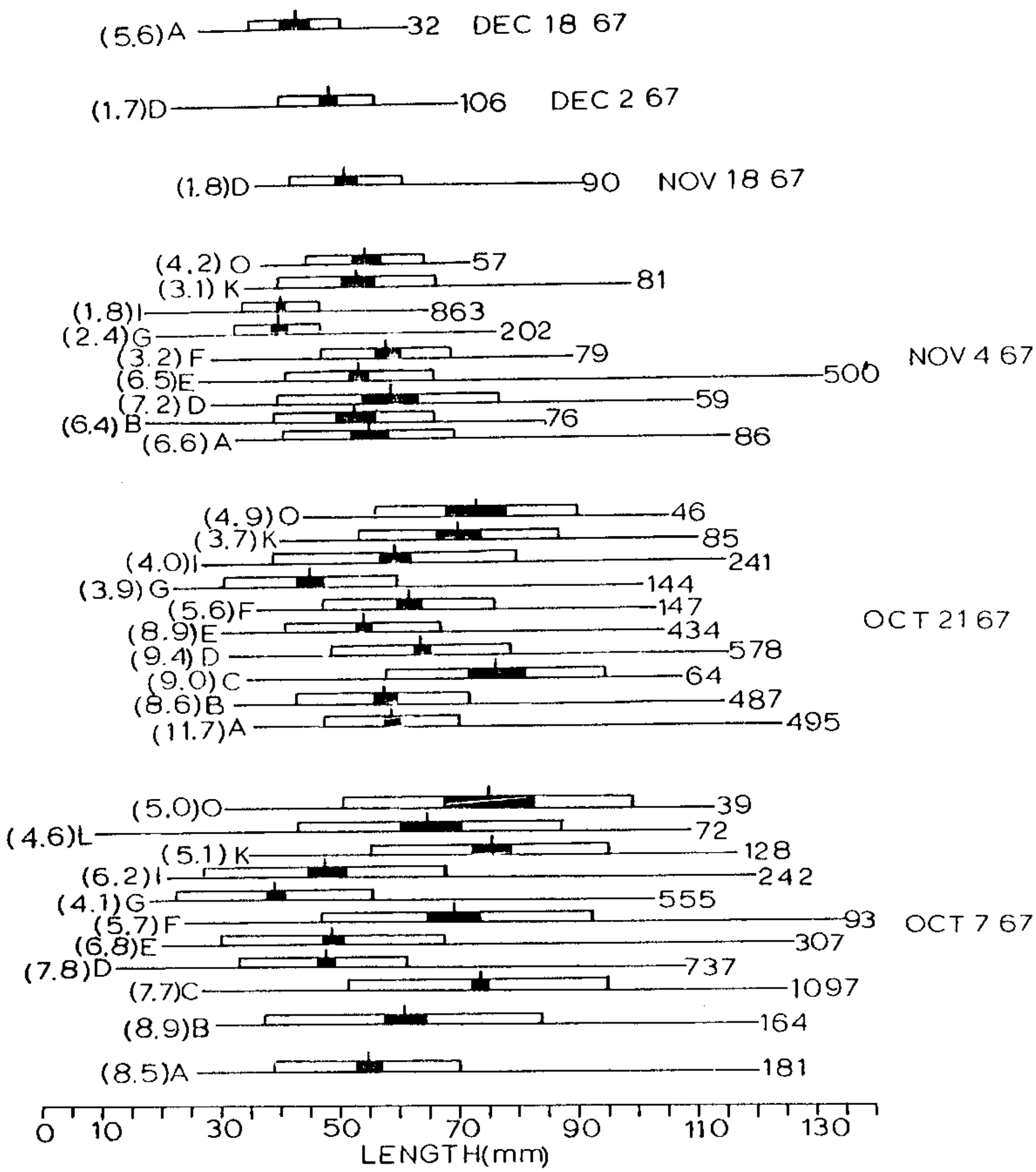

(5.6)A 32 DEC 18 67
(1.7)D 106 DEC 2 67
(1.8)D 90 NOV 18 67
(4.2) O 57
(3.1) K 81
(1.8)I 863
(2.4)G 202
(3.2) F 79
(6.5)E 500
(7.2) D 59
(6.4) B 76
(6.6) A 86
NOV 4 67
(4.9) O 46
(3.7) K 85
(4.0)I 241
(3.9) G 144
(5.6)F 147
(8.9)E 434
(9.4) D 578
(9.0) C 64
(8.6)B 487
(11.7)A 495
OCT 21 67
(5.0)O 39
(4.6)L 72
(5.1) K 128
(6.2)I 242
(4.1)G 555
(5.7)F 93
(6.8)E 307
(7.8)D 737
(7.7)C 1097
(8.9)B 164
(8.5)A 181
OCT 7 67
0 10 30 50 70 90 110 130
LENGTH(mm)

FIGURE 20

FIGURE 21.--Distribution of brown shrimp within the study area from trawl samples containing 30 or more specimens, April 16, 1966 through June 4, 1967. In each diagram the long horizontal line represents the sample range of total lengths; the number at the right of the horizontal line gives the sample size; to the left of the horizontal line the number in parenthesis gives the salinity in parts per thousand and the letter designates the station. The short vertical line represents the mean total length of the sample; the black rectangle represents two standard errors of the mean on each side of the mean and the white rectangle plus the black represent one standard deviation on each side of the mean.

