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Food Habits of Fishes and Larger Invertebrates of Lake Pontchartrain, Louisiana, an Estuarine Community

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Contents

Introduction

During recent years the study of quantitative aspects of community metabolism has occupied the attention of increasing numbers of aquatic ecologists. As pointed out by Lindeman (1942), Ivlev (1945), Macfadyen (1948), Teal (1957) and others, rates of turnover in community metabolism are more satisfactorily expressed in terms of energy than in terms of biomass. Accordingly, a number of important studies have recently appeared dealing with quantitative aspects of the energy transfer associated with primary production in aquatic communities. Studies of the energetics involved in secondary production within restricted communities (Teal, 1957) also have provided valuable information. However, few attempts have been made to quantify the energy relations involved in secondary production in more complex aquatic communities, and these have not, in the opinion of the writer, been as rewarding. This lack of success has been occasioned largely by the tendency of the workers to greatly oversimplify pathways of exchange of nutrients and energy among the consumer organisms.

The concept of consumer "levels" as employed by Lindeman (1942) and others has been justly and severely criticized by Ivlev (1945). Peterson and Jensen as early as 1911 stressed that the subdivision of animals into predators, detritus feeders, etc., must be treated with care since, "the boundaries are very often deleted in nature." Although, as suggested by Ivlev, some simplification may often be justified and necessary, such action should be based upon a thorough knowledge of the pathways of nutrient and energy transformation for the particular body of water. Computations regarding energy transfer resulting in secondary production should be preceded by adequate food analyses.

The study of the food habits of the Lake Pontchartrain inhabitants is based upon the above considerations and is intended as a first step toward the quantitative evaluation of the metabolic relations of the complex estuarine community. Whereas consideration of the food relations may carry certain value, practical and otherwise, intrinsic to each particular species, in aggregate this knowledge should also provide a reasonably detailed picture of the overall trophic processes of the community.

The present report embraces one aspect of an ecological survey of Lake Pontchartrain and adjacent waters of southeastern Louisiana. The physical environment and ecological aspects of the plankton, invertebrate, and fish populations will be published elsewhere. The organization of this survey and general sampling procedures have already been reported (Darnell, 1954). Research reports submitted to the State of Louisiana (Suttkus, Darnell, and Darnell, 1953, 1954, 1955, a-j) have included numerical aspects of the fish and invertebrate collections. All species of fishes listed in these reports as comprising at least one percent of the overall trawl and seine catches were included in the food studies, except three small, mainly shallow water species (*Cyprinodon v. variegatus, Fundulus grandis,* and *Syngnathus scovelli).* In addition, a number of species of fishes were included for food analyses which were especially important seasonally or locally, or species which, because of size, speed, or maneuverability, were judged to be more abundant than the collections might indicate. Several of the most important species of large invertebrates were also included.

In carrying out the present study 1,399 detailed quantitative analyses and about 100 qualitative analyses were carried out on specimens representing 35 of the most important estuarine species. Nearly all specimens were collected by the writer within a 14 month period (July 1953—August 1954), providing a reasonably instantaneous picture of the community. Species for which the analyses were most complete include the southern bay anchovy, channel catfish, silverside, sand trout, speckled trout, spot, Atlantic croaker, pinfish, and blue crab. Due to lack of specimens and time, the analyses of the remaining species were incomplete in various degrees, representing a regrettable shortcoming in the present data. From the community standpoint this incompleteness is most serious for the very abundant gulf menhaden. For a single species, the stingaree, no specimens were examined. However, this fish was considered to be of sufficient importance in the community for inclusion of its food habits as reported in the literature.

Since the fishes and invertebrates which frequent the brackish-water estuary are derived from a variety of habitats, the published information regarding their food and general ecological relations is widely scattered, and an effort has been made herein to bring together this pertinent literature. Altogether the food relations of the fishes and invertebrates of the estuaries of eastern North America are still poorly known.

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Methods

Specimens for food analysis were collected by trawls and seines and were preserved shortly after capture. Habitat notes and measurements of the environmental factors are summarized briefly in the following section. An early effort was made to neutralize the contents and inhibit enzyme activity in the stomachs of the moi e carnivorous species by injection of alkaline formalin (borax solution) into the lumen shortly after capture. This proved ineffective, however, and was abandoned. Reference collections of plankton, nekton, and benthic food organisms were identified by specialists, and considerable attention was devoted to the proper taxonomic verification of the food species.

Laboratory food analyses were carried out entirely by the author or under his supervision according to the following procedure. Stomach contents were examined and the items sorted and identified. The percent fullness of each stomach was estimated, and the percentage volume of each type of food item in each stomach was determined (by volumetric displacement, in the case of the larger items, or by estimation against a grid painted below the analysis dish, in the case of the smaller, and more amorphic materials) . Thus, for a given group of stomachs, not only is the often misleading "percentage of tracts containing each item" known ("percent frequency of occurrence" of authors) , but also the more informative "average percent of total stomach volume". Intestinal contents were examined qualitatively to reveal any types of food items not encountered in the stomachs, and the percent fullness of the intestines was also estimated. Qualitative analysis of the intestines proved quite rewarding and should be incorporated as standard procedure in future food studies. Body length, collecting and preserving data, sex (as determined by microscopic analysis of the gonads) , and other pertinent information were recorded on the form data cards. Future studies of this type and magnitude should unquestionably employ keysort or I.B.M. cards to facilitate handling of data and correlation of variables.

Summarized results of the food studies were plotted by size group in traditional bar d:agrams. Where data were especially complete individual food items were lumped into major food categories, and the results plotted on semilog paper as frequency polygons depicting the average ontogenetic food changes of the particular species population. The log plot was employed because it was observed that ontogenetic food changes occurred most rapidly in the smallest size classes. When graphed in this manner, many of the ontogenetic food changes approach linearity.

General Description of Lake Pontchartrain

The geological history of the Lake Pontchartrain basin has been discussed by Russell (1936, 1938, 1940), Steinmeyer (1939), Fisk (1944, 1947a, b), and Gunter (1952) . As indicated by these authors, the present Lake Pontchartrain represents a remnant of an arm of the Gulf of Mexico which was impounded by deltaic deposits of the Mississippi River around 2,000 years ago. Underlying sediments reveal a subsequent history of rapid filling chiefly by deposition of enormous quantities of silt and clay from overflow waters of the Mississippi River. Other streams and bayous have added smaller amounts of sandy sediments, and subaqueous tidal deltas have been deposited near the mouths of fresh and salt-water passes. Also active in filling the depression has been the persistent encroachment by marginal marsh and swamp. Wave dissection of such vegetation has resulted in rounding of shore contours and offshore deposition of great quantities of humus. This erosion is current and appears to have been most pronounced during hurricanes. Active subsidence of the lake bottom has partly counteracted these forces of deposition. Associated with the above processes a gradual freshening of the environment has taken place, and the area which some 5,000 years ago was characterized by marine species of Venus, Pecten, Dosinia, etc., and later by Crassostrea virginica and Thais spp., now forms habitat for large populations of Rangia cuneata and certain freshwater species.

Physiographically Lake Pontchartrain contains 635 square miles of surface area with a shoreline of about 100 miles. The average depth is around 11 feet, and except for a number of artificial dredge holes near the south shore which may exceed 30 feet, the maximum depth of the lake proper is 18 feet. The bottom of Lake Pontchartrain is characterized by gradual sloping although the only extensive stretches of shallow water, i.e. less than 6 feet, are found in the relatively infertile western sector.

During the period of the survey (July 1953–May 1955) the temperature of the open waters of Lake Pontchartrain ranged from a minimum of 9°C. in December to 34°C. in June and August. Shallow water temperatures often were higher, however, ranging up to 39°C. Winter temperatures were low and seldom exceeded 17°C., whereas the summer temperatures generally remained above 30°C. During the spring and fall an average monthly rate of change of about 5°C. was observed with the most rapid rise in April or May and the most rapid drop in early November. Extensive species migrations were found to coincide with marked temperature changes, especially in the fall, and temperature is undoubtedly one of several important factors regulating such movements. No outstanding differences were observed between the temperatures of the various parts of the lake.

The salinity of Lake Pontchartrain during the period of study varied from 1.2 per *r ille* after a heavy January rainfall to 18.6 per *mille* following influx of Gulf water in the wake of a September storm. The average salinity for most months, however, was less than 6 per mile and the maximum for most months was less than 9 per ***mille.*** The effect of addition of large quantities of fresh water (through rainfall and flooding) or salt water (through Gulf storms) was apparent for several months following the event. Marked differences in salinity from one part of the lake to another was obvious, and one month a salinity difference of 12.4 per *mille* was noted between different stations. In general, the freshest areas of the lake were found in the west and northwest sectors near the openings of the freshwater streams and passes, and the most saline areas in the eastern sector, especially near the mouths of the salt-water passes.

Stratification of the lake waters was not carefully investigated, although it was occasionally observed. As indicated by other workers, in warm water only a slight temperature differential is required to create density differences sufficient for stratification. In brackish waters such temperature-related density differences may often be reinforced by differences in salinity. This situation often manifests itself in the summer months, when a relatively cool wedge of salt water creeps in from the Gulf under the warmer and fresher lake waters. The importance of such salt water currents in facilitating the inward migration of Gulf-spawned larval fishes and invertebrates has been suggested by previous workers.

One of the most characteristic features of Lake Pontchartrain is the exceptionally high turbidity which imparts a chocolate appearance to the waters. The average summer Secchi disc visibility was about 6 feet, and rarely, on calm clear summer days the bottom was visible in 14 feet of water. During the remaining months, however, the visibility was lower, averaging only 2-3 feet the first winter. The turbid condition of the water was directly related to wind action which disturbed and raised bottom sediments even in the deepest portions of this shallow body of water. The most turbid portions of the lake appeared to be the shallowest waters, especially near the south shore, and in times of heavy wind and wave action Secchi disc readings of less than one inch were recorded for this disturbed area. The overall average of the Secchi disc readings for the total period of study was about 4 feet indicative of a highly and persistently turbid situation. Even this figure represents an understatement since on numerous occasions collecting trips were cancelled due to the stormy condition of the lake.

The plankton and the marsh and swamp vegetation bordering Lake Pontchartrain are discussed later in relation to the general nutrition of the community. It might be pointed out here that most of the fishes and larger invertebrates found in the lake are transients which normally spend only a portion of their life histories within the confines of the estuary. The marine species are most conspicuously represented by immature stages, whereas generally more mature individuals of the freshwater species are found in the lake.

Trophic Relations of Fishes and Invertebrates

FISHES

CARCHARHINIDAE

Carcharhinus leucas (Willer and Henle) . Bull Shark

The food habits of the bull shark have recently been discussed by Baughman and Springer (1950) who reviewed the works of Linton (1904), Nichols (1917), and Bell and Nichols (1921) . These authors found the shark to be highly carnivorous although of somewhat indiscriminate taste. Food included fishes (sting rays, other sharks, shad and mackerel), the fin of a porpoise, crabs, echinoderm plates, and some vegetable fibers.

The stomachs of three bull sharks from Lake Pontchartrain were examined, and only two contained recognizable food. One specimen (780 mm.) had consumed a single large striped mullet *(Mugil cephalus)* (255 mm.) almost one third of its own body length. The second shark (805 mm.) contained within its stomach ten small menhaden *(Brevoortia patronus)* (66-103 mm.) , a croaker *(Micropogon undulatus)* (67 mm.), a single white shrimp *(Penaeus setiferus)* and a small crab (probably *Callinectes sapidus).* Fishes made up over 90 percent of the food encountered in both sharks.

A number of sharks, rang:ng in length up to around 7 feet, were encountered in the shallows as well as the deeper offshore waters of the lake. These are most probably referable to the species *C. leucas.* On one occasion the carcass of a large black drum *(Pogonias cromis)* was found floating at the surface a few miles from the southwest shore, and at the approach of the boat a single large shark and two smaller individuals abandoned the remains. When retrieved, the drum was found to have been severed cleanly in two just behind the anus, the remaining anterior half weighing 35 lbs. It was assumed that this drum was attacked by one of the sharks while the drum was feeding upon bottom mollusks, standing vertically in the water as is the habit of this species (see the section on *Pogonias cromis).* A number of alleged shark attacks upon bathers at Pontchartrain Beach (New Orleans) in the summer of 1953 may possibly be attributable to this species.

In the Lake Pontchartrain community *C. leucas* must be considered one of the top predators in the shallow as well as the deeper waters since it is one of the largest and most carnivorous of the predatory species. Its influence upon both the fish and invertebrate populations appears to be limited only by the relative scarcity of the species during most of the year.

DASYATIDAE

Dasyatis sabina (Le Sueur) . Stingaree

The food of stingarees has received only minor attention in the literature. Linton (1904), Hildebrand and Schroeder (1928) , Gunter (1945), and McLane (1948) have reported the stomach content of stingarees to consist primarily of bottom-living invertebrates including clams, snails, annelids, amphipods, schizopods, mud crabs, sea urchin parts and fish bones, eye lenses, and sand.

No specimens from Lake Pontchartrain were examined although it may be assumed that in the lake the primary foods would be such small bottom invertebrates as clams

(*Rangia cuneata*), mud crabs (*Rithropanopeus harrisii*), and small blue crabs (*Callinectes sapidus*), supplemented with small shrimp, chironomid larvae, and annelids. A single cow-nosed ray (*Rhinoptera bonasus*) from Lake Pontchartrain examined in the field was packed with the bodies of small clams.

LEPISOSTEIDAE

Lepisosteus osseus oxyurus Rafinesque. Northern Longnose Gar

Food habits of the longnose gar have received attention by Forbes (1888), Mark (1890), Pearse (1918), Forbes and Richardson (1920), Evermann and Clark (1920), Hubbs (1921), Rimsky-Korsakoff (1930), Lagler and Hubbs (1940), Bonham (1941), Frisby (1942), and by Lagler, Obrecht, and Harry (1942) who summarized the work of earlier investigators. Published information indicates that the longnose gar feeds chiefly upon entomostraca and insect larvae until around 50 mm. (two inches) in length. At about this size it changes to a diet of fishes which then predominate in the food of the larger size groups. Depending upon the size of gar and upon the food available this fish has been reported to feed upon a variety of minnows, darters, silversides, and mosquitofish, as well as mullet, gizzard shad, smelt, suckers, bullheads, catfish, pike, killifish, perch, bluegills, rock bass, largemouth bass, and crappies. Crayfish, grass shrimp, and other invertebrates also have been noted in the stomachs of this fish. More recently McLane (1948) reported that longnose gar in Florida consume large numbers of threadfin shad (*Signalosa pet enensis vanhyningi*) when these are available.

In the present study eight longnose gars (706-1180 mm.) from Lake Pontchartrain were examined, but only four contained food. About 98 percent of this material was made up of small fishes, with miscellaneous invertebrates and other items constituting two percent. One third of the fishes eaten were menhaden (*Brevoortia patronus*), and as many as three were encountered within one stomach. A single sea catfish (*Galeichthys felis*), about 100 mm. in length, also made up about one third of the volume of fishes consumed. Additional fish remains were probably bigeye herring (*Elops saurus*). Miscellaneous material included clams (*Rangia cuneata*), crabs, insects (Coleoptera, D:ptera), and bits of undetermined organic material and detritus. The longnose gar is one of the top shallow water fish predators of the Lake Pontchartrain community.

