# OXYGEN DEPLETION IN COASTAL WATERS

Alva H. Harris, James Ragan, Ronald Kilgen

NOAA FORM 90-2
(5-71)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FORM APPROVED.
DECEMBER 31, 1972
OMB NO. 41-R3010

**SEA GRANT PROJECT SUMMARY**
*(Limit all information to this page)*

Completion Report

| PROJECT NO. | PROJECT TITLE ☐ NEW ☐ CONTINUING ☐ CHECK IF SEPARATE PROJECT GRANT | DATE INITIATED, IF CONTINUING |
|---|---|---|
| R/BOD-1 | Oxygen Depletion in Coastal Waters | 9/1/74-8/31/75 |
| GRANT NO. (Unless) | OLD TITLE (If different) | DATE OF THIS FORM: 3/10/76 |
| INSTITUTION: NSU | | ESTIMATED COMPLETION DATE: 3/10/76 |

| PRINCIPAL INVESTIGATOR AND COLLEGE OR DEPARTMENTAL AFFILIATION | % TIME | ASSOCIATE INVESTIGATOR | % TIME |
|---|---|---|---|
| A. H. Harris - Nicholls State University | 50 | J. Ragan; R. Kilgen | 33 1/3 |

| FUNDS EXPENDED TO DATE | | LAST YEARS FUNDING | | PROPOSED FUNDING | | RELATED PROJECTS (By numbers) |
|---|---|---|---|---|---|---|
| FED.-SEA GRANT | MATCHING | FED.-SEA GRANT | MATCHING | FED.-SEA GRANT | MATCHING | |
| $ 55,000 | $ 49,252 | $ | $ | $ | $ | |

| PART OF UNIVERSITY PROGRAM | OFFICE OF SEA GRANT CLASSIFICATION |
|---|---|
| | |

OBJECTIVES: 1) To determine the cause of oxygen depleted bottom waters in the Gulf of Mexico west of the mouth of the Mississippi that were discovered in May of 1973 and persisted until September of 1974; 2) to determine if the phenomenon can be expected to be a chronic or an occasional condition; to determine the biological effects of low oxygen on the location and movements of commercial shrimp, benthic species of commercial and sports fishes, and other forms of marine organisms in the area.

HOW INFORMATION WILL BE APPLIED *(Be specific)*:
An understanding of the interacting forces between the discharge of the Mississippi River and the physical and biological characteristics of the Gulf of Mexico where the two meet is the first step in comprehending the natural productivity of Louisiana's continental shelf and adjacent estuarine waters. This understanding must be used by state and federal agencies as they begin to manage and regulate the harvest of renewable marine resources within the newly proposed 200 mile contigeous fisheries zone.

ACCOMPLISHMENTS DURING PAST TWELVE MONTHS *(Not more than one sentence per accomplishment)*:

1. A hypothesis has been advanced as to the cause of oxygen depleted bottom waters in the Gulf of Mexico.
2. Low oxygen conditions appear to be seasonally chronic.
3. Most motile benthic organisms, including shrimp, leave areas of low oxygen.
4. Several hundred square miles of bottom waters are without oxygen during spring and summer months.
5. A lengthy technical report listing oceanic environmental conditions and associated biological data has been submitted to the L.S.U. Sea Grant Program.

NOAA FORM 90-2

FINAL REPORT

TO

THE OFFICE OF SEA GRANT

NOAA, U. S. DEPARTMENT OF COMMERCE

| | | |
|---|---|---|
| PROJECT | : | Oxygen Depletion in Coastal Waters (R/BOD-1) |
| YEAR | : | September 1, 1974 - August 31, 1975 |
| PRINCIPAL INVESTIGATOR | : | Alva H. Harris |
| ASSOCIATE INVESTIGATOR | : | James Ragan and Ronald Kilgen |
| DATE SUBMITTED | : | FEB. 11, 1976 |

## I. INTRODUCTION

The Sea-Grant Research Project (R/BOD-1) conducted by Nicholls State University in the Gulf of Mexico was an attempt to discover the factors causing oxygen depletion in marine bottom waters of the Gulf of Mexico adjacent to the Louisiana Coast, and to determine if low oxygen conditions had any effect on the distribution of marine organisms within the study area. As a result of studies conducted under this grant, and review of data compiled the year before on baseline studies for the proposed construction of a superport in the research area, a hypothesis is offered as to the cause and effects of the phenomena.

## II. BACKGROUND

During May, 1973, baseline studies collecting environmental data to be used in conjunction with application for the proposed construction of a superport in the Gulf of Mexico revealed the presence of a large anoxic area of marine bottom waters off the Louisiana Coast. Several hundred square miles of normally highly productive shrimping grounds in the Gulf of Mexico had little or no oxygen on the bottom, and there were significantly less fish, crabs, shrimps, and other motile benthic organisms within this area. Figure 1 maps the minimum extent of the anoxic area as it existed during June of 1973. Ship time was not available to completely map the westward extent of the area. Anoxic waters have persisted in varying degrees of magnitude, except following hurricanes that affected the area, through September of 1975.

The effects that these anoxic waters might have on the overall productivity of Gulf Waters and the adjacent estuaries in unknown. For many years, the health and viability of the Louisiana estuaries and their associated marshlands in terms of pollution, water temperatures, salt water intrusion, excessive fresh water, and abnormal tides, has been considered the determining factor for annual production levels of shrimp and other seafood. Comparisons of data have begun to show trends and correlations between annual production levels of some species and easily measureable environmental conditions. One such correlation is that in years of above average Mississippi River discharge, there is a below average shrimp crop. The Mississippi River discharge in 1973 was the highest in 25 years, and was above average during the Spring of 1974 and 1975. The Louisiana shrimp harvest for 1973 and 1974 was approximately 37,000,000 lbs. per year, the lowest annual catch since 1965, despite a substantial increase in the numbers of vessels shrimping in 1973 and 1974 as compared to 1965. The assumption has always been that excess fresh water in years of high river discharge entered the estuaries and either killed the postlarval and juvenile shrimp with reduced salinities or reduced the effective size of nursery area within the estuary that would support shrimp.

Brown (*Penaeus aztecus*) and white shrimp (*Penaeus setiferus*) that reach maturity in Louisiana waters spend the majority of their life cycle offshore as sub-adults and adults, and minority of their life cycle within the nursery areas as post-larvae and juveniles. Current research being conducted by Nicholls State University indicates that the nearest edge of important spawning grounds of brown shrimp to the Louisiana estuaries begins approximately 15 miles south of Grand Isle in 20 fathoms of water and lies immediately south of the anoxic area. The majority of brown shrimp spawning grounds for the whole state West of the Mississippi River is over 50 miles offshore. Thite shrimp spawning grounds are shoreward of the brown shrimp spawning grounds, and in general would encompass the entire area affected by anoxic waters. It is probable that anoxic conditions in bottom waters offshore of the Barataria and Timbalier estuarine nursery areas affects the spawning success, the mortality rates, and the migration patterns of larval, postlarval, and juvenile shrimp as they traverse or attempt to traverse the anoxic waters.