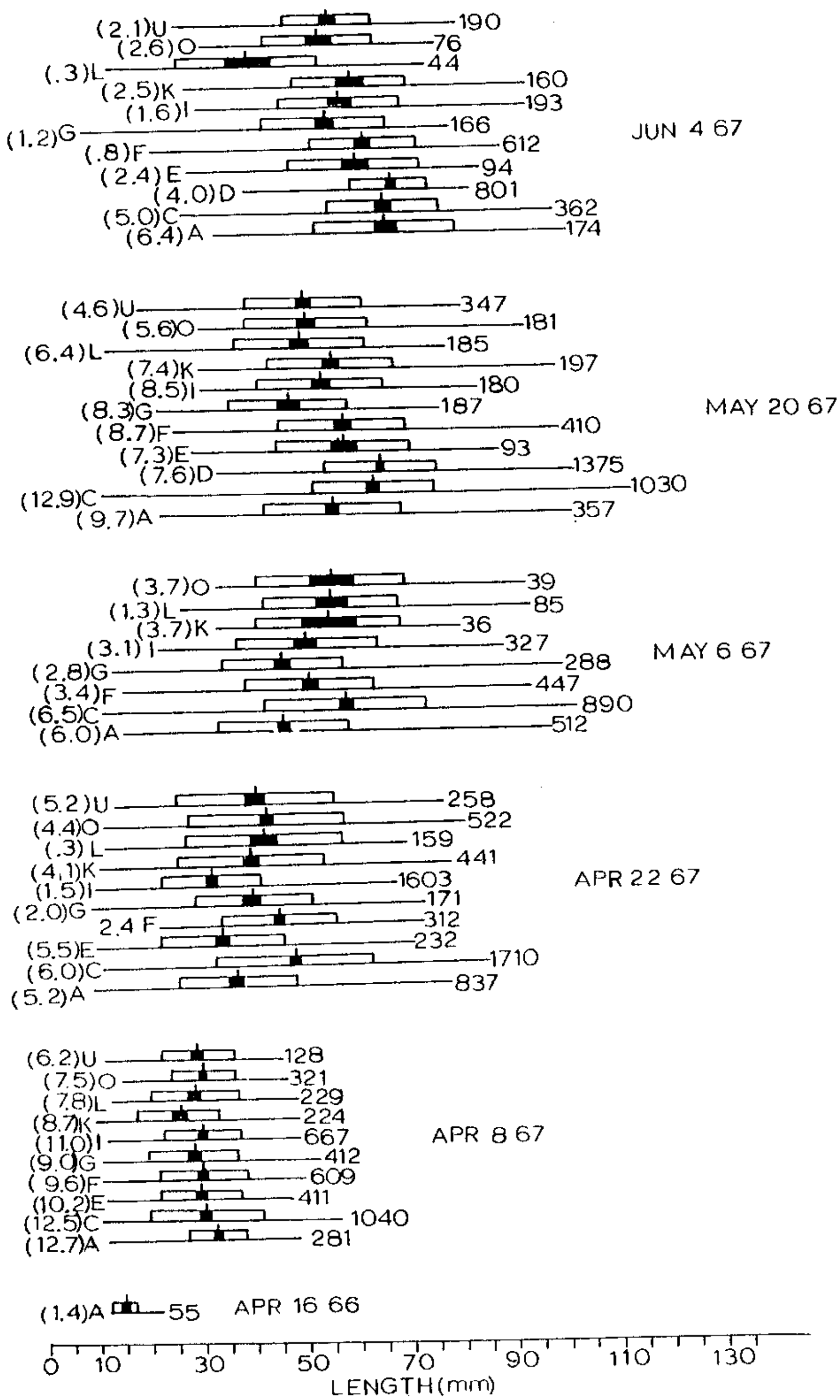

(2.1)U 190
(2.6)O 76
(.3)L 44
(2.5)K 160
(1.6)I 193
(1.2)G 166
(.8)F 612
(2.4)E 94
(4.0)D 801
(5.0)C 362
(6.4)A 174
JUN 4 67
(4.6)U 347
(5.6)O 181
(6.4)L 185
(7.4)K 197
(8.5)I 180
(8.3)G 187
(8.7)F 410
(7.3)E 93
(7.6)D 1375
(12.9)C 1030
(9.7)A 357
MAY 20 67
(3.7)O 39
(1.3)L 85
(3.7)K 36
(3.1)I 327
(2.8)G 288
(3.4)F 447
(6.5)C 890
(6.0)A 512
MAY 6 67
(5.2)U 258
(4.4)O 522
(.3)L 159
(4.1)K 441
(1.5)I 1603
(2.0)G 171
2.4 F 312
(5.5)E 232
(6.0)C 1710
(5.2)A 837
APR 22 67
(6.2)U 128
(7.5)O 321
(7.8)L 229
(8.7)K 224
(11.0)I 667
(9.0)G 412
(9.6)F 609
(10.2)E 411
(12.5)C 1040
(12.7)A 281
APR 8 67
(1.4)A 55
APR 16 66
0 10 30 50 70 90 110 130
LENGTH(mm)

FIGURE 21

FIGURE 22.--Distribution of brown shrimp within the study area from trawl samples containing 30 or more specimens, June 26, 1967 through December 2, 1967. In each diagram the long horizontal line represents the sample range of total lengths; the number at the right of the horizontal line gives the sample size; to the left of the horizontal line the number in parenthesis gives the salinity in parts per thousand and the letter designates the station. The short vertical line represents the mean total length of the sample; the black rectange represents two standard errors of the mean on each side of the mean and the white rectangle plus the black rectangle represent one standard deviation on each side of the mean.