Lepisosteus productus Cope. Spotted Gar

The food habits of the spotted gar in fresh water have been studied by Parker (1939), Bonham (1941), and Lagler, Obrecht, and Harry (1942). These authors have noted that fishes form the principal food of the adults, constituting up to 95 percent of the ingested material in some cases. Fishes consumed included gizzard shad (perhaps, the most important food), suckers, minnows, bullheads, pickerel, bluegills, round sunfish, black crappie, white crappie, largemouth bass, and yellow bass. When available large numbers of crayfish are consumed, as well as some grass shrimp and aquatic insects.

Food of the spotted gar in brackish water has been mentioned by Gunter (1945) and Lambou (1952, 1956). Gunter (*op. cit.*) cited a single unidentifiable fish from the stomach of a spotted gar taken from Copano Bay, Texas. Lambou (*op. cit.*), however, found that in the brackish coastal marshes of southeastern Louisiana the species consumed blue crabs and fishes (primarily sunfishes) in about equal percentages.

Hunt (1953) discussed the food habits and community relations of the closely related

-L. platyrhinchus from the Tamiami canal of southern Florida. In his study fishes made up 76 percent of the food of the gars, and the remainder consisted of invertebrates (snails, entomostraca, Palaemonetes sp., and insects). Fishes included the mosquitofish, killifish, molly, bluegill, spotted sunfish, and young warmouth bass.

Nine specimens of the spotted gar (405–555 mm.) from Lake Pontchartrain were examined, only seven of which contained food. This material consisted chiefly of crabs (70 percent) and fish (24 percent) with a small amount of miscellaneous material (6 percent). Crabs included the blue crab (Callinectes sapidus) which varied from 75 to 140 mm. in carapace width, surprisingly large for the size of the gars consuming them. At least some of the fishes consumed were clupeids, probably Signalosa petenensis. Included among the miscellaneous items were clam fragments (Rangia cuneata), insects (Odonata), and undetermined organic material and detritus. In the Lake Pontchartrain community the spotted gar appears to feed more upon shallow water invertebrates than does the longnose gar, although small fishes are also taken.

Parker (1939) concluded that the spotted gar feeds mainly in the early morning hours, although Lambou (1952) indicated that most active feeding probably takes place in late evening or at night. Hunt (1953) was unable to distinguish any periodicity in feeding of the Florida spotted gars during the daylight hours.

Lepisosteus spatula Lacépède. Alligator Gar

A number of workers have referred to the food of the alligator gar in fresh and brackish waters, but no detailed systematic study of the food habits of this important species seems to have been reported. Jordan (1905) indicated that the alligator gar is a scavenger around piers in Pensacola, Florida, vying with sharks for garbage, and Viosca (as reported by Weed, 1923) concluded that the species is almost strictly a scavenger. A number of workers, however, have referred to the predatory habits of the species. Wortman (1882) considered the alligator gar to be a predator. Hussakof (1914) mentioned a large crappie and a short-nosed gar taken from stomachs of this fish, and Hildebrand and Towers (1927) listed large fish among the food of this species in Mississippi. Gowanloch (1940) listed fish and crabs among the food of Louisiana specimens. Bonham (1941) recovered an eel, a buffalo fish, and what appeared to be a sheephead from alligator gars taken in Texas, and Raney (1942) added that Texas specimens also consume large birds including ducks and water turkeys. Gunter (1945) found that 12 large alligator gars (600–1590 mm.) from the brackish waters of Copano Bay, Texas contained 13 fish, all of which appeared to be Mugil cephalus. Lambou (1952, 1956) studied the food of 30 alligator gars taken from the brackish marshes adjoining the northeastern shore of Lake Pontchartrain, Louisiana. Small blue crabs made up about 87 percent of the food, and fishes, shrimp, and undetermined material made up from three to four percent each. Lambou concluded that active feeding occurs late in the evening and possibly at night and in the morning.

In the present study, five specimens of alligator gar (903–1472 mm.) were examined in the laboratory, of which only three contained food. This material included 65 percent large blue crabs (Callinectes sapidus) and 35 percent striped mullet (Mugil cephalus), as well as traces of clams (Rangia cuneata), vegetation, undetermined organic material, and detritus. In addition to the above analyses, the stomachs of a large number of alligator gars were examined qualitatively in the field, and these were all found to be loaded with medium-sized and adult blue crabs. On a number of occasions these large predatory fish were observed feeding upon the extensive schools of adult striped mullet which congregate along the north shore of Lake Pontchartrain in early fall. Active feeding was apparent both in the morning and in the afternoon. Large alligator gars were sometimes seen at the surface of deeper offshore waters of the lake. Hence they must be predators of deper, as well as shallow waters.

Whereas some scavenging undoubtedly does take place, the above studies leave little doubt regarding the predatory nature of this fish. In brackish coastal waters such as Lake Pontchartrain the primary foods of the species include the blue crab and the striped mullet, both of which are available in quantity in the shallow marshes and margins of the lake, as well as in the deeper waters.

ELOPIDAE

Elops saurus Linnaeus. Bigeye Herring, Tenpounder

As a group the tenpounders are known to be generally carnivorous. Linton (1904) recorded six large penaeid shrimp from the stomach of a single specimen of E. saums from Chesapeake Bay. Gunter (1945) reported that three out of five Texas specimens examined contained food including penaeid shrimp *(P.* setiferus) and two pinfish (Lagodon rhomboides). McLane (1948) stated that in the St. Johns River of Florida the bigeye herring consumes large numbers of shad (Signalosa petenensis vanhyningi). Knapp (1949) examined the stomachs of 156 specimens from the Texas coast and found shrimp in 76 percent, fishes in 34 percent, and crabs, squids, and other invertebrates in less than three percent each. Reid (1954) encountered only unidentifiable fish remains in the stomachs of Florida specimens. The same author (Reid, 1955a) analyzed eight bigeye herring (82-185 mm.) from northern Texas and found fishes (including clupeids and atherinids) in the stomachs of five individuals and small penaeid shrimp in the stomachs of four. A single stomach was empty. Dill and Woodhull (1942) mentioned that the related E. affinis in the Salton Sea, California, consumes desert minnows and beetles, and Hiatt (1947a) pointed out that in Hawaiian fishponds the congener, *E.* machnata, feeds primarily upon small fishes *(Gambusia* affinis and Mollienesia latipinna) with smaller quantities of crustaceans (Leander debilis and amphipods) and traces of snail shells.

Stomach contents of 16 bigeye herring (161-280 mm.) from Lake Pontchartrain were examined, although only five contained recognizable food. Fishes comprised the bulk (82 percent) of this material and included the anchovy (Anchoa mitchilli diaphana) (70 percent) and other unidentifiable fish remains (12 percent). Penaeid shrimp made up ten percent of the food and undetermined organic matter, eight percent. The presence of occasional strands of filamentous green algae (Cladophora sp.) indicated that foraging had probably taken place in the shallow margins of the lake.

Evidence from the south Atlantic and Gulf coasts points to the fact that E. saurus is an important shallow water predator, and within the size range 82-280 mm. it consumes quantities of small fishes and penaeid shrimp. Detailed study of the food of the different size groups would probably indicate food habits very similar to those of the speckled trout (Cynoscion nebulosus) of comparable lengths.

CLUPEIDAE

Brevoortia patronus Goode. Gulf Menhaden

A number of workers have discussed the food of the several species of menhaden inhabiting the south Atlantic and Gulf coasts of the United States, and opinions regarding the origin and nature of this food material have been divided among those who have held the species to be mud- or "ooze"-feeders and those who have considered the species to be plankton-strainers. Verrill (1871) reported that stomachs and intestines of menhaden *(B. tyrannus)* taken from the shallow coastal waters of New Jersey invariably were filled with the soft, "oozy" mud, containing a large proportion of organic matter such as abounds in the quiet parts of coastal bays, and he concluded that the menhaden obtains its nutriment, "by swallowing the mud and digesting the organic particles obtained in it". Goode (1879) examined the digestive tracts of about 100 menhaden (mostly *B. tyrannus)* taken from estuaries, rivers, and harbors along the Atlantic and Gulf coasts and also obtained the opinions of many commercial fishermen regarding the food of the species. On this basis, he stated, ". . . the plain inference seems to be that the food of the menhaden, in part at least, is the sediment which gathers upon the bottom of still, protected bays, which is largely composed of organic matter, and upon the vegetation which grows in such water." Goode presented further observations suggesting that the menhaden might also strain plankton from near-shore and marine waters. Linton (1904) reported the results of food studies of five menhaden *(B. tyrannus)* from North Carolina which seem to lend support to the notion of bottom feeding advanced by the above workers. Whereas the alimentary tracts of four of the menhaden were "packed with many kinds of copepods", the alimentary canal of the remaining fish was filled with greenish mud consisting of sand and vegetable debris together with diatoms and many kinds of algae, abundant foraminifera, numerous spines and spicules, and a small copepod fragment.

In describing the remarkable branchial filtering apparatus of the Atlantic menhaden, Peck (1894) pointed out the close resemblance between the microscopic appearances of the stomach contents and of plankton articially filtered from the surface waters at the time of capture, thus demonstrating rather conclusively that the menhaden does filter plankton from surface waters. He found that diatoms and dinoflagellates were especially abundant and that filamentous algae, copepods, a number of ciliate protozoans, and certain other small invertebrates were sometimes taken in quantity. In addition, large amounts of disintegrating organic matter from a variety of sources were consistently present, and varying quantities of "amorphous matter", which he assumed to be masses of bacteria, were noted to occur. Tintinnids were occasionally present in greater concentration in the food than in the surface water samples, however, suggesting that the menhaden might filter materials from subsurface waters as well. Bigelow and Schroeder (1953) described the feeding behavior of the species, and summarizing the work of Peck *(op. cit.)* they emphasized the mechanical nature of the straining action. Although no apparent voluntary selection takes place, larger animals are not consumed, and very small particles are not retained. Other writers including Gowanloch (1933), Gunter (1945), and Reid (1955a) have indicated that the related species of menhaden *(B. gunteri* and *B. patronus)* from the northern Gulf coast are also plankton-feeders, apparently basing their conclusions largely upon observation of surface-feeding schools.

In the present study 17 specimens of Gulf menhaden from Lake Pontchartrain were examined and all contained food material. In the five smallest individuals (38-48 mm.) the contents of both the cardiac and pyloric portions of the stomach were examined. Food of these small menhaden consisted chiefly of phytoplankton (82 percent), with small amounts of zooplankton and plant fragments. Detritus constituted 11 percent of the total food material. The bulk of the phytoplankton was made up of several species of Anabaena which together comprised 77 percent of the total food, whereas the remaining phytoplankton was composed of diatoms (Coscinodiscus sp., Melosira sp., Nitzschia sp., and Synedra sp.) . Zooplankton included rotifers (Keratella sp. and T***richocerca*** sp.), as well as a few copepods. These small menhaden obviously had been straining plankton, and the presence of large quantities of Anabaena indicates that they were feeding at the surface on floating blooms of this phytoplankter, substantiating direct observations to this effect. It appears likely that these young fishes may also strain plankton at depths below the surface, although there is no direct evidence supporting such activity.

The 12 larger menhaden (85-103 mm.) were examined early in the study, and unfortunately, only the contents of the muscular pyloric region of the stomachs of these specimens were included for analysis. At least 99 percent of the material encountered appeared to be ground organic matter and silt, and a few occasional diatoms (Coscinodiscus sp.), foraminiferans, and copepods were also present. Although these larger menhaden can not be compared exactly with the smaller specimens, certain qualitative differences in the food of the two groups were suggested. During the field studies menhaden around 100 mm. in length were frequently captured in great abundance near the south shore of Lake Pontchartrain where wave action was reducing the organic material of the marshy shore to the consistency of coffee grounds. Here a suspension of ground up organic matter was almost always in evidence, and at times of heavy wave action (northerly winds) the water frequently displayed the physical appearance of black drawing ink (giving Secchi disc readings of less than one inch) . The menhaden appeared to be thriving upon this suspended material, and the laboratory food analyses, while not proving the point, clearly substantiated this possibility. Phytoplankton was not the primary food of these larger menhaden since diatoms and other forms would have been recognizable, even if partially ground.

The conclusion reached on the basis of present knowledge is that the menhaden feeds by filtration. Although the primary food of the species seems to consist of planktonic algae and microcrustacea (suspended within the water) , alternate food sources may be exploited when available. Surface scums of Anabaena enter the diet of the young. Likewise, suspended material other than living plankton (silt, mud, chopped and decaying bits of vegetation, bottom invertebrates, etc.) may be filtered from the water, suggesting falsely that the species had been feeding directly upon the bottom. Suspended bacteria which are undoubtedly ingested in some quantity may be considered as planktonic (Eddy, 1934) . The real importance of each of these alternate food sources in the economy of the species remains to be determined, but from the foregoing it may be inferred that within turbid estuaries their combined importance may be considerable.*

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* In the spring and fall of some years the floating Anabaena scum is so abundant on Lake Pontchartrain that this phytoplankter literally forms mounds upon the surface of the water, and the fact that young menhaden are able to exploit this food source suggests that the numerical success of a particular young menhaden crop may be related to some extent, to the success of the Anabaena. In turn, the Anabaena crop (as indicated by unpublished quantitative plankton data) is most extensive during years of heavy rainfall when nutrient-rich waters drain from flooded marshes and swamps, maintaining relatively fresh conditions (less than 8‰) in the estuary. Under low salinity conditions, marine predators would tend to be less abundant, thus further enhancing the size of the young menhaden population. Suttkus (1956) has pointed out that spawning does not take place inside Lake Pontchartrain. Hence, in addition to the availability of food and predators, hydrographic conditions of a particular year, insofar as they affect transport of larvae, may also play a decisive role in determining the success of the new year-class.

Dorosoma cepedianum (Le Sueur) . Gizzard Shad

The food of the gizzard shad in fresh waters has received the attention of a number of investigators including Forbes (1878, 1880a, 1888) , Forbes and Richardson (1920) , Tiffany (1920, 1921), Hildebrand and Towers (1927) , Ewers and Boesel (1936) , Kuhne (1939) , Rice (1942), and Dendy (1946) . These workers have pointed out that young gizzard shad feed primarily upon planktonic crustaceans, minute algae, and insect larvae whereas adults consume chiefly vegetable debris and mud from the bottom supplemented by a variety of forms including planktonic protozoa, rotifers, crustaceans, and small fishes, as well as a number of bottom invertebrates and algae. From the brackish waters of Chesapeake Bay, Hildebrand and Schroeder (1928) analyzed the food of 10 specimens. Vegetable debris comprised 80 percent of the material with sand and mud making up the bulk of the remainder. Miscellaneous items included three foraminiferans, a diatom, a difflugia, and a copepod.