## III. DESCRIPTION OF RESEARCH AREA

Figure 1 encompasses the area investigated during this project. All samples taken were between 29°40' by 29°30'N Latitude and 89°30' by 90°35'W Longitude. The area is immediately South of the Louisiana coastline between the Southwest Pass of the Mississippi River and Ship-Shoal and includes water depths from the shoreline seaward to 44 meters. Extension of the Bird-foot delta of the Mississippi River Southward into the Gulf of Mexico tends to block normal littoral currents and has created a bay-like configuration of the Gulf between the Delta and the Grand Isle, Louisiana area. The majority of the Mississippi River discharge enters the Gulf via Southwest Pass, and this highly turbid, nutrient and sediment laden body of water

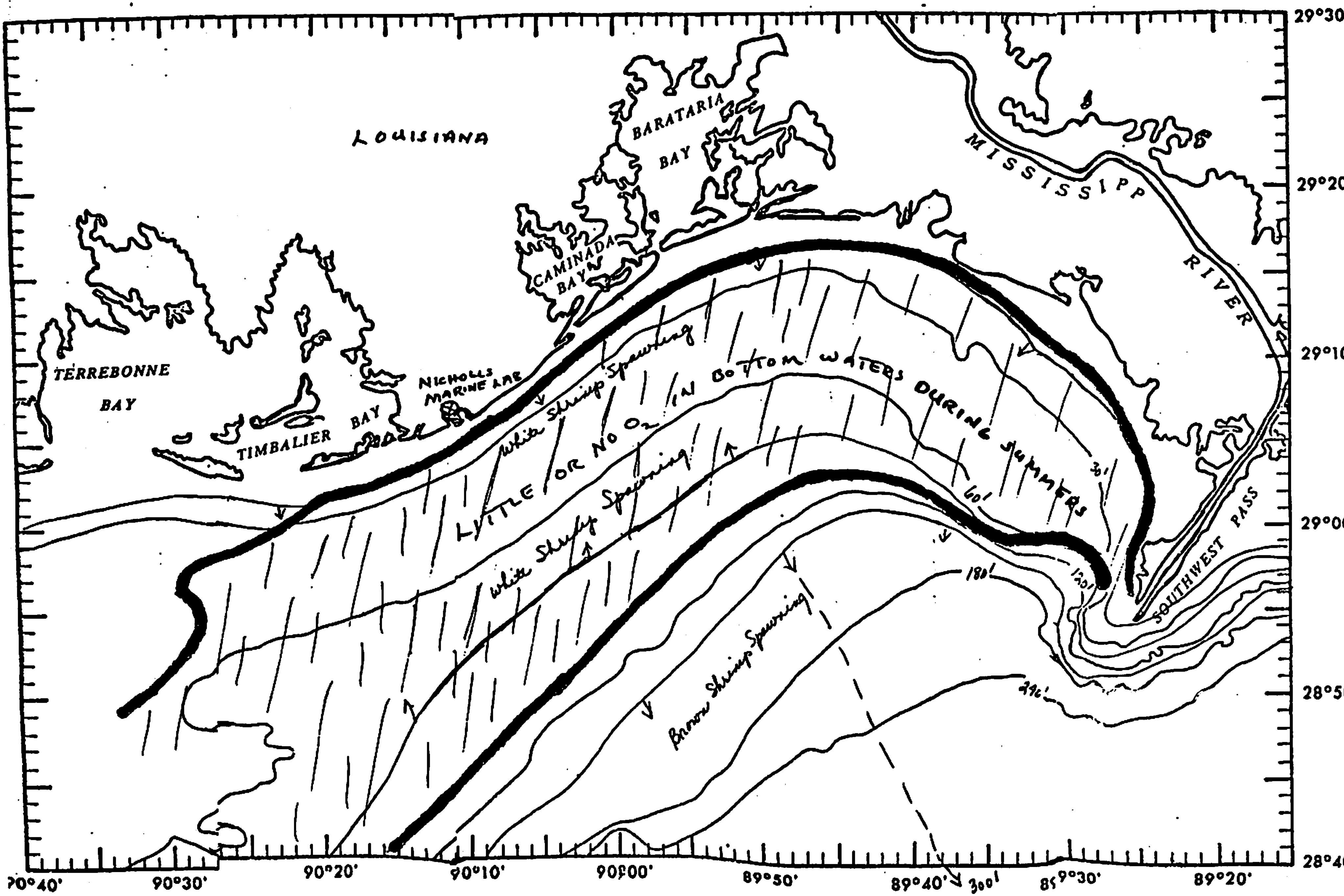


Figure 1 Map of Area Studies by Nicholls State Sea-Grant Research Project R/BOD-1.

flows generally North and West as a surface sheet over the bay-like configuration of Gulf waters that lie West of the River. The direction of the sheet-flow discharge of the South-West Pass of the Mississippi River is a result of prevailing oceanic currents and winds.

Offshore oil wells are abundant throughout the area with continued exploration occurring and the attendant boat traffic associated with offshore oil production increasing. LOOP, INC. proposes to build a superport oil terminal and lay oil transporting pipelines through the anoxic area.

## IV. OBJECTIVES

The objectives of the project were: (1) to determine the cause of oxygen depleted bottom waters that was discovered in the Gulf of Mexico West of the mouth of the Mississippi River in 1973; (2) to determine if the phenomena can be expected to be an annual or occasional condition; (3) to determine the biological effects of low or no oxygen on the migratory patterns and survival of benthic nekton and infauna; and (4) to establish a baseline of normal environmental conditions in areas where anoxic conditions do not occur. An initial objective that could not be met and that was dropped at the outset was to determine the combined effect of oxygen depleted bottom waters and low salinity surface waters on the migration and survival of larval shrimp and fishes that must migrate via currents through the area to reach estuarine nursery areas.

# V. METHODS AND MATERIALS

Sampling stations were selected between South-West Pass and Ship-Shoal and data was taken with the use of a Martek MARK II-A Water Quality Analyser, 16' shrimp trawls, plankton nets, and a ponar bottom grab. Physical, chemical, and biological data were taken as weather conditions and available boat facilities permitted. Nicholls State University provided a 21' Boston Whaler for data taking. The Whaler proved to be unsatisfactory for this type of sampling program, mainly because it was loaded beyond safe limits. The Whaler was swamped and almost lost in 4' seas 15 miles offshore on 10/22/74. All subsequent data for the duration of the project was obtained through the use of the Principal Investigator's personal boats. Part-time use of a Louisiana Wildlife and Fisheries Commission boat was requested, but the Commission condluded that it did not have an available boat that was sea-worthy enough to support this type of research program.

The Martek MARK II-A Water Quality Analyser was used for in situ field measurements of temperature, depth, conductivity, dissolved oxygen, and pH levels. A description of this instrument is attached. The instrument was calibrated immediately prior to each cruise following the specific instructions as outlined in the instruction manual in the appendix. The winkler method for determining dissolved oxygen as described in Standard Methods 13th Edition was used in calibrating the dissolved oxygen sensor using marine water for titration.