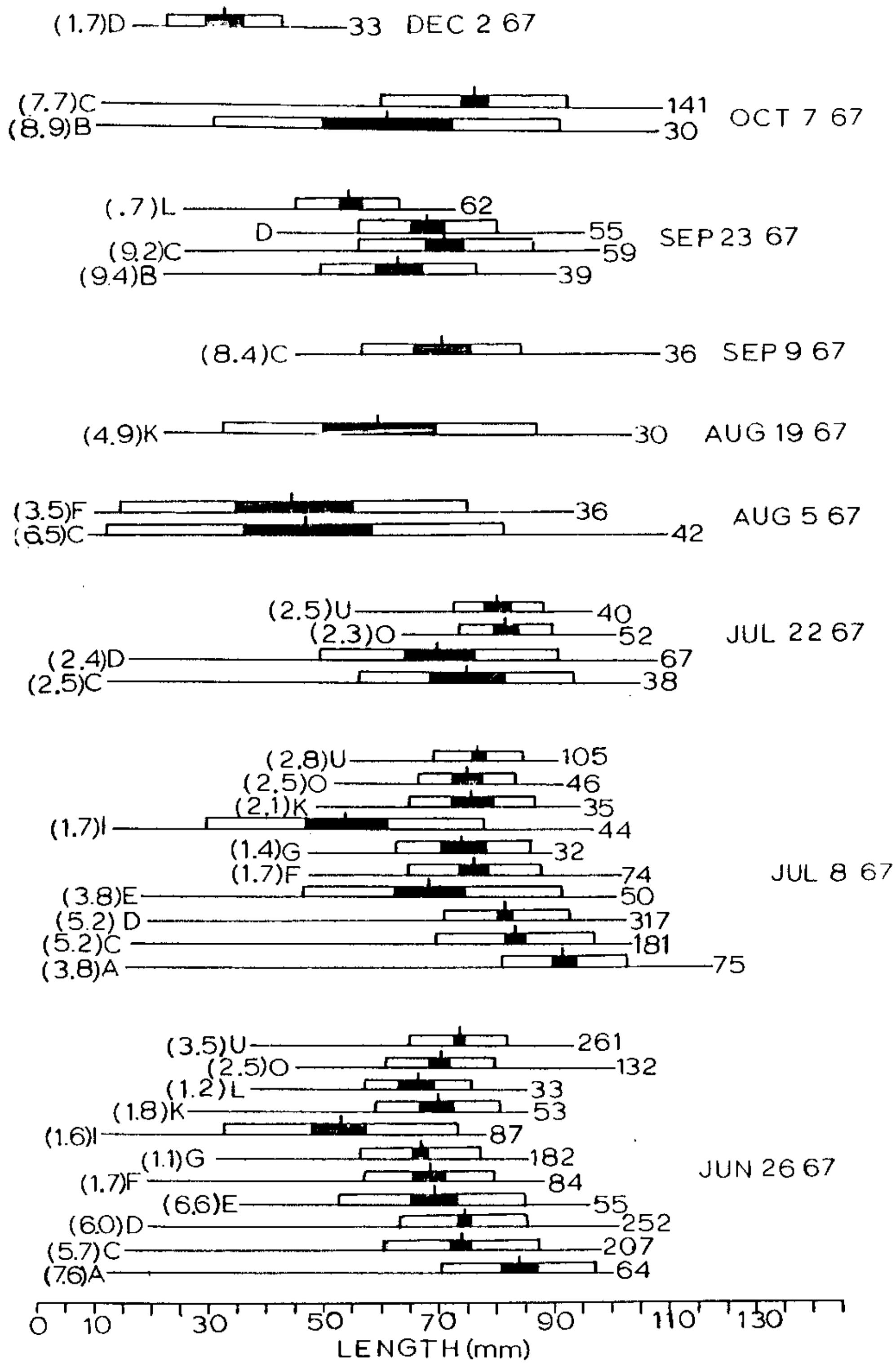

(1.7)D 33 DEC 2 67
(7.7)C 141
(8.9)B 30
OCT 7 67
(.7)L 62
D 55
(9.2)C 59
(9.4)B 39
SEP 23 67
(8.4)C 36 SEP 9 67
(4.9)K 30 AUG 19 67
(3.5)F 36
(6.5)C 42
AUG 5 67
(2.5)U 40
(2.3)O 52
(2.4)D 67
(2.5)C 38
JUL 22 67
(2.8)U 105
(2.5)O 46
(2.1)K 35
(1.7)I 44
(1.4)G 32
(1.7)F 74
(3.8)E 50
(5.2) D 317
(5.2)C 181
(3.8)A 75
JUL 8 67
(3.5)U 261
(2.5)O 132
(1.2)L 33
(1.8)K 53
(1.6)I 87
(1.1)G 182
(1.7)F 84
(6.6)E 55
(6.0)D 252
(5.7)C 207
(7.6)A 64
JUN 26 67
0 10 30 50 70 90 110 130
LENGTH (mm)

FIGURE 22