Eleven specimens of adult gizzard shad (101-278 mm.) from Lake Pontchartrain were examined Although all specimens contained some food material, this substance was found to be recognizable only before being subjected to the pulverizing action of the muscular pyloric portion of the stomach. Three primary types of material encountered in the digestive tracts included foraminifera, undetermined organic material and detritus, and silt, each of which made up over one-fourth of the total food volume. Eleven percent of the consumed material was sand, and traces of a variety of bottom invertebrates and plants made up the remainder. These included remains of sponges, snails, clams (Rangia cuneata), annelids, ostracods, and copepods, as well as filamentous algae, seeds, and leaves of vascular plants. The Louisiana specimens undoubtedly had fed exclusively upon the surface of the bottom, and the presence of a high percentage of foraminifera and other invertebrates suggests that the shad exercised considerable selectivity in their bottom feeding.

Signalosa petenensis (Günther). Threadfin Shad

Apparently the food habits of the threadfin shad have not previously been reported, although McLane (1948) observed that in the St. Johns River of Florida where the species is very abundant it frequently swims with its mouth open, just breaking the surface of the water while feeding upon plankton. In the Lake Pontchartrain study the stomach contents of five specimens (69-103 mm.) were examined, only three of which contained recognizable food. Plankton made up 76 percent of the material, whereas detritus made up 14 percent, and sand 10 percent. Included among the plankton organisms were diatoms (31 percent), flagellates (including *Volvox* sp.) (19 percent), rotifers (including Keratella gracilenta) (18 percent), and copepods (8 percent) . Recognizable amphipods were found in the intestines of one shad, although the intestines generally contained a mud-like material.

The threadfin shad, like young menhaden, appear to feed upon surface plankton, and this was borne out not only by food analysis but also by observations in Lake Pontchartrain of surface-feeding schools. The presence of amphipods, mud, and sand in the tracts of the Louisiana specimens, however, suggests that some feeding must take place near or upon the bottom.

ENGRAULIDAE

Anchoa *mitchilli* diaphana Hildebrand. Southern Bay Anchovy

Hildebrand and Schroeder (1928) analyzed the food of 44 specimens of *Anchoa* m.

mitchilli from Chesapeake Bay. The sole food of the young was found to be copepods, whereas the adults consumed both copepods and schizopods. In addition, cannibalism was indicated by the presence of two small anchovies in the food of the adults, and the occurrence of three small gastropods and an isopod indicated some bottom feeding. Reid (1954) mentioned that the food of anchovies from Cedar Key, Florida, is "small crustaceans of the class Malacostraca."

In the Lake Pontchartrain study micro-zooplankters, including rotifers and both cyclopoid and calanoid copepods, constituted an important portion of the diet of the smallest individuals (Table 1 and Fig. 1) . With increase in size these forms were con-

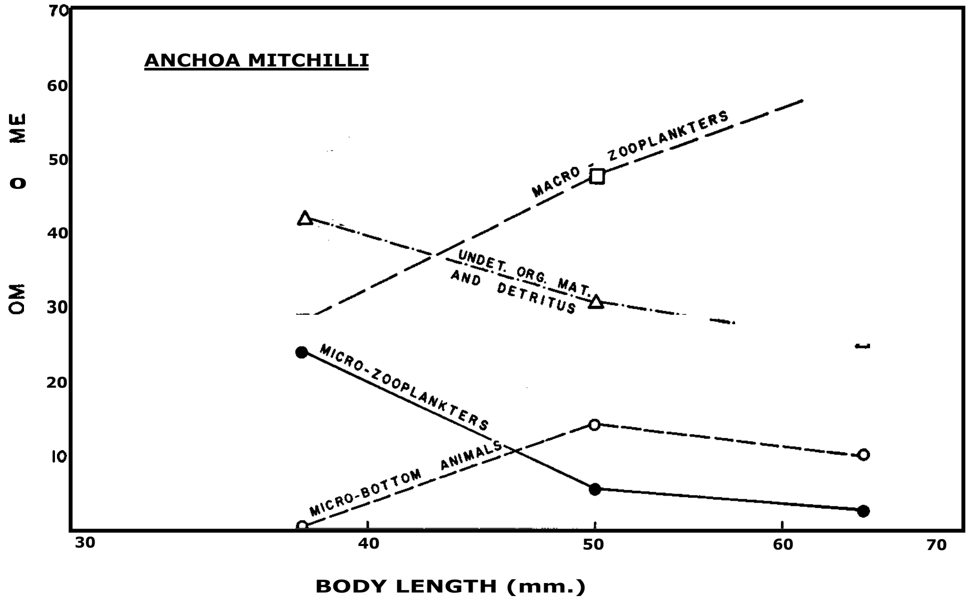


FIG. 1. Ontogenetic food progression of *Anchoa mitchilli.* (Body length refers to standard length.)

sumed less frequently, and in the largest anchovies they made up less than two percent of the food material. Undoubtedly, micro-zooplankton is also one of the chief sources of nutrition of anchovies smaller than 30 mm.

Remains of small shrimp and fishes made up a prominent portion of the food of anchovies of all sizes examined. These forms, somewhat loosely referred to as macro-zooplankton, constituted 28 percent of the material consumed by the smallest anchovies and increased to over 60 percent in the largest size class. Included in this food category are adult schizopods, larval and post-larval penaeid shrimp, larval fishes (including clupeids and probably some larval anchovies, again indicating cannibalism) and a single small naked goby *(Gobiosoma bosci).*

Small bottom-dwelling mollusks and crustaceans were scarcely represented in the diet of the smallest anchovies. This material was conspicuous in the food of the two larger size classes, however, making up over ten percent of the food volume in both groups. Included among these micro-bottom animals were minute snails, clams *(Rangia cuneata),* isopods, amphipods, ostracods, and harpacticoid copepods. The presence of such forms in the stomachs of the anchovies indicates that the species must feed to some extent upon the bottom since the mollusks and benthic microcrustaceans apparently are unavailable elsewhere. The micro-bottom animals, as well as small quantities of sand, were most

TABLE 1

Occurrence of food items in digestive tracts of 92 *Anchoa mitchilli*

	30.0-44.0 mm.		45.0-49.0 mm.		50.0-54.0 mm.		55.0-59.0 mm.		60.0-74.0 mm.	
	15 examined 13 with food		25 examined 21 with food		22 examined 19 with food		19 examined 18 with food		11 examined 10 with food	
FOOD ITEMS	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume
Rotifera	6.7	3.9	4.0	0.3						
Ostracoda			4.0	0.8			5.3			
Copepoda (undet.)	26.7	11.0	24.0	9.4	4.5		21.1	1.5		
Calanoid	26.7	9.0	16.0	1.4	4.5		21.1	3.5	27.3	0.5
Cyclopoid					4.5	0.5				
Harpacticoid	6.7	0.3	12.0	0.4	13.6	3.3			9.1	1.3
Mysid shrimp	20.0	28.1	48.0	52.0	50.0	43.8	42.1	34.5	45.5	40.3
Isopoda			8.0	5.4	4.5	8.5	10.5	7.3		
Amphipoda			16.0	6.0	9.9	1.2	10.5	2.6		
Insecta	6.7	1.0	4.0	0.8						
Mollusca										
Rangia cuneata			4.0	0.2	4.5	0.6	5.3	2.9		
Gastropoda			4.0	2.3			15.8	3.4	9.1	2.7
Vertebrata										
Gobiosoma bosci							5.3	6.8		
Fish larvae							5.3	7.3	9.1	13.4
Fish remains									27.3	19.3
Planktonic diatoms			4.0	0.4						
Seeds	6.7	1.0					5.3	1.2		
Eggs and cysts	13.3	3.2	4.0		4.5	0.2	5.3	0.5		
Organic mat. (undet.)	73.3	34.7	48.0	6.9	68.2	33.7	68.4	22.8	72.7	19.2
Detritus	33.3	7.2	48.0	13.4	72.7	7.3	63.2	5.1	90.9	3.3
Sand			12.0	0.4	13.6	0.8	15.8	0.4	27.3	
SUMMARY										
Copepoda		20.3		11.2		3.8		5.0		1.8
Mysid shrimp		28.1		52.0		43.8		34.5		40.3
Isopoda and amphipoda		0.0		11.4		9.7		9.9		0.0
Fishes		0.0		0.0		0.0		14.1		32.7
Miscellaneous		9.1		4.8		0.8		8.0		2.7
Incidental and undet.		41.9		20.7		41.8		28.3		22.5

* Stomach *and intestine* included.

frequently encountered in the stomachs of anchovies taken during the winter and spring months suggesting that more intensive bottom-feeding may take place at these seasons of the year.

Undetermined organic material and detritus was most prominent in the food of the smallest size class (42 percent) and declined to one-fourth of the food volume of the largest fish. This substance was generally of fine particulate nature and appeared to be derived primarily by straining of suspended matter from the water rather than by scooping of surface material directly from the bottom. The decline in consumption of this detritus by the larger anchovies paralleled a decline in consumption of micro-zooplankters, as might be expected if straining were involved, and the great volumetric preponderance of this suspended detritus in the food of the young raises the trivial question of which should be considered "incidental", detritus or micro-zooplankton. The fact that the detritus was decreasing as the micro-bottom animals increased points to a greater degree of selectivity by the larger anchovies, and this, in turn, was related to the increased consumption of shrimp and fishes.

In summary, the Lake Pontchartrain anchovy population appears to pass through two ontogenetic feeding stages. Young individuals are plankton strainers and consume large quantities of micro-zooplankton and suspended detritus. The relative absence of phytoplankton suggests that such straining occurs near the bottom. With increasing size the species exercises greater selectivity, preying chiefly upon small shrimp and fishes and supplementing this diet with occasional bottom-dwelling mollusks and crustaceans. Detritus apparently forms an important nutritional supplement in both the young and adult.

In connection with his studies in East Bay, Texas, Reid (1955a, b) indicated that the abundance of the anchovy population depends "upon the mass of zooplankton". Whereas this may be the case for the Chesapeake Bay specimens of Hildebrand and Schroeder *(loc. cit.),* it is only partially true for the Louisiana population which, as indicated, consumes copious quantities of detritic matter.

The daily pattern of feeding activity of the anchovy is not entirely clear. Examination of Figure 2 indicates that both the young and adults feed during the middle portion of the day, although the adults seem to commence feeding activities earlier in the morning than do the young.

BELONIDAE

Strongylura marina (Walbaum) . Atlantic Needlefish

Hildebrand and Schroeder (1928) recorded the food of 18 specimens of needlefish. Seventeen had taken small fishes *(Mugil curema, Fund ulus diaphana,* and silversides) while a single specimen had eaten shrimp. McLane (1948) reported that needlefish consume large numbers of shad *(Signalosa petenensis vanhyningi)* in the St. Johns River of Florida.

Seven specimens of the needlefish (357 457 mm.) from Lake Pontchartrain were examined, all of which contained food. Small fishes *(Anchoa mitchilli diaphana* and others) made up almost two-thirds of this material. Insects (adult Diptera and Coleoptera) and vegetation (*Cladophora* sp. and some vascular plant material) made up less than five percent. Almost one-third of the stomach content consisted of undetermined organic matter which appeared to be largely fishes and invertebrates in advanced stages of digestion.

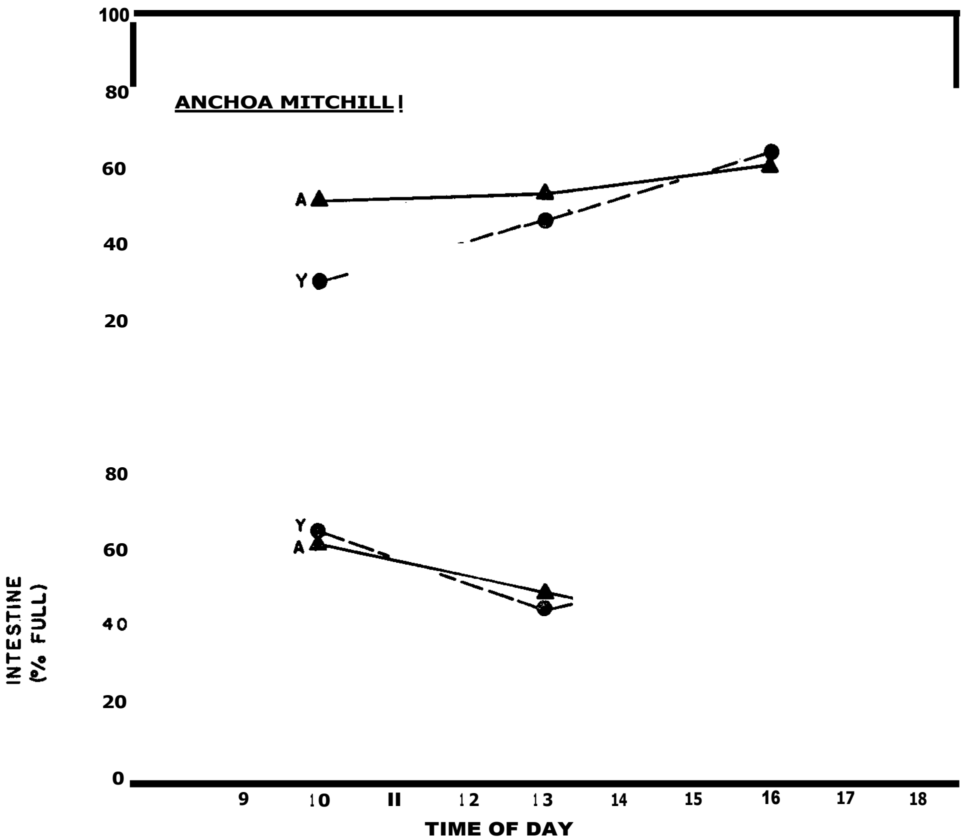


FIG. 2. Hourly pattern of percent-fullness of stomach and intestine of Anchoa mitchilli (young and adult).

The food habits of the needlefish are not well known. Within the size range studied, the species is a predator, feeding upon small fishes, insects, and crustaceans. This fish was frequently observed to be active near the surface in deeper water throughout the lake where it must feed on anchovies and young clupeids, although stomach analyses show that it does forage in the weedy shallows of Lake Pontchartrain.

ARIIDAE

Bagre marina (Mitchell) . Gafftopsail Catfish

The food of adult gafftopsail catfishes has been reported by Gudger (1916) , Gunter (1945), Knapp (1949), Reid (1955b), and Reid, Inglis, and Hoese (1956) . These authors have shown that this fish feeds primarily upon blue crabs and penaeid shrimp, although fishes (including menhaden, worm eels, and other species), and various invertebrates (squids, small crabs, and insects) may also be taken. A single adult specimen from Lake Pontchartrain contained only unrecognizable material. Nothing is known of the food habits of small individuals.

Galeichthys felis (Linnaeus) . Sea Catfish, Hardhead

Linton (1904) examined the food of 17 hardhead catfish from Chesapeake Bay and found clams (soft parts and valves), snails, annelids, amphipods, shrimp, sea urchin re mains, and fish bones and eye lenses, as well as some sand. Smith (1907) indicated that in North Carolina this fish is a bottom-loving species which feeds chiefly on worms and small crustaceans, but readily eats fish flesh or fowl, dead or alive. Perhaps, he had in mind the baits with which this catfish may be taken.