Nekton was sampled during September, October, and November 1974, and February 1975 at 23 stations. Each location was occupied once during the four month sampling period using a 16 foot nylon shrimp trawl with 1 1/4 inch stretch mesh with a 1/4 inch mesh liner on the cod end. Stations were trawled for 10 minutes at approximately 3 Knots/hour.

The entire catch was iced down in insulated containers and returned to the laboratory for processing.

The sampled animals were grouped by taxa, and those within each group were counted and weighed collectively.

Zooplankton was obtained from 20 locations during September, October, and November, 1974 and February, 1975. During this period, two tows were taken once at each of 20 locations. A single two minute (approximate) tow was made at the surface while a second tow was being made concomitantly below the level of Secchi disc visibility. The short towing time was suggested by Marilyn Gillespie of the Louisiana Wildlife and Fisheries commission because of high plankton density in coastal waters of southeastern Louisiana.

Mouth size of the metered plankton net was 12 inches and the net and basket mesh was a standard #10 (.0058 inches). A depressor was used to maintain the desired sampling depth. The amount of water strained was calculated by multiplying the number of flowmeter revolutions by the volume of water (in $m^3$) passing through the net with each revolution (a calibrated factor of .4).

Samples were washed down into a bucket, transferred to screw capped 8-ounce bottles containing 5 percent formalin, and delivered to the laboratory for processing.

The volume of zooplankton was determined by allowing settling for 20 minutes in clear graduated cyclinders. Each sample was diluted to a level ranging between 500 to 1000 milliliters depending on the density of organisms. The contents of the cyclinder were thoroughly shaken after which a portion was extracted from the middle level using a pipette. A one milliliter aliquot was placed on a Sedwick-Rafter cell where the zooplankton was identified and counted under 100X. The larger macro-plankters were subsequently removed and counted under 10-20X.

Macrobenthic infauna were obtained during September, October, November, 1974 and February 1975. Nineteen samples obtained during this period represent a single sampling effort at each of nineteen locations.

A ponor grab sampler was employed to obtain a 9" xy 9" portion of substrate at each location. The sampler is discussed by Sly (1969) and Powers and Robertson (1967).

The entire sediment sample was washed through a standard wash bucket with #30 wire mesh (0.59 mm). Organisms retained on this method were placed in plastic jars containing 5% buffered formalin and stored until processing.

Where necessary, organisms were separated from debris by the sugar floatation method of Anderson (1959) which uses the principle of density differences. Animals were identified, grouped, counted and subsequently expressed as numbers of organisms per square meter of substrate sample through multiplying by a factor of 19.2.

# VI. RESULTS

The following tables and Figures documents and summarizes the data that was collected in support of this program. The number of sampling trips and the type data collected on each trip was dictated by weather conditions and available boats.

Hurricane Carmen passed over the research area and buffeted the Fort Fourchon area, which is where the Nicholls State University Laboratory is located, with 100 MPH winds and 6' tides on September 7, 1974. The access road to Port Fourchon and the Laboratory was completely washed out for several miles and re-opened for travel in December of 1974. Access to the Marine Laboratory was by small boat during this period.

## Water Quality

Tables 37-127 include all in situ readings that were obtained during the course of this study using the Martek MARK II-A Water Quality Analyser. The water column was profiled from Surface (S) to bottom at increments of 1, 3, 5, 7, 10, 15, 20, 25, etc., meters. Additional increments were taken if low oxygen existed to detect its upper limits in the water column. Tables 128-135 contain monthly summaries of Martek data but include only Surface, Mid-depth, and Bottom readings from each sampling location.

Critical examination of the data in Tables 37-135 reveal several important characteristics of the marine waters within the study area. The water column is highly stratified in respect to salinity, temperature, pH and dissolved oxygen during the greater part of the year. The degree of stratification was highest during the spring and summer months and lowest during the fall and winter. The degree of stratification coincides with the seasonally higher discharge rates of the Mississippi River, and is obviously a direct result of river discharge rates.

Oxygen levels in bottom waters drop to below critical levels at some locations during February and remain low until October. Mississippi River discharge is normally at its lowest rate during September and October. Review of data taken during 1973 for LOOP, INC. Superport studies, data from the 1974-1975 Sea Grant Study, and data from a Nicholls State supported study presently being conducted for 1975-1976 all reveal the same trend. It seems safe to conclude that low oxygen conditions in the bottom waters of the study area is a chronic condition likely to reoccur every year so long as river discharge rates and oceanic current patterns approximate those of the past 3 years.

The following hypothesis has evolved during the past 3 years and is offered as an explanation for the cause of low oxygen conditions that has been recorded annually since its discovery in 1973.

Answer: The cause of eutrophication in the Gulf is apparently the result of many identifiable and unidentifiable factors acting together and perhaps uniquely to produce a profound effect on the marine environment. Known factors are listed in order.

A. The Mississippi River drains approximately 1/2 the land mass of the continental U. S. of America.

B. The Mississippi River has levees throughout its flood plains all the way to its discharge passes in the Gulf of Mexico. The majority of the river discharge enters the Gulf through south-west pass. Flood waters that historically overflowed the levees of the Mississippi River and flowed as a broad sheet over the deltaic flood plains, depositing its silt and organic loads as it passed, are now introduced into the Gulf at one point.

C. The Mississippi delta near the passes juts out into the Gulf in the shape of a mushroom, making a semi-enclosure of the Gulf in the area northwest of south-west pass. This geographic configuration of the coastline has interrupted normal littoral currents, and created an eddying effect in the oceanic currents in the area.

D. The fresh-water discharge from south-west pass flows north and west in response to prevailing marine currents and wind. This fresh water mixes slowly with the marine waters it encounters, and because of its low density as compared with marine water, it spreads like a sheet over the Gulf north and west of the river mouth. A distinct stratification of marine waters occurs in the study area, with low salinity, highly turbid waters near the surface, and higher salinity waters on the bottom that show much less temperature fluctuations. The eddying effect of marine currents within the semi-enclosure compliments a continued stratification during periods of high river discharge.

E. The Mississippi River waters are highly charged with detritus, dissolved organics, and nutrients. As the river water loses its velocity while spreading across the surface of the Gulf, these materials either settle to the bottom, or furnish the nutrients to produce a continual plankton bloom in the upper waters. Turbidity of surface waters is maintained by plankton blooms for long distances from the mouth of the river, and sunlight is blocked from bottom waters, preventing photosynthesis. The highly organic fallout from surface waters has built up bottom muds with Biological Oxygen Demands (BOD) equivalent to that of raw domestic sewerage. Any oxygen present in the high salinity bottom water is rapidly depleted by bacterial decomposition of organic material. Oxygen replenishment is apparently prevented by stratification and non-mixing with surface waters and by a lack of photosynthesis. Highly stratified conditions often exist in waters as shallow as 25' and continues offshore to beyond the 100' curve.