Gunter (1945) examined the stomach contents of 85 individuals from Texas of which 59 contained recognizable food. These fish ranged in size from 240 to 360 mm. except for one which was only 100 mm. in length. Blue crabs *(Callinedes sapidus)* and mud shrimps *(Callianassa jamaicense lousianensis)* made up about 90 percent of the food of these large catfishes, and Gunter *(op. cit.)* suggested that this fish can root soft-shelled crabs from hide-aways in the mud. Other identified material included penaeid shrimp *(P. aztecus),* oyster crabs *(Panopeus* sp.), hermit crabs, a nudibranch, a small mullet, and a small sea catfish (indicating cannibalism). Fish bones and a clam shell were present, and although no specific mention was made of the presence of bottom detritus, indistinguishable material was noted in five stomachs. Knapp (1949) reported that of 468 hardhead catfish examined from the Texas coast, 87 percent had consumed shrimp, whereas fishes (including menhaden) appeared in about 14 percent, crabs in 6 percent, and squids and other invertebrates were present in less than one percent. Reid (1954) analyzed the food of five specimens from Florida. Four small individuals (91-116 mm.) contained many copepods as well as amphipods, mysids, polychaetes, and shrimp. One adult contained crabs, shrimp, and fishes. Reid (1955a) later reported on the examination of 14 specimens from northern Texas, of which 11 contained food. Six small individuals (82-91 mm.) had eaten "myriads" of copepods, some shrimp, and unidentified fish. Five larger catfishes (144-191 mm.) had consumed one xanthid crab, one fish, and quantities of "pelecypod debris".

Of the specimens examined from Lake Pontchartrain, smaller individuals had consumed quantities of small bottom-dwelling invertebrates (Table 2). These included amphipods (10 percent), mud crabs (16 percent), and chironomid larvae and pupae (13 percent), as well as smaller percentages of hydroids, clams, snails, harpacticoid copepods, schizopods, isopods, and water beetles. Bottom invertebrates were also prominent in the food of the larger sea catfishes, although these invertebrates tended to be somewhat larger in size and included higher percentages of both mud crabs and blue crabs. Adults consumed fewer amphipods, but the percentages of most other invertebrate groups remained relatively unchanged.

Fish remains consisting mainly of bones, scales, and lenses of eyes were present in the stomachs of catfishes of both size groups. Since no soft remains of fishes were encountered, however, it is assumed that no live fishes had been eaten and that the hard parts were strained from the surface of the bottom mud. These remains were least prominent in the stomachs of the adults indicating a greater apparent degree of selectivity within this group. Undetermined organic material and detritus constituted over one-third of the stomach contents in both sizes of sea catfish. This material which appeared to have been derived from the surface layer of the bottom deposits was more prominent in the diets of the young than of the adults.

The Lake Pontchartrain specimens indicate that within the size range investigated both young and adult sea catfish are bottom feeders which take in quantities of benthic invertebrates together with much bottom surface debris and detritus. Although little change was evident in the types of food consumed by the two size groups, the adults appeared to take in larger items, and especially more crabs. Increase in size appeared to be accompanied by somewhat greater selectivity involving a decrease in the consumption of both miscellaneous bottom materials and detritus.

TABLE 2

Occurrence of food items in digestive tracts of 40 *Galeichthys felis*

	90.0-169.0 mm.		170.0-229.0 mm.	
	19 examined 19 with food		21 examined 17 with food	
FOOD ITEMS	Percent age of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume
Copepoda-Harpacticoid	5.2			
Mysid shrimp	10.5	1.9	4.8	1.3
Isopoda	42.1	1.8	23.8	2.1
Amphipoda	68.4	9.5	38.1	4.0
Palaemonidae			4.8	0.5
Crabs (undet.)			4.8	3.8
Rithropanopeus harrisii	47.4	15.7	61.9	27.8
Callinectes sapidus			9.5	2.3
Insecta (undet.)	5.2	0.1		
Coleoptera	10.5	0.7	28.6	3.7
Diptera-larvae	89.5	10.6	61.9	10.3
Pupae, adults	26.3	2.0	14.3	0.6
Arachnida			4.8	0.4
Mollusca				
Rangia cuneata	15.8	1.3	4.8	
Gastropoda	5.2		4.8	
Hydroids	10.5	0.1		
Vertebrata				
Fish remains	63.2	11.1	38.1	5.2
Vascular plants	10.5			
Organic mat. (undet.)	78.9	31.6	76.2	27.3
Detritus, Sand	68.4	13.6	81.0	10.8
SUMMARY				
Mysid shrimp		1.9		1.3
Isopoda, Amphipoda		11.3		6.1
Insecta		13.4		14.6
Crabs		15.7		33.9
Miscellaneous		12.5		6.1
Detritus, undet.		45.2		38.1

* Stomach and intestine included.

The total evidence available indicates that during its life history the sea catfish may actually pass through three feeding stages. Zooplankton, especially copepods, appears to be an important food for individuals less than 100 mm. in length. Above this size micro-bottom invertebrates assume importance, and these grade into larger crabs and fishes in "sea cats" above 200 mm. Much bottom detritus was noted in the Louisiana specimens, although this material has not been recorded as food for the species by workers in other areas.

ICTALURIDAE

Ictalurus furcatus (Le Sueur). Blue Catfish

The food of the blue catfish appears to have been largely neglected in the literature. Forbes (1888) found that a single specimen had eaten only fishes. Forbes and Richardson (1920) mentioned that fragments of bark, insect remains, and miscellaneous organic debris were also consumed and that blue catfish are caught on trot-lines baited with fishes and crayfish. Hildebrand and Towers (1927) reported a single small specimen (195 mm) had fed on crustaceans, insects, fishes, and vegetation. Gunter (1945) found that four large blue catfish (280-305 mm.) from brackish waters of southern Texas had consumed grass shrimp (Palaemontes sp.), algae, and some indistinguishable material.

In the Lake Pontchartrain specimens of the smallest size group (60-129 mm.) , zooplankton, including schizopods and calanoid copepods, constituted the most important single food, making up almost one-half of the stomach volume (Table 3 and Fig. 3). This material, however, was barely represented in the stomachs of the larger fish. Undoubtedly

TABLE 3

Occurrence of food items in digestive tracts of 78 *Ictalurus furcatus*

FOOD ITEMS	60.0-129.0 mm. 18 examined 15 with food		130.0-199.0 mm. 18 examined 16 with food		200.0-229.0 mm. 17 exam'ned 15 with food		230.0-411.0 mm. 25 examined 23 with food	
	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume
Ostracoda			11.1	T	17.6	0.2		
Copepoda								
Calanoid	5.6	12.6						
Harpacticoid			11.1	0.5				
Mysid shrimp	27.8	36.0	16.7	1.5	11.8	0.4	24.0	0.2
Isopoda	22.2	4.2	11.1		23.5	0.4	16.0	4.8
Amphipoda	50.0	4.4	55.6	19.1	29.4	23.0	52.0	1.8
Pal aemonetes sp.					5.9		8.0	2.6
Macrobrachium ohione							4.0	1.0
Penaeus setiferus							4.0	2.6
Callianassa sp.					5.9	5.1	4.0	1.3
Crabs								
Rithropanopeus harrisii			44.4	10.9	47.1	2.4	20.0	6.4
Callinectes sapidus	5.6		5.6	1.0	5.9	0.8	24.0	3.0
Insecta								
Coleoptera	16.7	1.7	33.3	0.3	29.4	0.5	8.0	
Diptera	27.8	0.5	27.8	1.3	52.9	0.8	40.0	0.6
Hemiptera			5.6		5.9			
Homoptera							4.0	
Hymenoptera			5.6		11.8		4.0	
Orthoptera			5.6		5.9		4.0	
Arachnida					5.9			
Annelida	5.6		5.6	1.3			12.0	0.7
Mollusca								
Rangia cuneata	5.6		72.2	25.3	76.5	36.0	52.0	9.9
Mytilopsis leucopheata			5.6		23.5	6.7	16.0	2.1
Gastropoda			5.6		35.3	0.5	4.0	
Hydroids					5.9	0.1	4.0	
Vertebrata								
Anchoa mitchilli					11.8	9.9	4.0	0.5
Citharichthys spilopterus							8.0	7.3
Menidia beryllina							4.0	0.4
Micropogon undulatus					5.9	0.7	12.0	8.3
Syngnathus sp.							4.0	0.4
Fish remains			11.1	3.5	11.8	2.3	24.0	13.5
Algae-filamentous			5.6	3.3			32.0	25.7
Vascular plants	5.6	0.2	5.6		5.9		24.0	0.5
Eggs and cysts			5.6					
Organic mat. (undet.)	88.9	26.3	66.7	25.5	76.5	10.1	52.0	3.3
Detritus	33.3	10.6	27.8	6.2	23.5	0.3	32.0	1.1
Sand and silt	11.1	3.8	16.7	0.4	17.6	0.1	40.0	2.3
SUMMARY								
Copepoda, Ostracoda, Mysids		48.6		2.0		0.6		0.2
Isopoda, Amphipoda		8.6		19.1		23.4		6.6
Macrocrustacea		0.0		11.9		8.3		16.9
Mollusks		0.0		25.3		43.2		12.0
Fishes		0.0		3.5		12.9		30.4
Vegetation		0.2		3.3		0.0		26.2
Misc. Invertebrates		2.2		2.9		1.4		1.3
Incidental and Undet.		40.7		32.1		10.5		6.7

* Stomach and intestine included.

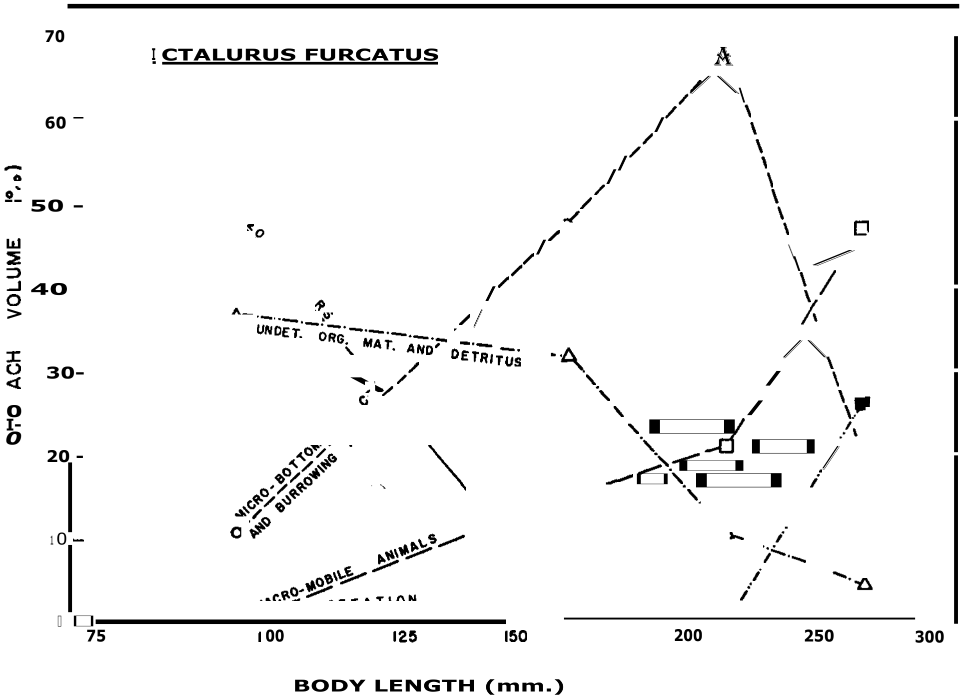


FIG. 3. … *furcatus.*

zooplankton also constitutes a major portion of the diet of fishes smaller than 60 mm.

Small bottom animals, including surface as well as burrowing forms, made up 11 percent of the food of the smallest size class. This material increased in the intermediate size classes, reaching a peak of consumption in the 200-229 mm. blue catfish where it constituted over two-thirds of the total food. In the largest size class this material declined, however, to one-fifth of the volume of the material consumed. Included among these bottom dwellers were amphipods and clams (Rangia cuneata) which made up the bulk of the food, and smaller amounts of gastropods, mussels (Congeria leucopheata), annelids, harpacticoid copepods, ostracods, isopods, and aquatic beetles.

Increase in size of the catfish was accompanied by a progressive increase in the utilization of large mobile animals which together made up almost one-half of the food of the largest size group. These larger animals included crabs (Rithropanopeus harrisii and Callinectes sapidus), shrimp (Macrobrachium ohione, Palaemonetes sp., Penaeus spp., and Callianassa sp.) and fishes (Anchoa mitchilli diaphana, Citharichthys spilopterus, Menidia beryllina, Micropogon undulatus, and Syngnathus sp.), as well as unidentified remains referable to these categories.

Vegetation was virtually absent from the lower three size groups, although in the largest size of catfish it constituted 26 percent of the food material. Most of this vegetation was made up of dense mats of filamentous green algae (primarily *Cladophora* sp., although some Rhizoclonium sp. was noted) . Since most of this vegetation appeared in the stomachs of seven specimens from only two collections made in February and March, it is probable that the percent of vegetation is somewhat exaggerated in this series of analyses. Detritus and unidentified organic material were most abundant in the smallest size group, making up 37 percent of the food volume in this group. This material declined thereafter to four percent in the largest fish.

Most of the smaller catfish appear to have concentrated upon one or a few food items, and only a relatively small number of foods figured prominently in this group as a whole. With increase in size an increase in diversity was noted, and in the upper size class a single fish (390 mm.) contained the following: 3 Macrobrachium ohione, 27 Palaemonetes sp., 5 palaemonids (undetermined), 13 Callinectes sapidus, 1 Menidia beryllina (70 mm.), 1 Micropogon undulatus (28 mm.), 2 Syngnathus sp. (90 mm. each), 1 fish (undetermined), and a trace of plant material.

As indicated in Figure 4, the degree of fullness of the stomachs suggests that some

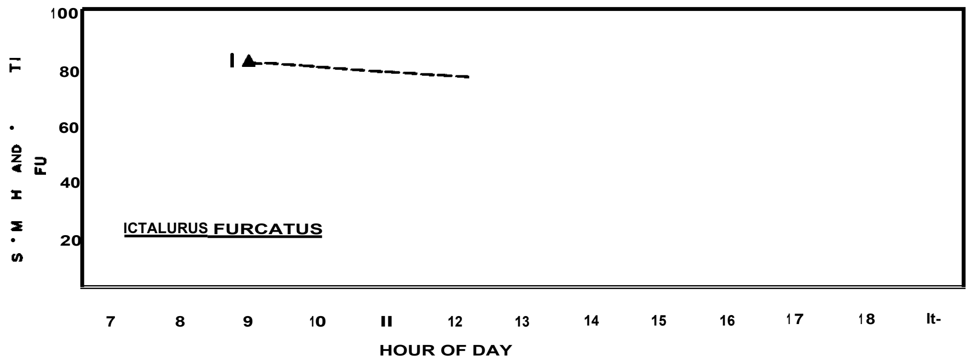


FIG. 4. Hourly pattern of percent-fullness of stomach and intestine of Ictalurus furcatus.

feeding must occur throughout the day with, perhaps, a diminution in feeding activity in the late afternoon and early evening. The condition of the intestines, however, points to the fact that the main feeding must take place either at night or in the early morning hours.