Nekton

Ten minute trawls were taken once at each of 23 locations during September, October and November, 1974 and February, 1975. Trawling was confined to relatively shallow depths ranging from 5 to 28.5 M and averaging 12.6 M.

Physical, chemical and catch data appear in Tables 1-4. Average catch weights were greatest in September when water temperatures were highest (Table 5). This may reflect a movement of predominant forms (fishes) away from the nearshore areas to deeper warmer waters. There is evidence (Ragan, 1961 and 1962) that such migrations do occur during the fall in the Northern Gulf.

The distribution of fish by depth further indicates that such a migration was taking place. The average fish catch was far heaviest at the shallowest stations ( 10 M) in September, but by October it was greatest at intermediate depths, a trend that became more pronounced during November (Tables 1-3). By February, fish catches were heaviest at the deepest stations ( 20 M), and lightest at the shallowest stations where temperatures had reached their lowest points (Table 4).

Bottom salinities varied little at sampling locations and were not correlated with size of catch (Tables 1-4).

Oxygen values were occasionally very low, being less than two parts per million at two stations and 2.2 ppm at a third (Tables 1 and 4). No organisms were found in the trawl at the latter station but catch was not usually low at the other two (Tables 1 and 4). There are at least three possible explanations for this. First, the method used in obtaining oxygen readings had an inherent limitation. Readings were taken from a stationary vessel either before or after a trawling distance of approximately one-half mile was covered. Hence, the reading obtained may not represent conditions over the entire area trawled. Secondly, anoxic waters are sometimes confined to very narrow layers on the bottom. The nekton was composed of fairly powerful swimmers which may move vertically into and out of such layers as the need dictates. Thirdly, the trawl fishes all depths during its descent and ascent.

Actual numbers and weights of the fishes, commercial shrimp and other invertebrates taken by trawl also appear in Tables 1-4.

Commercial shrimp were given a special category because of local economic importance.

Fish were the prime contributors to catch weight (83%) followed by benthic invertebrates (12%), and shrimp were last with 5%. Ragan (unpublished) found that fish comprised 92%, invertebrates 5% and commercial shrimp 2% of the catch weight in a more extensive sampling program conducted in the same offshore region of Louisiana.

A tabulation of the overall abundance of organisms by category is less informative due to the inclusion of over 25 thousand tiny sergistid shrimp (Lucifer faxoni) in two September samples. If this statistic is ignored, the numbers of organisms in each category is similar to their representation based on weight (fish 77%, invertebrates 17%, commercial shrimp 6%).

Overall, 36 species of fish were recorded (Table 6). The five most abundant species (Table 7) constituted 90% of the total number taken. The five species which contributed most heavily to catch weights accounted for 76% of the total weight (Table 8).

The species most important on the basis of both numbers and weight were, in the order of overall importance, the Atlantic croaker (Micropogon undulatus), the sea catfish (Arius felis), and the sand seatrout (Cynoscion arenarius). The bay anchovy (Anchoa mitchilli) contributed little to catch weight but was the most abundant species due to unusually high representation at one station. This species travels in dense schools in upper pelagic waters, (Breder, 1948), and was probably obtained while the trawl was being raised.

The composition of fishes in the catch was similar to those found in other studies (Ragan, 1961 and 1962; Moore et al., 1970) conducted in the Northern Gulf. Sampling was less extensive in the present study, and fewer species were recorded.

The five species of invertebrates that were most abundant are shown in Table 9 while those that contributed most to catch weights are in Table 10. The small sergisted shrimp (Lucifer faxoni) comprised 99% of the total number of invertebrates but its contribution to catch weight was neglible. The scyphozoan medusa (Stomolophus meleagris) ranked first in contribution to catch weight. However, this species is not demersal, and it is probable that the few large specimens that account for this were captured while the trawl was being hoisted from the bottom. The same was probably true for the ctenophore (Pleurobranchia sp.) which is generally high in the water column (Hyman, 1940). The inshore squid (Loliguncula brevis) and the mantis shrimp (Squilla sp.) were consistantly important from the standpoint of both numbers and weight, and are regarded as predominant bottom forms. Other benthic invertebrates that were well represented include the blue crab (Callinectes sapidus) and the sergistid shrimp (Acetes americanus).

White shrimp (Penaeus setiferus) was the predominant commercial shrimp species in the catch constituting 52% of the numbers and 60% of the weight (Tables 11 and 12). The seabob (Xiphopenaeus kroyleyi) was second (25%; 11%) and brown shrimp last (12%; 11%). Other than these, a few penaeid postlarvae made up the remainder of organisms in the commercial shrimp category.

The predominance of white shrimp over the brown is to be expected as trawling occurred during the day in relatively shallow waters.

Brown shrimp off of Texas and Louisiana are fished during the night at depths of 55 to 75 M while white shrimp are taken by day inside of 35 M (Kutkuhn, 1966).

A phylogenetic listing of all invertebrates taken by trawl, including the commercial shrimp appears in Table 13.

Zooplankton

Surface and mid-depth tows were obtained at each of 19 stations. The physical and chemical data and the numbers of zooplankton per $M^3$ is shown for all tows in Tables 14-17.

Average density of zooplankton ($M^3$) and average volumes ($ml/M^3$) are summarized by month and station depth in Tables 18-21. These values are expected to be somewhat divergent for corresponding samples because of variability in the size composition of component zooplankton. For example, the inclusion of a few large forms, such as medusa and ctenophores, would raise the volume considerably while changing the density to a very slight extent. The two measurements did show a general correspondence in that both density (Table 18) and volume (Table 20) of zopplankton were lowest in September and highest in October. This trend may indicate that zooplankton populations rose from a low summer level still visible in September to a fall peak that crested in October and began to decline in November. Ragan (unpublished) working in the same offshore area during 1973 found zooplankton peaks in late Spring (May-June) and in fall (October), with a minimum in winter (December through February). Gillespie (1971) reported that Louisiana coastal zooplankton peaks occurred in May and November with a winter low that dropped to a minimum in February.

Zooplankton samples taken in February contained much detritus that was difficult to separate out. The resulting settling volumes were not representative, and are omitted from this account. Average volumes for the remaining months varied between 1.1 to 3.0 $ml/M^3$ while averaging 2.0 (Table 20). These values are very high. Arnold (1958) reported plankton volumes for the Gulf shelf to 0.171 $ml/M^3$. This value is comparable to those of Austin and Jones (in press) who found summer zooplankton levels in the Florida "middle ground" to be 0.10 - 0.20 $ml/M^3$, and winter standing crop to be somewhat higher at 0.25 - 0.50 $ml/M^3$. They found short term concentrations of up to 8.0 $ml/M^3$, and suggested that these maxima are associated with LOOP current mixing.

The most extensive data on Gulf shelf zooplankton are those available from the Soviet-Cuban fisheries investigatons which sought to delineate areas of high plankton productivity and standing crop in the Gulf and Caribbean. Bogdonov, et al., (1969) have identified three regions of high productivity on the eastern shelf: 1) east of the Mississippi River mouth; 2) northern and 3) southwestern section of the Florida shelf. Highest annual biomass (0.3 to 1.0 $ml/M^3$) were encountered in regions 1 and 2, and were attributed to the influence of nutrient rich runoff, principally that from the Mississippi (Khromov, 1965; Bogdonov, et al., 1969). Maximum values for region 1 east of the Mississippi exceeded 2.0 $ml/M^3$.

Most of the water leaving the Mississippi discharges through Southwest Pass, and courses in a westerly direction (Walsh, 1969). The present study area west of Southwest Pass is directly under the influence of this discharge. Salinities (Tables 14-17), which were normally below 30 ppt, are obviously low for an offshore area, and provide evidence of the diluting influence of river waters. There is little doubt that river discharge with its high nutrient load plays an important part in ultimately sustaining the heavy volumes of zooplankton recorded. Ragan (unpublished) found comparable levels during the corresponding sampling months, and an annual average of 5.3 ml/$M^3$. The study took place during 1973 when Mississippi discharge reached its highest level in recent years (U. S. Army Engineering District, 1975).

Zooplankton abundance and volume (Tables 19 and 21) were highest at intermediate depths (10-20 M). This trend was pronounced in the case of overall abundance but settling volumes of samples varied only slightly with depth.

Numbers and volumes of zooplankton were almost consistantly higher in mid-depth than in surface tows. This pattern is exhibited when samples are grouped by month or by station depth (Tables 18-21), and is attributed to the fact that samples were taken during the day when vertically migrating forms tend to occupy deeper levels (Raymont, 1963; Hardy, 1956).

All zooplankton is listed phylogenetically in Table 22. The composition of all tows (types per $M^3$) is presented in Tables 23-26.

Copepods comprised 61% of total catch and contributed 55 to 66 percent during the four sampling months (Table 27). Three genera accounted for 65% of the copepods collected. *Acartia* (primarily *A. tonsa*) was the dominant species (39%), followed by a second calinoid type (Paracalanus) with 16% and the cyclopoid genus Oithona was third with 10%. The percent contribution of these forms is shown by month in Table 28. The average number ($M^3$) is given by month in Table 29. Acartia sp. reached a peak in February with a smaller peak in October. Paracalanus and Oithona were most numerous in October (Table 29).

Ragan (unpublished) during one year of sampling in the same area found that copepods made up between 52 and 97 percent of the monthly totals while averaging 79%. Acartia made up 53% of the copepods sampled. As in the present study, Paracalanus and Oithona were second and third, respectively.

Gillespie (1971) identified Acartia tonsa as the principal species of zooplankton in coastal (estuarine) of Louisiana. She found A. tonsa to be present year around, and to average 60 percent of her plankton counts. McIllwain (1968), in his investigation of Mississippi Sound, also noted the dominance of A. tonsa and found it to be the only species present throughout the year. Hopkins (1966) called A. tonsa the major plankton species in Florida's St. Andrew Bay System. Woodmansee (1958) found that this copepod constituted 60 percent of the zooplankton population of Chicken Key, Florida and Simmons (1957) listed A. tonsa as the most abundant copepod of Laguna Madre, Texas. Hence, it would appear that this copepod is the principal zooplankter in the estuarine and nearshore waters of the northern Gulf.

Meroplankton such as the larvae of benthic invertebrates and the eggs and larva of fishes comprised 10% of the zooplankton.

Infauna

The numbers ($M^2$) of infauna are given with ambient physical and chemical data for each of the nineteen sampling points in Tables 30 to 33. Catch data is summarized by month in Table 34.

The abundance of infauna per $M^2$ rose from 687 during September to a peak of 1555 in October before dropping to 210 in November and to a minimum of 179 in February (Table 34). These limited observations point to a fall peak and winter minimum. Ragan (unpublished) found a density of approximately 1000 individuals per $M^2$ throughout fall and winter. The annual peak which occurred during June was only slightly higher (1192).

The average numbers of invertebrates decreased with depth in this, and the aforementioned study as well. The present densities (Table 35) were $877/M^2$ at stations shallower than 10 M, $452/M^2$ at the 10 - 20 M stations, and $179/M^2$ at stations deeper than 20 M.

Overall, the average density of samples was $610/M^2$ for the four month period or about $200/M^2$ lower than in the 1973 investigation. Smith (1971) found that infaunal populations off the Georgia Coast ranged between 744 and 14,213 individuals/$M^2$, suggesting that the Georgia and Louisiana Coasts differ considerably in this regard.

It is difficult to explain low infaunal density in a region that appears to be otherwise highly productive. It is known that anoxic bottom waters have been recurrent in the sampling area since

1973, and probably longer. The condition was more widespread and persistant in 1973 than it was during this study. Even so, values of 0.0, 0.3 and 2.2 were recorded at 3 of 19 stations (Tables 30 and 33). The average density of infauna at the three locations combined was $154/M^2$ - less than one-fourth that of the remaining stations.

Ragan (unpublished) using non-parametric tests in a more extensive sampling program found a highly significant correlation between dissolved oxygen and total numbers of invertebrates in the substrate of this region during 1973. On the other hand, probabilities did not reach significance when only those oxygen values of 4 ppm or less were used.

There are no known studies that demonstrate the impact of lethal oxygen concentrations on populations of marine infauna. It appears that the phenomenon has not been reported for offshore waters. Oxygen depletion has been reported frequently in the hypölimnion of freshwater lakes during summer and winter stagnation (Hutchinson, 1957). While the more mobile inhabitants are capable of avoiding these layers, the infauna has no such recourse. However, burrowing species generally are more resistant to oxygen deprivation than epifaunal forms (Packard, 1905). Some authors (Cole, 1921; Cleary, 1948; Von Brand, 1946; Welch, 1957) have noted that many bottom dwellers can survive anaerobic conditions for considerable periods, and have speculated on the adaptations which might make this possible. It seems likely that such adaptations would be acquired from long-term selection in an environment that is periodically anaerobic. If not, marine fauna may be generally as viable in this situation as their freshwater counterparts.

In any case, it may be presumptive to attribute the low infaunal densities to the frequent recurrence of anoxic bottom waters. However, it would seem that such conditions would eventually have a negative impact on the abundance of these organisms. As in freshwater, some populations would likely be more affected than others. The composition of infauna may reflect this selective pressure.