Although the food habits of the blue catfish are quite complex, three general feeding stages are recognizable. In smaller individuals a zooplankton-feeding stage is dependent chiefly upon calanoid copepods and schizopods. This stage appears to be largely completed by a size of 100 mm. A bottom-feeding stage dependent upon small bottom-inhabiting invertebrates is prominent in the 100-240 mm. catfish. Finally, a stage dependent primarily upon macro-mobile animals such as fishes, crabs, and shrimp achieves significance in catfishes over 200 mm. in length. This general pattern of food stages is displayed in common with a number of other species inhabiting Lake Pontchartrain, and it appears that from the standpoint of nutrition the blue cat is highly successful in the estuarine environment.

Ictalurus punctatus (Rafinesque). Channel Catfish

Food of the channel catfish in fresh water has been the subject of investigation by many workers. In a recent study, Bailey and Harrison (1948) reviewed a number of the more pertinent references including the following: Forbes (1888), Smith (1907), McAtee and Weed (1915), Shira (1917), Mobley (1931), Ewers and Boesel (1936), Aitken (1936), Boesel (1938), McCormick (1940), Dill (1944), Menzel (1945), and Dendy (1946). As indicated by these writers up to 98 percent of the diet of the very young channel catfish (less than 100 mm.) consists of small aquatic insects. With increase in size the catfish have been found to consume a much lower percentage of insects, and within wide ranges of tolerance, larger individuals appear to subsist upon whatever food happens to be locally available in quantity. Evidence indicates that many types of food materials are probably consumed in direct proportion to their availability.

Groups of channel catfish have been found to specialize at least temporarily upon algae, mollusks (especially gastropods) , microcrustaceans, crayfish, insects (aquatic and terrestrial) , and fishes. Even young of the same species have been found to enter the diet of the adults with a frequency proportional to their relative abundance in the fish population (Bailey and Harrison, 1948) . In the Chickahominy River of Virginia Menzel (1945) found that algae and blue crabs formed a large proportion of the diet of this species when available. Because of this wide range of food tolerance, the channel catfish is generally considered to be omnivorous.

Fourteen specimens of channel catfish were examined from Lake Pontchartrain of which 13 contained food. Stomach contents of the 11 smaller individuals (76-119 mm.) consisted primarily of small bottom-living arthropods (isopods, amphipods, xanthid crabs, and chironomid larvae and pupae, as well as occasional microcrustaceans) . Undetermined organic material and detritus made up about one-fourth of the stomach contents. Traces of foraminifera, filamentous algae, and vascular plants were present, and sand made up about eight percent of the material encountered. Two larger catfishes (207-312 mm.) had consumed quantities of crustaceans (isopods, xanthid crabs, and others), as well as smaller amounts of fish, hydroids, and undetermined organic matter.

In the brackish water environment of Lake Pontchartrain young channel catfish maintain themselves upon a diet composed primarily of small bottom crustaceans and insects together with bottom detritus. Food of the larger fish probably includes the same materials with the addition of fishes and large crustaceans as in the case of the related blue catfish. A wide variety of miscellaneous items appears to be consumed by both the young and adults.

MUGILIDAE

Mugil cephalus Linnaeus. Striped Mullet

Species of the genus Mugil are rather widely distributed throughout the tropical and subtropical shores of the world, and in some areas they assume a position of considerable importance in the economy of local human societies. Hence, it is not surprising that the food habits of the group in natural as well as artificial environments have received the attention of many workers. Much of this literature has recently been summarized by Pillay (1953) , Thomson (1954), and Ebeling (1957) . Most species of this genus are considered to feed upon plankton, filamentous algae, diatoms and other minute vegetable matter, or upon organic detritus and such nutritive material as may be procured by filtration of the bottom mud, although some divergence has been noted. Morphological and behavioral adaptations of these mugilids for obtaining and processing the nutriments are well known (see Ebeling, 1957, and the bibliography listed therein). The adults of most species browse upon the surface of shallow water sediments, and by means of a remarkable pharyngeal filtering device (supplemented by pharyngeal taste buds) they sort out the coarser materials which are expelled through the mouth. Finer filtered material receives mucus in the esophagus, and the mass is pulverized by the grinding action of the gizzard-like pyloric portion of the stomach. In the very long intestine the nutritive matter is digested from the mineral matter, apparently in the absence of either proteolytic or lipolytic enzymes (Ishida, 1935) .

The food habits of Mugil cephalus have been discussed by several writers including Gunther (1880) , Linton (1904) , Jordan (1905) , Smith (1907) , Jacot (1920) , Hildebrand and Schroeder (1928), Ghazzawi (1933) (not seen) , Hiatt (1947a-b), and Reid

(1955b) . An excellent review of most of this literature was presented by Hiatt (1947a-b) , therefore, only a summary will be undertaken here. It is generally agreed that the striped mullet feeds largely upon epiphytic algae, littoral diatoms, and finely divided organic detritus scraped from the surface layer of shallow mud flats or from the surface of roots and other objects present in such habitats. Remains of larger invertebrates and vascular plants sometimes appear among the ingested detritus, and the presence of planktonic crustacea and surface algae indicates that some plankton straining must also take place, especially among the younger individuals.

In the Lake Pontchartrain study 57 specimens of striped mullet (97-327 mm.) were examined, only 54 of which contained food. A few preliminary analyses of the contents of the muscular pyloric region of the stomachs yielded virtually no identifiable material, and it became necessary to include the contents of the cardiac region as well. Even examination of the material previous to grinding, however, provided little definitely identifiable matter, and since no clear distinctions could be made between the food of the different size groups, all specimens are treated below as a unit.

Almost one-half of the material encountered was classified as detritus and undetermined organic matter which seemed to have some cellular and tissue structure, although it was generally in an advanced state of decomposition. More than one-third of the substance appeared to be mud, silt, and sand, and only about 14 percent could be definitely recognized. Eleven percent of the material was of vascular plant origin, but could not be categorized further. About two percent was algal in nature including both flat and filamentous algae and littoral diatoms (***Biddulphia*** sp., ***Terpsinoë*** sp., and others) . Miscellaneous fish scales, foraminifera, sponge spicules, and minute gastropods each constituted less than one percent of the contents.

These results indicate that in Lake Pontchartrain, as elsewhere, the striped mullets are iliophagous and that their food consists chiefly of bottom surface material. Decomposing organic matter, detritus, and mud were much too abundant to be considered incidental in the food of the species, and it was not possible to detect any significant indictations of selectivity for the minor items such as algae, foraminifera, minute gastropods, etc. Undoubtedly some selection in feeding site does take place based primarily upon taste and size and consistency of the particles. This study suggests that the vegetable matter itself, or the decomposing bacteria, or a combination of the two factors may have influenced the feeding site of the mullets examined. Field observations indicated that striped mullet do feed at the surface, and schools were occasionally observed to be actively feeding upon surface scums of Anabaena spp. which were seasonally abundant. This material was not encountered, however, during the course of stomach analyses. Judging from the degree of fullness of the alimentary tracts, striped mullets appear to feed throughout the day, and on the basis of what is known of other iliophagous species (Gneri and Angelescu, 1951), it is probable that they feed throughout most of the night as well.

ATHERINIDAE

Menidia beryllina (Cope) . Silverside

Hildebrand and Schroeder (1928) examined the stomachs of 20 silversides from Chesapeake Bay and encountered the following food items (listed in order of importance) : small crustaceans, small mollusks, insects, worms, and a few strands of algae. Reid (1954) found that in the Cedar Key area of Florida the food of this species consisted primarily of plankton organisms, especially copepods, as well as some algae and amphipods. Six specimens taken under night lights contained freshly-ingested insects.

In the smallest size class of silversides examined from Lake Pontchartrain, calanoid copepods made up six percent of the food, although they were practically absent from individuals above 55 mm. (Table 4 and Fig. 5) . These copepods undoubtedly represent

TABLE 4

Occurrence of food items in digestive tracts of 60 Menidia beryllina

	40.0-54.0 mm.		55.0-64.0 mm.		65.0-79.0 mm.	
	21 examined 19 with food		20 examined 20 with food		19 examined 16 with food	
FOOD ITEMS	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume
Ostracoda			5.0	T	5.3	
Copepoda						
Calanoid	9.5	5.5	5.0	0.4		
Mysid shrimp	4.5	3.0	15.0	10.5	10.5	2.5
Isopoda	38.1	42.3	30.0	12.4	10.5	0.3
Amphipoda	42.9	18.9	70.0	58.7	73.7	61.0
Insecta (undet.)	9.5	0.5	20.0	2.8	21.1	0.5
Coleoptera					5.3	
Diptera-larvae	4.8	1.5	10.0	0.4		
Pupae, adults	9.5	3.0	15.0	4.4	21.1	15.4
Hymenoptera	14.3	5.3	10.0	4.5	5.3	9.9
Arachnida					5.3	0.1
Annelida	4.8					
Hydroids	4.8					
Vertebrata						
Fish remains	9.5		5.0	T	10.5	
Algae-filamentous	4.8		15.0	0.1	10.5	0.2
Vascular plants	4.8	0.6	5.0			
Eggs and cysts			5.0			
Organic mat. (undet.)	47.6	17.0	70.0	5.0	73.7	9.5
Detritus	33.3	2.5	35.0	0.3	15.8	0.5
Sand	9.5		5.0	0.7		
SUMMARY						
Copepoda		5.5		0.4		0.0
Mysid shrimp		3.0		10.5		2.5
Isopoda		42.3		12.4		0.3
Amphipoda		18.9		58.7		61.0
Insect pupae, adults		8.8		11.7		25.8
Misc. Invertebrates		2.1		0.5		0.3
Incidental, Undet.		19.5		6.0		10.0

* Stomach and intestine included.

the remnants of an earlier important zooplankton-feeding stage in individuals less than 40 mm.

Isopods and amphipods together made up the bulk of the food, constituting from 61 percent to 71 percent of the stomach contents in all size classes. Stomach analysis records indicate isopods were abundant in the 40-54 mm. size class and declined thereafter to less than one percent in the largest fish. Although Leptochelia sp. and a number of other tanaids and anthurids were definitely recognized, it appears now that at least some of these crustaceans identified as isopods may in reality have been dorso-ventrally flattened amphipods. Whatever the taxonomic position of these forms may be, they should eventually provide important evidence regarding the feeding site of the young silversides. Other species of amphipods displayed a progressive increase from 19 percent

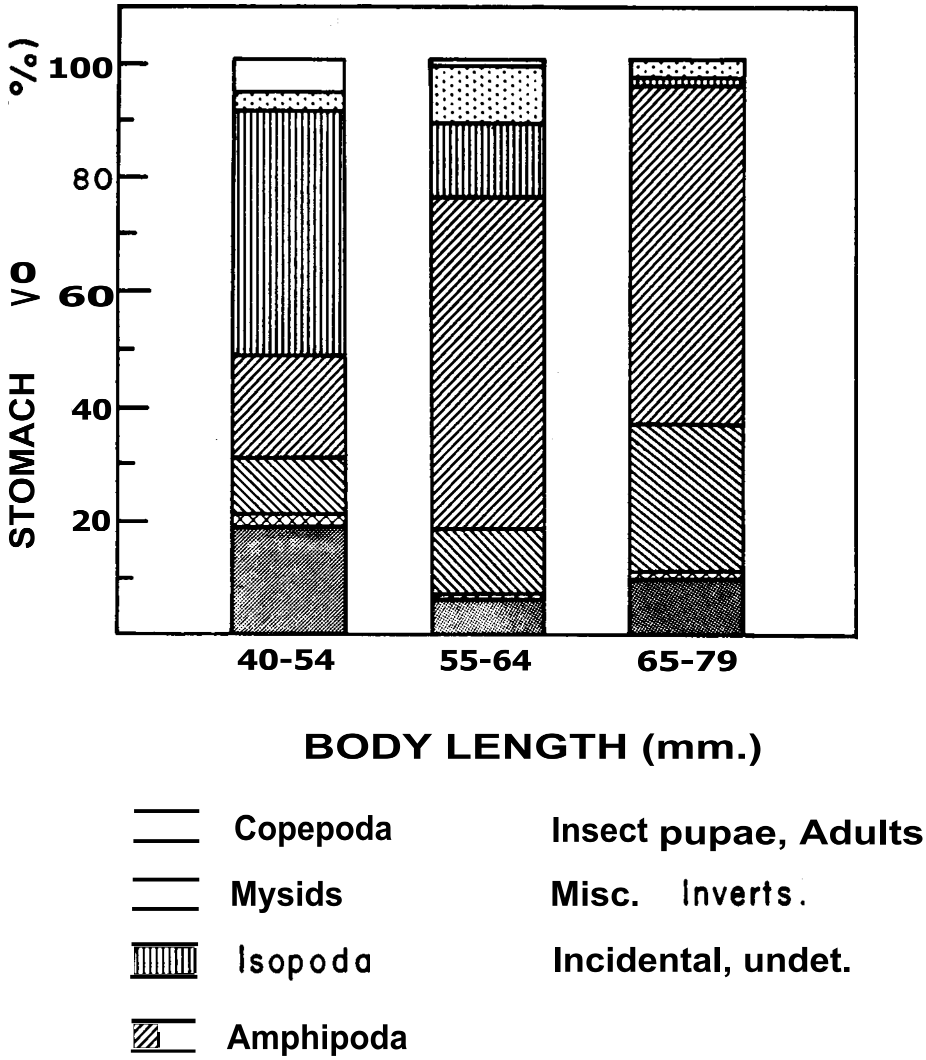


FIG. 5. Ontogenetic food progression of Menidia beryllina.

to 61 percent. These included primarily Corophium spp. in addition to a number of gammarids and a few tube dwellers (probably Cerapus sp.). A progressive increase in the consumption of insects from 9 percent to 25 percent involved primarily an increase in the utilization of chironomid pupae and adults, although some ants and a single beetle also were taken.

Schizopods were present in all size groups, but they were most abundant in the intermediate fish where they made up 11 percent of the food. Detritus and undetermined organic matter constituted 20 percent of the food of the smallest silversides and declined in the larger size groups. Miscellaneous items included filamentous algae and vascular plant material as well as annelids, ostracods, chironomid larvae, arachnids, eggs and cysts, and fish remains.

Although not demonstrated by the present series, the very young silversides probably pass through a zooplankton-feeding stage dependent primarily upon calanoid copepods.

at which time they are either pelagic or benthic inhabitants of the open water (see Hubbs', 1921, discussion of the behavior and habitat of the fresh-water atherinid, Labidesthes sicculus). With increasing size this voracious and adaptable little fish moves into shallow waters where it forages among the emergent hydrophytes collecting small arthropods such as ants, beetles, and spiders which fall into the water. It is also active among the submerged vegetation where it obtains quantities of isopods, amphipods, and other small invertebrates. Direct observations and the presence in the stomachs of tube-dwelling amphipods and chironomid larvae indicate that some foraging may take place at the surface and bottom in deeper water. Gunter (1945) has noted a movement by larger individuals to more saline waters.

As indicated by Figure 6, young silversides appear to feed both in the morning and in the afternoon, whereas the adults feed primarily in morning. Although the feeding habits are undoubtedly correlated with the availability of the food items, detailed conclusions can not be drawn because of inadequate knowledge of the habits and habitats of the invertebrates. Young silversides consumed the creatures identified as isopods largely in the afternoon, whereas the adults ate amphipods chiefly in the morning. As mentioned earlier, Reid (1954) found evidence of feeding under night lights.