Based on class groupings, Polychaetes were the dominant forms making up 60% of the samples, followed by Pelecypods with 27% and Crustaceans with 3% (Table 36). Ragan (unpublished) found a similar composition during 1973 with the exception that Phornids were the second most abundant group due to high concentrations at a few stations.

| | Depth M | Temp. (°C) | D.O. (PPM) | Sal. (PPT) | Fish No. | Fish wt(gms) | Shrimp No. | Shrimp wt(gms.) | Other Invert. No. | Other Invert. wt(gms) | Total Nekton | Total Nekton wt(gms) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 27.8 | 5.5 | 27 | 60 | 877 | 0 | 0 | 66 | 136 | 126 | 1013 |
| | 7 | 27.5 | 3.3 | 26 | 82 | 2851 | 4 | 103 | 8 | 714 | 94 | 3668 |
| | 7 | 27.2 | 4.0 | 12 | 148 | 5695 | 4 | 101 | 20,000 | 36 | 20153 | 5832 |
| Ave | <10 | 27.5 | 4.3 | 21.6 | 97 | 3141 | 3 | 68 | 6692 | 295 | 6791 | 3504 |
| | 12 | 28.8 | 2.9 | 28 | 22 | 654 | 1 | 5 | 26 | 5 | 49 | 664 |
| | 19 | 27.8 | 7.0 | 30 | 2 | 1 | 1 | 6 | 12 | 1 | 15 | 8 |
| Ave. | 10-20 | 28.3 | 5.0 | 29 | 12 | 328 | 1 | 6 | 19 | 3 | 32 | 336 |
| | 22 | 27.7 | 0.3 | 25 | 51 | 1026 | 0 | 0 | 5010 | 248 | 5061 | 1274 |
| Total | | | | | 365 | 11104 | 10 | 215 | 25123 | 1140 | 25498 | 12459 |
| Ave | 12.2 | 27.6 | 3.8 | 24.7 | 61 | 1851 | 2 | 36 | 4187 | 190 | 4250 | 2077 |

Table 1. Physical, chemical and catch values at the depths trawled during September, 1974.

| | Depth M | Temp. (°C) | D.O. (PPM) | Sal. (PPT) | Fish No. | Fish wt(gms) | Shrimp No. | Shrimp wt(gms) | Other Invert. | Other Invert. (wt.gms) | Total Nekton | Total Nekton wt(gms) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 22.5 | 7.4 | 27 | 80 | 591 | 36 | 254 | 26 | 239 | 142 | 1084 |
| | 6 | 22.5 | 5.6 | 27 | 2009 | 1372 | 1 | 11 | 11 | 24 | 2021 | 1407 |
| Ave. | <10 | 22.5 | 6.5 | 27 | 1045 | 982 | 19 | 133 | 19 | 132 | 1082 | 1247 |
| | 16 | 24.2 | 3.1 | 29 | 22 | 1421 | 0 | 0 | 14 | 27 | 36 | 1448 |
| | 16 | 24.0 | 5.3 | 31 | 20 | 1283 | 1 | 22 | 67 | 349 | 88 | 1654 |
| Ave. | 10-20 | 24.1 | 4.2 | 30 | 21 | 1352 | 1 | 11 | 41 | 188 | 62 | 1551 |
| Total | | | | | 2133 | 4667 | 37 | 287 | 118 | 639 | 2287 | 5593 |
| Ave. | 12.5 | 23.3 | 5.4 | 28.5 | 533 | 1167 | 9 | 72 | 30 | 160 | 572 | 1399 |

Table 2. Physical, chemical and catch values at the depths trawled during October, 1974.

| Depth M | Temp. (°C) | D.O. (PPM) | Sal. (PPT) | Fish No. | Fish wt(gms) | Shrimp No. | Shrimp wt(gms) | Other Invert. | Other Invert. (wt.gms) | Total Nekton | Total Nekton wt(gms) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 17 | 7.5 | 26 | 44 | 697 | 47 | 295 | 232 | 261 | 323 | 1253 |
| 9 | 20 | 8.7 | 29 | 5 | 36 | 0 | 0 | 19 | 49 | 24 | 85 |
| 9 | 20.5 | 8.3 | 30 | 10 | 1465 | 0 | 0 | 6 | 8 | 16 | 1473 |
| Ave. <10 | 19.2 | 8.2 | 28.3 | 20 | 733 | 16 | 93 | 86 | 106 | 121 | 937 |
| 14 | 22 | 5.2 | 29 | 43 | 2134 | 13 | 123 | 11 | 49 | 67 | 2306 |
| 16 | 23 | 7.8 | 31 | 35 | 1817 | 2 | 61 | 15 | 10 | 52 | 1888 |
| Ave. 10-20 | 22.5 | 6.5 | 30 | 39 | 1976 | 8 | 92 | 13 | 30 | 60 | 2097 |
| 27 | 23.2 | 8.1 | 33 | 1 | 1 | 4 | 2 | 1 | 1 | 6 | 4 |
| 28.5 | 22.5 | 7.0 | 30 | 33 | 1826 | 15 | 100 | 106 | 14 | 154 | 1940 |
| Ave. >20 | 22.9 | 7.6 | 31.5 | 17 | 914 | 10 | 51 | 54 | 8 | 80 | 972 |
| Total | | | | 171 | 7976 | 81 | 581 | 390 | 392 | 642 | 8949 |
| Ave. 16 | 21.2 | 7.5 | 29.7 | 24 | 1139 | 12 | 83 | 56 | 56 | 92 | 1274 |

Table 3. Physical, chemical and catch values at the depths trawled during November, 1974

| | Depth M | Temp. (°C) | D.O. (PPM) | Sal. (PPT) | Fish No. | Fish wt(gms) | Shrimp No. | Shrimp wt(gms) | Other Invert. No. | Other Invert. wt(gms) | Total Nekton | Total Nekton wt(gms) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 17.8 | 3.1 | 27 | 37 | 371 | 13 | 100 | 2 | 1200 | 52 | 1671 |
| | 5 | 16 | 4.9 | 20 | 61 | 417 | 22 | 183 | 12 | 346 | 95 | 946 |
| | 5 | 17.2 | 6.7 | 22 | 48 | 252 | 35 | 182 | 2 | 318 | 85 | 752 |
| Ave. | <10 | 17 | 4.9 | 23 | 49 | 347 | 23 | 155 | 5 | 621 | 76 | 1123 |
| | 10 | 18.5 | 3.6 | 28 | 13 | 1429 | 1 | 1 | 1 | 18 | 15 | 1488 |
| | 13 | 19.2 | 0.0 | 29 | 25 | 1183 | 2 | 45 | 0 | 0 | 27 | 1288 |
| Ave | 10–20 | 18.9 | 1.8 | 28.5 | 19 | 1306 | 2 | 23 | 1 | 9 | 21 | 1338 |
| | 26 | 20.5 | 2.2 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | | | | 184 | 3652 | 73 | 511 | 17 | 1882 | 274 | 6045 |
| Ave. | 10.6 | 18.2 | 3.4 | 26.2 | 31 | 609 | 12 | 85 | 3 | 314 | 46 | 1008 |

Table 4. Physical, chemical and catch values at the depths trawled during February, 1975.

| Month | No. of Stations | Ave. Depth | Fish | Shrimp | Other Inverts. | Combined Ave. |
|---|---|---|---|---|---|---|
| September 1974 | 6 | 12.2 | 1851 | 36 | 190 | 2077 |
| October 1974 | 4 | 11 | 1167 | 72 | 160 | 1398 |
| November 1974 | 7 | 15.5 | 1139 | 83 | 56 | 1278 |
| February 1975 | 6 | 10.7 | 609 | 85 | 314 | 1008 |
| All | 23 | 12.6 | 1191 | 69 | 176 | 1437 |