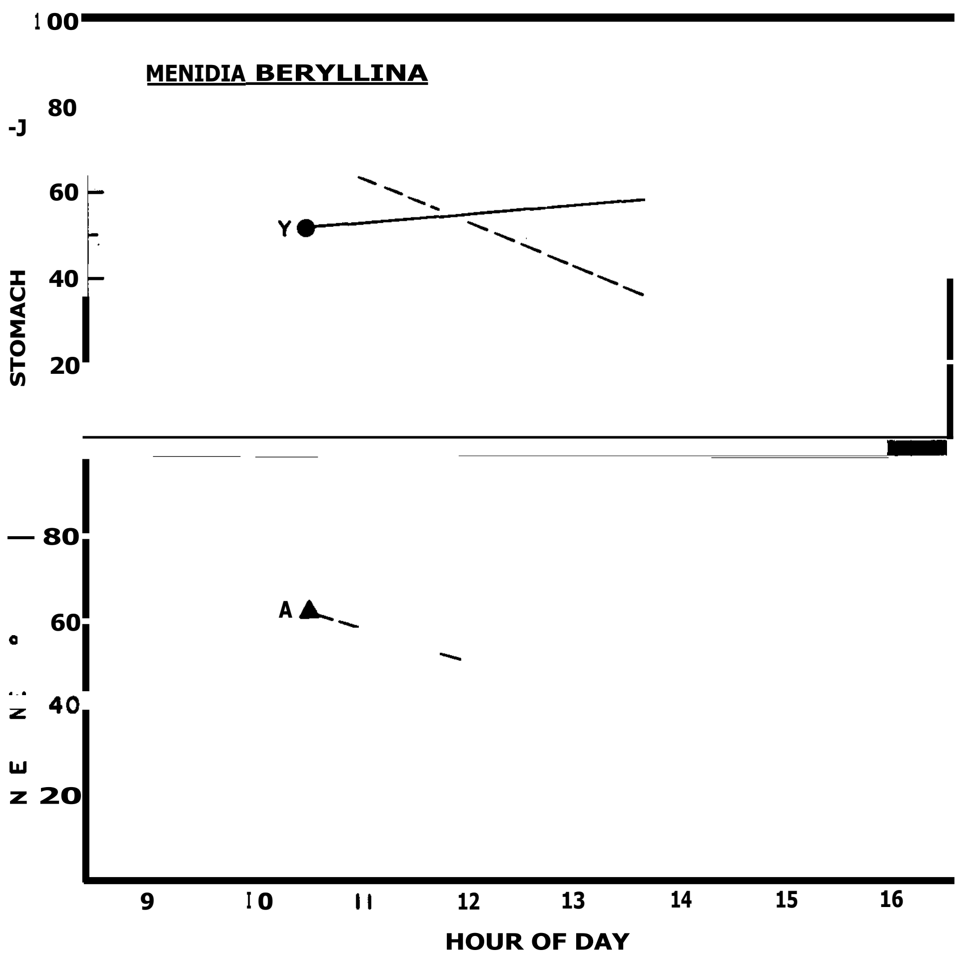


Fig. 6. Hourly pattern of percent-fullness of stomach and intestine of Menidia beryllina (young and adult).

SERRANIDAE

Morone interrupta Gill. Yellow Bass

Studies on the food of the yellow bass from fresh water by Forbes (1878,1880a, b), Hildebrand and Towers (1927), and McCormick (1940) indicate that the species consumes small aquatic animals including entomostraca, aquatic insect larvae, and small fishes, as well as occasional bits of vegetation and some terrestrial insects. The food of the species in brackish-water environments apparently has been studied only by Lambou (1952) who examined the stomach contents of 273 large specimens (*ca.* 127-292 mm.) taken from the marshes bordering the northeastern shore of Lake Pontchartrain. Only 167 of these fish contained food. Fish, insects, vegetable matter, and unrecognizable organic material were each encountered in less than five percent of the stomachs. Crabs and penaeid shrimp, each appeared in about 30 percent of the stomachs, and palaemonid shrimp in about 10 percent, indicating a high percentage of crustaceans consumed in the brackish-water marshes.

In the present study crustaceans made up over half of the food material and included 24 percent shrimp (schizopods, juvenal penaeids, *Palaemonetes* sp., and *Macro brachium ohione)* and 28 percent crabs *(Callinectes sapidus* and *Rithropanopeus harrisii)* (Table 5) . Fishes constituted 35 percent of the stomach contents and included *Cynos-*

TABLE 5

Occurrence of food items in digestive tracts of 27 *Morone interrupta*

	130.0-195.0 mm.	
	27 examined 18 with food	
FOOD ITEMS	Percentage of tracts* containing item	Percentage of total stomach volume
Copepoda (Arguloid)	3.7	0.1
Mysid shrimp	18.5	18.2
Isopoda	7.4	0.3
Amphipoda	22.2	2.1
Palaemonid shrimp (undet.)	7.4	0.1
Palaemonetes sp.	3.7	4.8
Macrobrachium ohione	3.7	1.1
Crabs		
Rithropanopeus harrisii	22.2	18.0
Callinectes sapidus	18.5	9.7
Insecta (undet.)	3.7	
Diptera	7.4	
Odonata	3.7	0.1
Annelida	3.7	0.3
Hydroids	3.7	T
Sponge	7.4	
Vertebrata		
Cynoscion sp.	3.7	7.7
Cyprinodon variegatus	3.7	0.5
Gobiosoma bosci	3.7	4.8
Micropogon undulatus	3.7	1.1
Mollienesia latipinna	3.7	4.3
Fish remains	29.6	16.5
Algae-filamentous	3.7	0.1
Organic mat. (undet.)	63.0	6.8
Detritus	18.5	3.5
SUMMARY		
Microcrustacea		20.7
Macrocrustacea		33.7
Fishes		34.9
Miscellaneous, Undet.		10.8

* Stomach and intestine included.

cion sp., *Cyprinodon variegatus, Gobiosoma bosci, Micropogon undulatus, Mollienesia latipinna,* and other small forms. Undetermined organic material and detritus constituted 11 percent of the food volume, and incidental items included filamentous algae, sponge, hydroid, annelids, arguloid copepods, isopods, amphipods, and odonate and dipteran insects.

The above studies point to the fact that the yellow bass is a predatory species which in the brackish-water environment takes in a variety of shrimps, crabs, and fishes. The presence of bits of filamentous algae, sponge, and hydroid in the Lake Pontchartrain specimens indicates feeding near the bottom, either around the shallow margins of the lake or near the mouths of freshwater passes.

CENTRARCHIDAE

Micropterus s. salmoides (Lacépède). Northern Largemouth Bass

The food of the largemouth bass in freshwater environments has been extensively investigated, and since the literature has recently been reviewed in some detail by McLane (1948) it need not be reiterated here. In general, these works have shown that with increasing size there occurs a progressive change in the food of this species from microcrustaceans to insects to fishes, although crayfish and other arthropods may also form important portions of the adult diet.

McLane, himself *(op. cit.),* carried out a study of the seasonal food habits of the largemouth bass in St. Johns River of Florida where a number of estuarine species were available for consumption. He found that very young bass consumed large amounts of cladocera and other entomostraca. In slightly larger fish these items were replaced by schizopods. Bass belonging to larger size groups fed chiefly upon macrocrustacea *(Palaemonetes paludosa, Procambarus fallax,* and *Rithropanopeus harrisii)* and at least twenty-five species of fishes, many of which are also available in Lake Pontchartrain.

Lambou (1952) examined the stomachs of 93 largemouth bass *(ca.* 203-432 mm.) taken from the marshes bordering the northeastern shore of Lake Pontchartrain. Fifty-three of these bass contained food. Crabs were present in 56 percent of the stomachs, "shrimp" (presumably *Penaeus* spp.) appeared in 25 percent, "freshwater shrimp" (presumably *Macrobrachium ohione* and *Palaemonetes* sp.) and insects appeared in 7 percent each, and vegetable matter and undetermined material in 2 percent each. Thus, crabs and shrimp made up the bulk of the diet of the largemouth bass in the marshes, whereas fish and other materials were of much less importance.

Three specimens of the largemouth bass (175-209 mm.) from Lake Pontchartrain were examined in the present study, only two of which contained food. This material included a single grass shrimp *(Palaemonetes* sp.) and five small blue crabs *(Callinectes sapidus)* which together made up 97 percent of the stomach contents. Additional material included vegetation *(Vallisneria spiralis* and the filamentous green alga, *Cladophora* sp.), as well as small amounts of undetermined organic material and detritus. These studies together with those of McLane *(op. cit.)* and Lambou *(op. cit.)* demonstrate that when available a number of species of estuarine invertebrates and fishes are readily utilized by the largemouth bass.

CARANGIDAE

Caranx hippos (Linnaeus). Common Jackfish

Food habits of the common jackfish have been reported by Linton (1904), Hildebrand and Schroeder (1928), Knapp (1949), and Reid (1954). These authors have found this fish to be highly predatory consuming large quantities of fishes and crabs, as well as smaller percentages of squids, shrimp, and smaller invertebrates.

Only a single young specimen of the common jack (79 mm.) from Lake Pontchartrain was examined, and this contained one anchovy (Anchoa mitchilli diaphana) 30 mm. in length which constituted about 98 percent of the stomach contents. A small amount of undetermined matter also was present. Although only a few jacks were captured and only a single specimen was examined for food, many jacks were observed in the open waters of Lake Pontchartrain. These were generally presumed to be actively feeding at the surface upon small fishes, probably clupeids and engraulids.

SCIAENIDAE

Aplodinotus grunniens Rafinesque. Freshwater Drum

Studies on the food of the freshwater drum by Forbes (1878, 1880a, b), Forbes and Richardson (1920), Hildebrand and Towers (1927), Rimsky-Korsakoff (1930), Ewers (1934), and Dendy (1946) have indicated that in fresh waters this species normally passes through a series of ontogenetic food stages. Thus, the smallest individuals feed upon entomostracans. These are followed by aquatic insects, and the large drums feed chiefly upon clams and snails, supplemented by crayfish and other material. Dendy (1946) has pointed out that if insects and mollusks are essentially unavailable the drum may get along by abbreviating the insect-feeding stage and by replacing the mollusk-feeding stage with one dependent upon small fishes.

In the present study five specimens of the freshwater drum (211-347 mm.) from Lake Pontchartrain were examined, of which only four contained food. This material included 73 percent clams (Congeria leucopheata and Rangia cuneata), 11 percent mud crabs (Rithropanopeus harrisii), 10 percent undetermined organic material, and 6 percent amphipods. Additional items present in trace amounts included remains of blue crabs (Callinectes sapidus), gastropods, hydroids, and leaves and twigs of vascular plants. The food of this species appears to be quite similar to that of the young black drum.

Bairdiella chrysura (Lacépède). Silver Perch

Food habits of the silver perch have been studied by Linton (1904), Welsh and Breder (1923), Hildebrand and Schroeder (1928), Hildebrand and Cable (1930), Reid (1954), and Reid, Inglis, and Hoese (1956). These workers have shown that the chief food of the smallest silver perch is copepods supplemented by smaller amounts of ostracods, cladocera, schizopods, amphipods, and chaetopods. With increase in size there is greater emphasis upon annelids and larger crustaceans (schizopods, amphipods, isopods, small shrimp, and crabs) with occasional mollusks. Largest individuals have been reported to consume a few anchovies and other fishes, as well. These considerations led Hildebrand and Cable (op. cit.) to conclude that the silver perch feeds largely on the bottom and is strictly carnivorous.

The food of the silver perch from Lake Pontchartrain was made up of four primary types, each constituting roughly a quarter of the total stomach volume. These included schizopods, larger shrimp, fishes, and miscellaneous material (including smaller invertebrates and detritus) (Table 6) . Stomachs of the silver perch frequently were packed

TABLE 6

Occurrence of food items in digestive tracts of 41 *Bairdiella chrysura*

	70.0–143.0 mm.	
	41 examined 20 with food	
FOOD ITEMS	Percentage of tracts* containing item	Percentage of total stomach volume
Copepoda	4.8	
Mysid shrimp	14.6	24.3
Isopoda	7.3	8.3
Amphipoda	2.4	0.8
Palaemonid shrimp	7.3	19.8
Penaeid shrimp	12.2	6.1
Crabs		
Rithropanopeus harrisii	7.3	1.0
Callinectes sapidus	2.4	2.4
Vertebrata		
Anchoa mitchilli	7.3	12.1
Fish remains	12.2	12.3
Vascular plants	2.4	0.2
Organic mat. (undet.)	53.7	12.5
Sand	9.8	
SUMMARY		
Mysid shrimp		24.3
Palaemonid, Penaeid shrimp		25.9
Isopoda, Amphipoda		9.1
Crabs		3.4
Fishes		24.4
Incidental, Undet.		12.7

* Stomach and intestine included.

with schizopods, and one individual contained more than 100 of these small crustaceans. Larger shrimp included grass shrimp (chiefly Palaemonetes pugio) and considerable numbers of young penaeids. Fish food included mainly Anchoa mitchilli diaphana as well as unidentified remains, and one large silver perch had swallowed a 40 mm. anchovy. The miscellaneous material encountered in the stomachs included copepods, isopods (Aegathoa sp.) , and crabs (Callinectes sapidus and Rithropanopeus harrisii), as well as a small amount of vascular plant material and sand. Undetermined organic material made up 13 percent of the contents.

On the basis of present knowledge of the food of the silver perch, two general feeding stages may be recognized, an early copepod-feeding stage which is completed before a length of 50 mm. and a later schizopod-palaemonid-penaeid shrimp stage. In this second stage a great variety of other invertebrates as well as occasional fishes are consumed. Further work will undoubtedly result in the recognition of subdivisions of the shrimp-feeding stage of this voracious fish. In Lake Pontchartrain the food of the silver perch overlaps that of many other species and appears especially similar to that of young speckled trout (Cynoscion **nebulosus**) of comparable size.

Cynoscion arenarius Ginsburg. Sand Trout, Sand Squeteague

The food of the sand trout in Florida and Texas has been investigated by Reid (1954, 1955b, 1956) and by Reid, Inglis, and Hoese (1956) . These workers have indicated that trout less than 60 mm. subsist largely upon small crustaceans (copepods, larval and metamorphosing shrimp and crabs, and others) . Shrimp, although consumed to some extent by trout of all sizes, appeared to be an important element in the diet of the intermediate-sized trout. Fishes were found to be consumed by sand trout as small as 34 mm., and they were present in the stomachs of at least four-fifths of all trout over 80 mm. in length. Among the fishes consumed, the menhaden *(Brevoortia patronus)* was the most conspicuous, although other clupeids, anchovies, and young sciaenids were also noted. The presence of young sand trout indicated cannibalism. Miscellaneous items included crustacean and molluscan debris, as well as undetermined organic matter.

In the smallest sand trout (40-99 mm) from Lake Pontchartrain schizopods constituted almost one-third of the food volume, and traces of other small invertebrates included amphipods, palaemonid shrimp, and bits of crabs (Table 7 and Fig. 7) . These small invertebrates were almost entirely absent from the food of the larger size groups.