Table 5. Average weight (gms) of fish, shrimp, and other invertebrates taken in 10 minute trawl hauls by month.

| Scientific Name | Common Name |
|---|---|
| Opisthonema oglinum | Atlantic thread herring |
| Anchoa hepsetus | Striped anchovy |
| Anchoa mitchilli | Bay anchovy |
| Synodus foetens | Inshore lizardfish |
| Chloroscombrus chrysurus | Bumper |
| Caranx hippos | Crevalle jack |
| Vomer setapinnis | Atlantic Moonfish |
| Lutjanus campechanus | Red snapper |
| Archosargus probatocephalus | Sheepshead |
| Cynoscion arenarius | Sand seatrout |
| Cynoscion nothus (Juv.) | Silver seatrout |
| Larimas fasciatus | Banded drum |
| | Juvenile Sciaenids |
| Leiostomus xanthurus | Spot |
| Menticirrhus americanus | Southern kingfish |
| Menticirrhus littoralis | Gulf kingfish |
| Micropogon undulatus | Atlantic croaker |
| Stellifer lanceolatus | Star drum |
| Arius felis | Sea catfish |
| Bagre marinus | Gafftopsail catfish |
| Urophycis floridanus | Southern hake |
| Ophidium welshi | Crested cusk-eel |
| Centropristis philadelphica | Rock sea bass |
| Chaetodipterus faber | Atlantic spadefish |
| Sphyraena barracuda | Great barracuda |
| Trichiurus lepturus | Atlantic cutlassfish |
| Peprilus alepidotus | Harvestfish |
| Peprilus burti | Gulf butterfish |
| Prionotus roseus | Bluespotted searobin |
| Prionotus rubio | Blackfin searobin |
| Prionotus tribulus | Bighead searobin |
| Citharichthys spilopterus | Bay whiff |
| Etropus crossotus | Fringed flounder |
| Paralichthys albigutta | Gulf flounder |
| Symphurus plagiusa | Blackcheek tonguefish |
| Sphoeroides maculatus | Northern puffer |
| Sphoeroide parvus | Least puffer |

Table 6. A Phylogenetic List of Fishes Taken at 23 Stations during September, October and November, 1974 and Feburary, 1975.

| | No. Taken | % |
|---|---|---|
| Bay anchovy (Anchoa mitchilli) | 2067 | 73 |
| Atlantic croaker (Micropogon undulatus) | 166 | 6 |
| Sea catfish (Arius felis) | 151 | 5 |
| Star drum (Stellifer lanceolatus) | 108 | 4 |
| Sand seatrout (Cynoscion arenarius) | 49 | 2 |
| | | 90 |

Table 7. Numerical contribution of the 5 most abundant fish species in trawl catches.

| | Weight (gms) | % |
|---|---|---|
| Atlantic croaker (*Micropogon undulatus*) | 9125 | 33 |
| Sea catfish (*Arius felis*) | 6594 | 24 |
| Sand seatrout (*Cynoscion arenarius*) | 1849 | 7 |
| Atlantic spadefish (*Chaetodipterus faber*) | 1719 | 6 |
| Spot (*Leiostomus xanthurus*) | 1597 | 6 |
| | | 76 |

Table 8. The five species of fishes which contributed most heavily to the weight of the trawl catches.

| | No. Taken | % | % Excluding Lucifer |
|---|---|---|---|
| *Lucifer faxoni* | 25,312 | 99 | |
| Inshore squid (*Loliguncula brevis*) | 132 | <1 | 29 |
| Ctenophore (*Pleurobranchia sp.*) | 60 | <1 | 13 |
| *Acetes americanus* | 60 | <1 | 13 |
| Mantis shrimp (*Squilla sp.*) | 24 | <1 | 5 |
| | | | 60 |

Table 9. Numerical contribution of the five most abundant species of invertebrates (excluding commercial shrimp) in trawl catches.

| | Weight (gms) | % |
|---|---|---|
| Cabbage head (*Stomolophus meleagris*) | 2434 | 60 |
| Blue crab (*Callinectes sapidus*) | 956 | 24 |
| Inshore squid (*Lolliguncula brevis*) | 276 | 7 |
| Ctenophore (*Pleurobranchia* *sp.*) | 120 | 3 |
| Mantis shrimp (*Squilla* *sp.*) | 85 | 2 |
| | | 96 |

Table 10. The five invertebrate species (excluding commercial shrimp) that contributed most heavily to weight of trawl catches.

| | No. Taken | % |
|---|---|---|
| White shrimp (Penaeus setiferus) | 105 | 52 |
| Sea bob (Xiphopenaeus sp.) | 50 | 25 |
| Brown shrimp (Penaeus aztecus) | 25 | 12 |
| | | 89 |

Table 11. Numerical contribution of the three most abundant commercial shrimp species taken by trawl.

| | No. Taken | % |
|---|---|---|
| White shrimp (*Penaeus setiferus*) | 1222 | 77 |
| Sea bob (*Xiphopenaeus sp.*) | 183 | 11 |
| Brown shrimp (*Penaeus aztecus*) | 174 | 11 |
| | | 99 |

Table. 12. The three species of commercial shrimp which contributed most heavily to the weight of trawl catches.

Phylum: COELENTERATA
  Class: Scyphozoa
    Stomolophus meleagris (cabbage head)
    Unidentified medusa

PHYLUM: CTENOPHORA
  Class: Tentaculata
    Pleurobranchia sp.

PHYLUM: ANNELIDA
  Class: Polychaeta
    Diopatra sp.

PHYLUM: MOLLUSCA
  Class: Pelecypoda
    Cancellaria reticulatum (nutmeg)
    Polinices duplicatus (moonshell)
  Class: Cephalopoda
    Loliguncula brevis (inshore squid)

PHYLUM: ARTHROPODA
  Class: Crustacea
    Subclass: Malacostraca
      Order: Stomatopoda
        Squilla sp. (Mantis shrimp)
      Order: Decapoda
        Unidentified hermit crab
        Acetes americanus
        Lucifer faxoni
        *Penaeus aztecus (brown shrimp)
        *Penaeus setiferus (white shrimp)
        *Trachypenaeus sp.
        *Xiphopenaeus kroyeri (sea bob)
        Arenarius cribrarius (speckled crab)
        Callinectes sapidus (blue crab)
        Callinectes similis
        Portunus gibbesii
        Unidentified brachyuran crab

*Commercial shrimp

Table 13. A Phylogenetic List of Invertebrates Taken by Trawl at 23 Stations During September, October, and November, 1974 and February, 1975.

| Depth(M) | | Zooplankton($M^3$) | Temperature (°C) | Salinity (PPT) | D.O.(PPM) |
|---|---|---|---|---|---|
| 6-7* | Sur | 2409 | 27.4 | 23.6 | 5.4 |
| | Mid | 5673 | 27.3 | 23.7 | 5.3 |
| 12 | Sur | 603 | 28.2 | 26 | 4.5 |
| | Mid | 4696 | 27.8 | 28 | 3.1 |
| 19 | Sur | 1205 | 27.9 | 27 | 11 |
| | Mid | 6331 | 27.7 | 30 | 7.2 |
| 22 | Sur | 829 | 27.7 | 25 | 10.5 |
| | Mid | 2411 | 27.5 | 23 | 7.0 |

*Average of three stations.