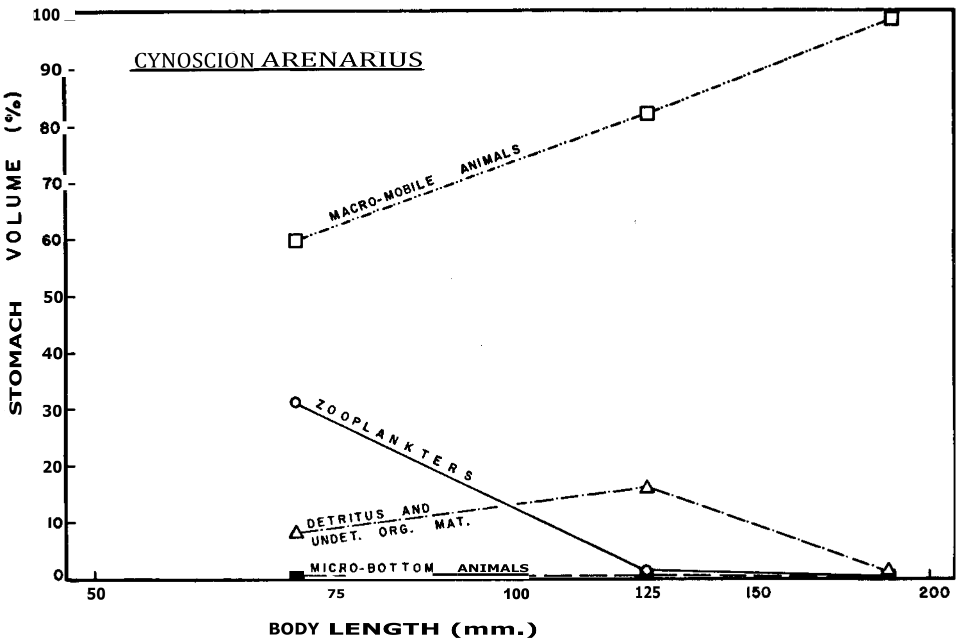
Fish remains constituted over one-half of the food of the smallest sand trout examined, and this material increased to over 90 percent of the stomach contents in the larger trout (150-225 mm.) . Fishes consumed included *Anchoa mitchilli diaphana* and the remains of other unidentified species, probably young clupeids. Penaeid shrimp made up 8 per-

TABLE 7

Occurrence of food items in digestive tracts of 64 *Cynoscion arenarius*

	40.0–99.0 mm.		100.0-149.0 mm.		150.0-225.0 mm.	
	22 examined 18 with food		29 examined 21 with food		13 examined 8 with food	
FOOD ITEMS	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume
Mysid shrimp	45.5	31.9	3.4	1.0		
Amphipoda	9.1	0.2				
Palaemonetes sp.	4.5	2.7				
Penaeus sp.					7.7	7.7
Crabs (undet.)	4.5	2.7				
Annelida			3.4	T		
Mollusca						
Rangia cuneata	4.5					
Gastropoda			3.4	0.4		
Hydroids			3.4			
Vertebrata						
Anchoa mitchilli	4.5	10.2	37.9	54.1	30.8	56.7
Fish remains	45.5	44.1	37.9	28.9	53.8	34.1
Algae-filamentous			3.4	0.1		
Organic mat. (undet.)	68.2	7.7	72.4	15.3	23.1	1.5
Detritus	40.9	0.4	6.9		15.4	
Sand			3.4	0.1		
SUMMARY						
Microcrustacea		32.1		1.0		0.0
Macrocrustacea		5.4		0.0		7.7
Fishes		54.3		83.0		90.8
Misc. and Undet.		8.1		15.9		1.5

* Stomach and intestine included.



Fic. 7. Ontogenetic food progression of *Cynoscion arenarius.*

cent of the food of the adults. Undetermined organic material and detritus constituted 8-15 percent of the food of sand trout less than 150 mm., although such material was scarcely represented in the food of the larger fish. Incidental items included traces of mollusk shells, annelids, hydroids, filamentous algae, and sand.

On the basis of the work of Reid *(op. cit.)* it appears that the youngest sand trout pass through a copepod-feeding stage. This is followed in Lake Pontchartrain by a schizopod-feeding stage which grades into the piscivorous adult, dependent chiefly upon the anchovy. This predatory fish is highly selective in its food habits and consumes surprisingly few incidental items. The virtual absence of sand and vascular plant remains from the stomach contents points to the fact that sandy bottoms and vegetation beds are probably not primary feeding sites.

Cynoscion nebulosus (Cuvier and Valenciennes).

Speckled Trout, Spotted Squeteague

The food habits of the speckled trout have received the attention of a number of workers. Linton (1904) found that 18 specimens had consumed chiefly fish and shrimp. Hildebrand and Schroeder (1928) concluded from examination of the stomachs of 20 individuals that small trout feed mainly upon crustaceans, whereas large trout consume primarily fish. Pearson (1929) examined the stomachs of 220 specimens (60-600 mm.) from Texas. His data indicate that shrimp and fishes were the predominant foods, and throughout the size range investigated shrimp appeared about twice as frequently as fishes. Species of fishes encountered included the young of *Leiostomus xanthurus, Micropogon undulatus,* and *Mugil* sp., as well as both young and adult of *Anchoa* sp. and *Menidia* sp. He also noted that "grass-dwelling" gobies were extensively consumed, and crabs were found in a few of the larger specimens.

Gunter (1945) reported on the analyses of 153 stomachs of adult speckled trout (275-555 mm.) from southern Texas, 93 of which contained food. Crustaceans including palaemonid shrimp (*Palaemonetes* sp.), penaeid shrimp (P. *setiferus* and either P. aztecus or P. duorarum), and the blue crab (Callinectes sapidus) were present in 3 to 20 stomachs each. Fishes, however, constituted the most important food material and included Mugil cephalus in 18 stomachs, and Menidia peninsulae, Cyprinodon v. *variegatus,* Brevoortia sp., Lagodon rhomboides, *Orthopristes* chrysopterus, and Lucania parva venusta, each occurring in 5 stomachs or less. Speckled trout were noted to consume fishes more than one-half their own body length. Knapp (1949) analyzed the stomach contents of 2,698 speckled trout from Texas. Of this number 70 percent had fed on shrimp, and over 33 percent on fishes, whereas squids, crabs, and other invertebrates were each present in less than 10 percent of the stomachs.

Moody (1950) conducted a detailed study of the food of the speckled trout at Cedar Key, Florida. Of the 954 stomachs analyzed only 511 contained food. Moody found that during its life history the speckled trout passes through four recognizable feeding stages, in which it specializes alternately upon copepods, caridean shrimp, penaeid shrimp, and fishes. Copepods, which were prominent in the diet of small trout up to about 30 mm., had almost completely disappeared by the 50 mm. stage. Schizopods formed an important supplement in the 20-70 mm. group. Caridean shrimp reached a peak in the 50-80 mm. group, constituting up to 80 percent of the stomach contents of this size group. The percentage of caridean shrimp declined gradually, and they were less frequent in the food of the adults. These shrimp included, in the order of abundance, *Hippolyte* sp., Angasia carolinense, *Periclimenes longicaudatus,* Palaemonetes pugio and Palaemonetes intermedius, Periclimenes ainericanus, and Palaemon floridanus, as well as an unidentified crangonid. Moody pointed out that a shift in food habits takes place around 150 mm., and that above this size the speckled trout assumes the diet of the adult, i.e. penaeid shrimp and fishes. Penaeid shrimp (P. duorarum) were most promiment in the food of the 150-300 mm. class, being replaced thereafter by fishes. Both young and adult trout were noted to consume quantities of fishes, and whereas Anchoa mitchilli was the principal fish food in size classes below 150 mm., Lagodon rhomboides was most important in the diet of larger individuals. Additional fish species encountered included Cynoscion nebulosus in the stomachs of 3 adults (indicating cannibalism), *Mollienesia* latipinna encountered twice, and *Mugil cephalus,* Menidia sp., Gobiosoma sp., Bairdiella chrysura, Chloroscombrus chrysurus, and a scombrid only once. Miscellaneous food items included sponge, shell, amphipods, stomatopods, portunid crabs, tunicates, and a wood fragment. Grass particles were present in 10 percent of the stomachs. On the basis of the above information Moody concluded that the speckled trout is a voracious feeder preferring live active food, a conclusion also reached by Eigenmann (1902) regarding the related species C. regalis.

In the smallest speckled trout (40-99 mm.) from Lake Pontchartrain small crustaceans made up 44 percent of the food material (Table 8 and Fig. 8). These included the more planktonic schizopods (20 percent), bottom-living isopods and amphipods (18 percent), and a lower percentage of palaemonid shrimp (6 percent). Small fishes made up almost one-half of the food of the young trout and included Anchoa *mitchilli* diaphana, undetermined larvae, and other fish remains. Undetermined organic material comprised eight percent of the stomach contents.

In all size groups above 100 mm. shrimp and fishes predominated, constituting over

TABLE 8

Occurrence of food items in digestive tracts of 66 *Cynoscion nebulosus*

FOOD ITEMS	40.0-99.0 mm. 10 examined 9 with food		100.0-149.0 mm. 17 examined 14 with food		150.0-199.0 mm. 10 examined 8 with food		200.0-406.0 mm. 29 examined 17 with food	
	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume
Copepoda (Arguloid)	10.0	T						
Mysid shrimp	50.0	19.9						
Isopoda	40.0	2.1	5.9	0.2				
Amphipoda	50.0	16.2			10.0			
Palaemonetes sp.	10.0	6.1			10.0	17.2	3.4	0.1
Penaeus sp.			11.8	14.2			6.9	4.9
Crabs			5.9	2.8			3.4	0.4
Insecta					10.0			
Hydroids			5.9					
Vertebrata								
Anchoa mitchilli	10.0	12.1	11.8	28.4	30.0	62.1	10.3	40.9
Micropogon undulatus			5.9	14.2	10.0	9.3	3.4	6.5
Fish larvae	10.0	12.1						
Fish remains	40.0	24.1	35.3	32.1	20.0	1.4	51.7	40.8
Algae-filamentous							3.4	0.8
Vascular plants			11.9	1.5	10.0	1.7	3.4	2.7
Seeds			5.9					
Organic mat. (undet.)	60.0	8.0	58.8	6.6	60.0	6.6	24.1	2.0
Detritus	30.0		11.9	T	50.0	1.7	20.7	0.8
Sand			11.9	0.3	10.0		6.9	0.3
SUMMARY								
Microcrustacea		38.2		0.2		0.0		0.0
Macrocrustacea		6.1		17.0		17.2		5.4
Fishes		48.3		74.7		72.8		88.2
Misc. and Undet.		8.0		8.4		10.0		6.6

• Stomach and intestine included.

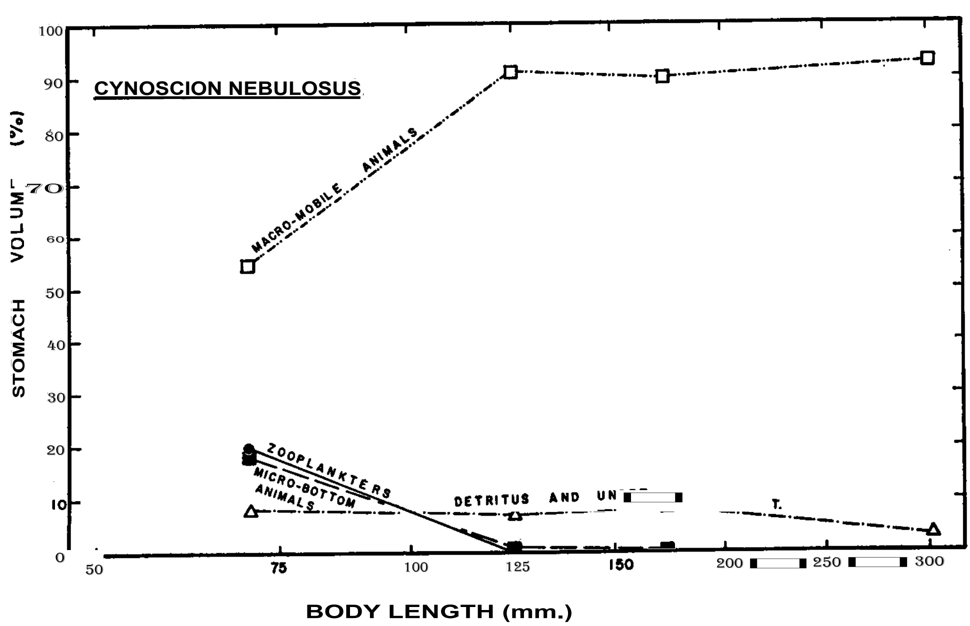


FIG. 8. Ontogenetic food progression of *Cynoscion nebulosus*.

90 percent of the food volume in the adults. Both palaemonid and penaeid shrimp were taken, and these shrimp together, made up one-sixth of the food of the 100-200 mm. individuals. The fish food of the adult trout included Anchoa mitchilli diaphana (30-60 percent), small Micropogon undulatus (7-14 percent) , and large quantities of unidentified fish remains (definitely clupeiform and probably Brevoortia patronus). Small amounts of vascular plant remains were uniformly present in the stomachs of the adults. Detritus and undetermined organic material made up only a small percentage of the stomach contents, and miscellaneous items included algae and seeds, as well as hydroids, crabs, and insects.

Although very small speckled trout (less than 40 mm.) were not included in the present study, the investigations of Moody (op. cit.) demonstrated that very young individuals subsist almost entirely upon copepods. In the Lake Pontchartrain specimens a schizopod-amphipod feeding stage was indicated in the 40-100 mm. size class and, perhaps, traces of a palaemonid-penaeid shrimp stage in the 100-200 mm. group. The predominant food of the subadult and adult speckled trout, however, was fishes. These entered the diet early, and they comprised one-half of the food the smaller trout (40-99 mm.) and three-quarters of the food of the adults.

Judging from the degree of fullness of the stomachs (Fig. 9), the speckled trout feeds heavily in the early to mid-morning hours and takes in little, if anything, during the afternoon. In this respect it apparently differs from the sand trout which feeds earlier in the morning and which appears to resume feeding in the mid-afternoon.