Table 14. Quantitative physical, chemical and zooplankton data at surface and mid-depth during September, 1974.

| Depth(M) | | Zooplankton($M^2$) | Temperature (°C) | Salinity (PPT) | D.O. (PPM) |
|---|---|---|---|---|---|
| 6* | Sur | 6245 | 22.2 | 27 | 8.4 |
| | Mid | 7920 | 22.4 | 27 | 8.1 |
| 16* | Sur | 14887 | 23.1 | 28 | 8.2 |
| | Mid | 9502 | 23 | 26.5 | 9.7 |

*Average of two stations.

Table 15. Quantitative physical, chemical and zooplankton data at surface and mid-depth during October, 1974.

| Depth(M) | | Zooplankton($M^3$) | Temperature (°C) | Salinity(PPT) | D.O.(PPM) |
|---|---|---|---|---|---|
| 5 | Sur | 4445 | 15.5 | 25 | 9.2 |
| | Mid | 3427 | 16 | 25 | 8.5 |
| 9* | Sur | 13022 | 19.7 | 27.5 | 9.2 |
| | Mid | 8421 | 19.9 | 28.5 | 9.2 |
| 16 | Sur | 13866 | 20 | 26 | 10.2 |
| | Mid | 4770 | 21.3 | 30 | 9.3 |
| 27 | Sur | 866 | 19.9 | 26 | 10.5 |
| | Mid | 2838 | 23 | 32 | 9.1 |

*Average of 2 stations.

Table 16. Quantitative physical, chemical, and zooplankton data at surface and mid-depth during November, 1974.

| Depth(M) | | Zooplankton($M^3$) | Temperature(°C) | Salinity(PPT) | D.O.(PPM) |
|---|---|---|---|---|---|
| 5 | Sur | 7669 | 17 | 21 | 7.5 |
| | Mid | 5556 | 16 | 18 | 9.6 |
| 10 | Sur | 1011 | 17 | 21 | 3.2 |
| | Mid | 14161 | 17 | 21 | 13.9 |
| 13 | Sur | 1250 | 16 | 21 | 8.1 |
| | Mid | 26564 | 16 | 16 | 16.2 |
| 26 | Sur | 728 | 20 | 31 | 3.2 |
| | Mid | 4569 | 14.5 | 15 | 11.2 |
| 34 | Sur | 9087 | 20 | 30 | 5.4 |
| | Mid | 13125 | 18.2 | 22 | 10 |

Table 17. Quantitative physical, chemical and zooplankton data at surface and mid-depth during February, 1975.

| Month/Year | No. of Stations | Average No. Zooplankton ($M^3$) Surface Tows | Middepth Tows | Combined Tows |
|---|---|---|---|---|
| September, 1974 | 12 | 1644 | 5076 | 3360 |
| October | 8 | 10692 | 10544 | 10618 |
| November | 10 | 6440 | 5575 | 6008 |
| February, 1975 | 10 | .4009 | 12795 | 8402 |
| All | 40 | 5244 | 8224 | 6734 |

Table 18. Density of Zooplankton ($M^3$) by sampling month.

| Depth (M) | No. of Stations | Average No. Zooplankton ($M^3$) Surface Tows | Middepth Tows | Combined Tows |
|---|---|---|---|---|
| <10 | 18 | 5017 | 6602 | 5810 |
| 10-20 | 14 | 6887 | 11731 | 9309 |
| >20 | 8 | 2878 | 5736 | 4307 |
| All | 40 | 5244 | 8224 | 6734 |

Table 19. Density of Zooplankton ($M^3$) by station depth.

| Month (1974) | No. of Stations | Average Volume Zooplankton ($Ml/M^3$) Surface Tows | Middepth Tows | Combined Tows |
|---|---|---|---|---|
| September | 12 | 1.1 | 1.9 | 1.6 |
| October | 8 | 2.8 | 3.0 | 2.9 |
| November | 10 | 2.1 | 1.8 | 1.9 |
| All | 30 | 1.9 | 2.1 | 2.0 |

Table 20. Settling volumes of zooplankton ($ml/M^3$) by sampling month.

| Depth M | No. of Stations | Average Volume Zooplankton (Ml/M$^3$) Surface Tows | Middepth Tows | Combined Tows |
|---|---|---|---|---|
| <10 | 16 | 1.5 | 1.7 | 1.9 |
| 10-20 | 10 | 3.8 | 3.9 | 2.1 |
| >20 | 4 | 0.3 | 1.1 | 2.0 |
| All | 30 | 1.9 | 2.1 | 2.0 |

Table 21. Settling volumes of zooplankton (ml/M$^3$) by station depth.

PHYLUM: PROTOZOA
  Class: Sarcodina
    Shelled sarcodinian

PHYLUM: COELENTERATA
  Class: Hydrozoa
    Unidentified medusa

PHYLUM: CTENOPHORA
  Class: Tentaculata
    Misc. Ctenophores
  Class: Nuda
    Beroe ovata

PHYLUM: ASCHELMINTHES
  Class: Rotifera
    rotifers

PHYLUM ANNELIDA
  Class: Polychaeta
    Sandworm larvae

PHYLUM: MOLLUSCA
  Class: Pelecypoda
    Lamellibranch larvae
  Class: Gastropoda
    Gastropod larvae

PHYLUM: ARTHROPODA
  Class: Crustacea
    Subclass: Branchiopoda
      Order: Diplostraca
        Suborder: Cladocera
          Cladocerans
    Subclass: Copepoda
      Order: Calanoidea
        Acartia sp.
        Centropages sp.
        Eucalanus sp.
        Labidocera sp.
        Paracalanus sp.
        Pontella sp.
        Misc. copepods
      Order: Cyclopoidea
        Oithona sp.
      Order: Harpacticoida
        Euterpina acutifrous

Order: Caligoida
parasitic copepods (*Caligus sp.*)

Subclass: Malacostraca
Order: Amphipoda
Suborder: Gammaridae
amphipods
Order: Cumacea
cumaceans
Order: Stomatopoda
*Squilla sp.* larvae
Order: Decapoda
*Acetes americanus*
*Lucifer faxoni*
Caridean shrimp
Penaeid P.L.
Hermit crab P.L.
Hippolitidae
Unident. decapod crustacean
Nauplei
Zoea
Megalops
PHYLUM: CHAETOGNATHA
*Sagitta*
PHYLUM: CHORDATA
Subphylum: Urochordata
Class: Larvacea
*Oikopleura sp.*
Class: Thaliacea
*Doliolum sp.*
Salpa sp.
Subphylum: Vertebrata
Fish eggs
Larval fishes

Table 22. A Phylogenic List of Zooplankton Taken With #10 Mesh at Stations During September, October, and November, 1974 and February, 1975.