A number of authors including Pearson (1929), Moody (1950), Pew (1954), and Reid (1956) have discussed the habitat relations of the speckled trout in Florida and

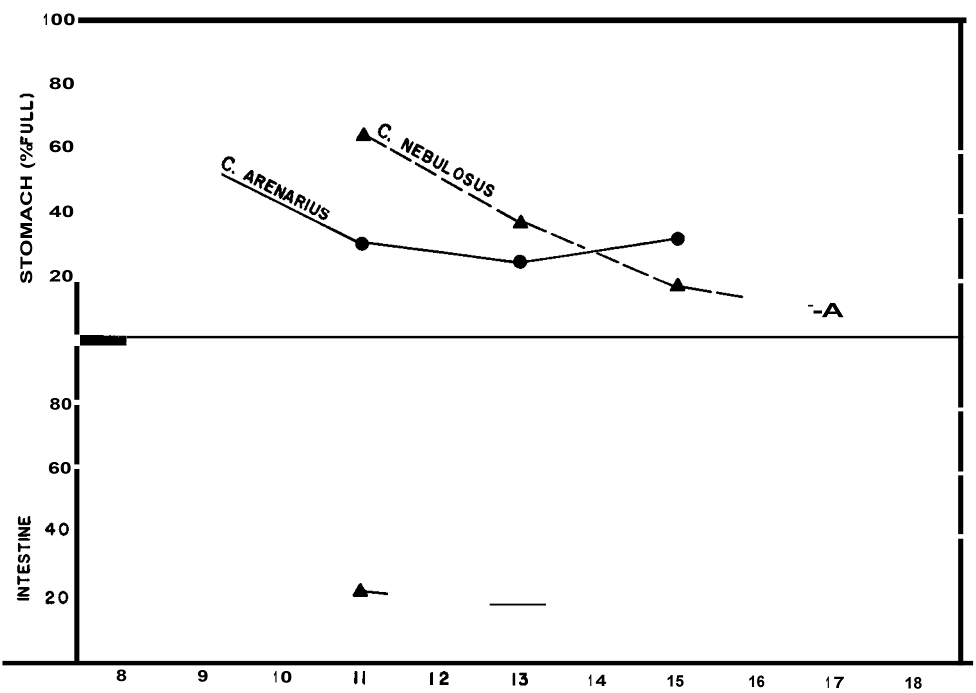


Fig. 9. Comparison of hourly patterns of percent-fullness of stomach and intestine of Cynoscion arenarius and C. *nebulosus*.

Texas, and they have generally agreed that the speckled trout is an inhabitant of clear waters with heavy grass bottom. These authors have pointed out that young trout seem to be critically associated with quiet shallow lagoons and coves possessing grassy flats where they consume great numbers of caridean shrimp. Adults, on the other hand, have been noted to remain in deeper water although frequently coming into the shallow grassy areas to feed upon shrimp and small fishes, especially the pinfish.

On a priori grounds, therefore, it might be assumed that the speckled trout would not regularly inhabit Lake Pontchartrain which is characterized by high turbidity and sparse grassy flats. In view of their presence in the lake, some deviation from the accepted patterns of food and habitat utilization by resident individuals is not at all surprising. In the virtual absence of weed beds caridean shrimp were essentially unavailable and were insignificant in the diet of the young trout. Likewise, as mentioned above. very few penaeid shrimp were taken. This may have been due in part to the relative absence from Lake Pontchartrain of the pink shrimp (P. duorarum) (see Darnell and Williams, 1956) , which is the staple penaeid for the Florida population, or to greater difficulty in locating and apprehending the mud-loving brown and white shrimp (P. aztecus and P. *setiferus*) which are abundant in the lake. Finally, in the virtual absence of weed beds, the adult trout of Lake Pontchartrain were not dependent upon the pinfish as in the case of the Florida trout. Instead, it appeared that the young Louisiana speckled trout partially substituted schizopods and bottom-living amphipods for the caridean shrimp and began to exploit at an early age the enormous populations of anchovies and larval fishes which inhabit the lake. In addition, the Louisiana population essentially bypassed the penaeid shrimp stage achieving the adult diet by a length of 100 mm. rather than 150 mm. as in the Florida population.

Actually, the food of the young and adult trout indicated that in Lake Pontchartrain, neither is critically associated with shallow grassy areas. The presence of such forms as *Palaemonetes* sp. and the tanaid (Leptochelia rapax) did indicate some association of the young with grassy shallows, but the presence of quantities of schizopods and bottom-living amphipods is taken as evidence of feeding outside of the shallow flats. Stomachs of adults also contained some Palaemonetes sp. as well as bits of grass. The anchovies, however, which constituted the bulk of the adult food, are ubiquitous in the lake, and neither these nor the young croakers and penaeid shrimp give much indication of feeding habitat. Positive evidence that adult speckled trout feed in the deeper areas stems from the centers of successful sport-fishing activity, aimed primarily at obtaining this species. Using shrimp or small croakers as bait, fishermen regularly obtain this trout by trolling in deeper waters and by still-fishing around the wooden pilings of the railroad bridge which crosses the eastern neck of the lake.

Gunter (1945) pointed out a relationship between the availability of shrimp and the utilization of these crustaceans as food by the speckled trout. He found shrimp to be the predominant food in Texas during the summer months and noted a shift from shrimp to fishes (Mugil sp.) when shrimp suddenly became scarce following a January freeze. In line with Gunter's observations, Mody (1950) demonstrated that in Florida during the spring and summer months fishes and crustaceans contributed about equally to the diet of the adult speckled trout, whereas during the winter months fishes were about three times as important as crustaceans. This did not occur, however, in the Lake Pontchartrain series. Although all speckled trout over 150 mm. which were analyzed for food were taken during the warm months (March-September), fishes greatly predominated in the diets. This again seems to point to the great availability of small fishes as opposed to penaeid shrimp in the muddy Louisiana waters.*

Leiostomus xanthurus Lacépède. Spot

The food of the spot has been reported by Linton (1904) , Smith (1907) , Welsh and Breder (1923) , Hildebrand and Schroeder (1928) , Hildebrand and Cable (1930), Gunter (1945), Roelofs (1954), and Reid (1954, 1955b) . These investigators have analyzed spots of different sizes from various parts of their geographical range and have accumulated a long list of food items. In general, the smallest spots have been found to feed upon planktonic or benthonic microcrustaceans including chiefly copepods, ostracods, and amphipods. Adults have been shown to be bottom feeders, specializing upon small mollusks, polychaetous annelids, and small crustaceans. Occasional items encountered in the stomachs of the spots have included foraminifera, nematodes, chironomid larvae, mysids, shrimp, mites, small crabs, sea urchin spines, bryozoa, small fishes and fish scales, diatoms and other algae, vegetable debris, "grass", seaweed, and sand. Quantities of detritus and undetermined organic matter have consistently been encountered in the stomachs of all sizes, but have been especially prominent in the food of the adults.

Among the spots examined from Lake Pontchartrain, the smallest individuals contained three percent rotifers and schizopods, and this material may represent the vestiges of an earlier plankton-straining stage. These forms were virtually absent in the larger-sized fish (Table 9 and Fig. 10) .

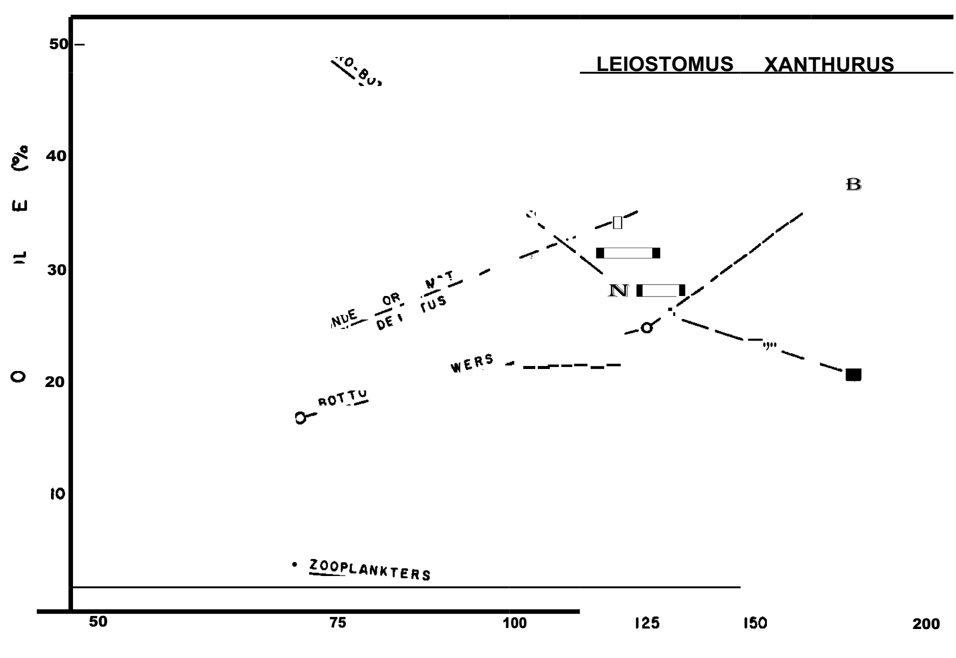


FIG. 10. Ontogenetic food progression of L[illegible].

* It appears to be a habit of the speckled trout to regurgitate the stomach contents at intervals following a meal. On such occasions a putrid mass of partially-digested fish appears on the surface surrounded by a small round oil slick. Commercial fishermen familiar with this habit frequently locate their quarry by the appearance and characteristic "fishy" odor of these oil spots. The low percentages of stomachs with food given in the literature undoubtedly reflect, in part, this phenomenon.

TABLE 9

Occurrence of food items in digestive tracts of 88 *Leiostomus xanthurus*

	40.0-99.0 mm.		100.0-149.0 mm.		150.0-203.0 mm.	
	22 examined 18 with food		38 examined 28 with food		28 examined 20 with food	
FOOD ITEMS	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume
Rotifera	9.1	2.0				
Ostracoda	40.9	13.2	15.8	0.6	3.6	0.3
Copepoda (undet.)	13.6	6.2	2.6		3.6	T
Harpacticoid	63.6	11.3	13.2	0.7		
Mysid shrimp	4.5	1.0	7.9	0.3		
Isopoda	31.8	7.6	44.7	9.0	35.7	11.8
Amphipoda	31.8	7.8	42.1	10.3	32.1	7.0
Cirripedia					3.6	
Insecta						
Coleoptera			13.2	0.5		
Diptera	22.7	1.3	44.7	1.3	50.0	9.0
Arachnida	4.5	1.0	2.6			
Annelida	4.5	2.0				
Mollusca						
Rangia cuneata	68.2	13.5	60.5	23.7	46.4	29.7
Mytilopsis leucopheata			2.6			
Gastropoda	50.0	4.0	31.6	5.5	30.0	1.9
Hydroids	4.5		2.6	0.1		
Foraminifera	27.3	0.5	7.9	0.1		
Vertebrata						
Fish remains			15.8	8.4	3.6	
Algae-filamentous	4.5		5.3		14.3	0.3
Vascular Plants	4.5		7.9	4.5	14.3	0.6
Organic mat. (undet.)	63.6	26.5	52.6	20.6	67.8	19.0
Detritus	68.2	0.5	47.4	6.7	35.7	19.2
Sand	31.8	1.5	39.5	8.4	10.7	0.6
SUMMARY						
Rotifera, Copepoda, Ostracoda, Mysid shrimp		33.7		1.6		0.3
Gastropoda, Foraminifera		4.5		5.6		1.9
Isopoda, Amphipoda		15.4		19.3		18.8
Rangia cuneata		13.5		23.7		29.7
Misc. Invertebrates, Vertebrates		4.3		10.3		9.0
Vegetation		0.0		4.5		0.9
Incidental, Undet.		28.5		35.7		38.8

* Stomach and intestine included.

A number of small invertebrates grouped together as micro-bottom surface animals, made up over one-half of the food volume of the smallest spots. These species declined somewhat in importance in the larger fish, and constituted only one-fifth of the food of the largest spots. Included among the micro-bottom surface animals were ostracods (in heavy concentrations), copepods (primarily harpacticoids), isopods, amphipods, minute gastropods, and foraminifera. All these species presumably could have been either scooped from the bottom surface or strained from the immediately overlying layer of water.

Another group of small invertebrates consumed in quantity by the spot included the bottom-burrowers, animals which could be obtained only by digging into the bottom surface material. These forms made up only 17 percent of the food of the smallest size group, but they increased in importance in the food of the larger spots and constituted 39 percent of the material consumed by the largest individuals. Included among the bottom-burrowers were large numbers of the clam (Rangia cuneata) and smaller quantities of chironomid larvae and annelids.

Undetermined organic material and detritus made up a considerable proportion of the food of spots of all sizes, and this material increased from 27 percent of the food volume in the smallest fish to 38 percent in the largest. The high percentage of this material in the diet of the spot is associated with the bottom habitat of the fish, and the increase in percent consumption of this matter by larger individuals parallels the increase in consumption of bottom-burrowers.

The stomach contents indicated that individuals occasionally specialize temporarily upon one food or another. A single stomach contained 250 harpacticoid copepods and five chironomids, another contained 200 amphipods, still another adult spot had 76 unbroken Rangia cuneata in its stomach. Most fishes, however, and especially those in the small and intermediate size categories, contained a variety of foods indicating more of a straining or sifting process than selective capture of individual animals.

Filamentous green algae including Cladophora sp., Rhizoclonium sp. and others, were encountered in one-tenth of the stomachs. Some vascular plant matter (probably *Vallisneria* spiralis) was found in the stomachs of eight individuals, one of which was packed with this material. The presence of this vegetation in the diet of the spot suggests some shallow water feeding. Most of the amphipods encountered were gammarids, but species of Corophium which were so abundant in the grassy shallows appeared to be entirely absent from the stomachs. Many of the invertebrate species which were abundant in the food of the spot appear to be inhabitants of the deeper waters indicating that this fish, in its feeding, utilizes such areas to a large extent. The presence of large quantities of detritus and the virtual absence of sand suggests that the species feeds largely on mud rather than on sandy bottoms. At least 6 species of minute gastropods were encountered, and the distributional patterns of these may eventually be employed to pinpoint the feeding ground of the spot.

The spot appears to consume a limited amount of material throughout the morning and early afternoon. An increase in feeding intensity apparent in the late afternoon points to the fact that this fish may feed primarily at twilight or during the night hours (Fig. 11).

Hildebrand and Cable (op. cit.) pointed out that the very young spots tend to swim in schools and that a number of changes take place when the fish reach a length of ap-

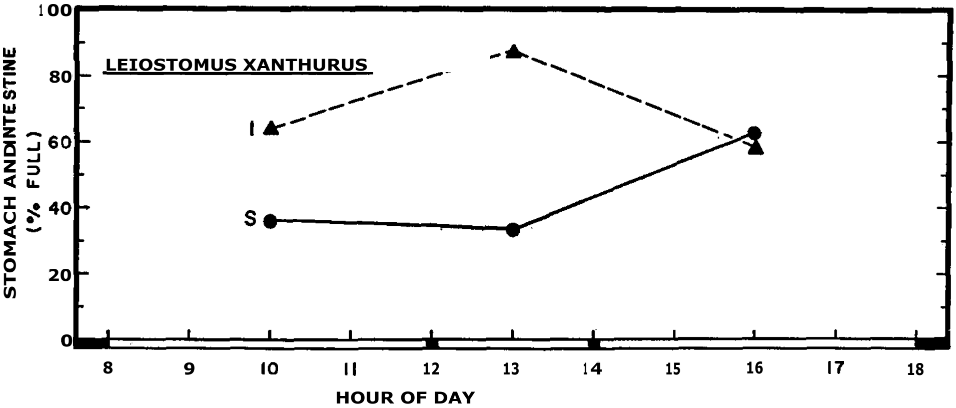


Fig. 11. Hourly pattern of percent-fullness of stomach and intestine of Leiostomus xanthurus.

proximately 25 mm. At about this size the schools break up, the oblique terminal mouth becomes inferior, and the food emphasis shifts from microcrustaceans to bottom material. Roelofs (1954) observed that in laboratory aquaria spots obtained food by making shallow dives to the bottom and scooping up mouthfuls of bottom material. Examining the gill structure of the spot he found that the alternating gill rakers and numerous fine setae comprise an excellent straining device for filtering small food particles from the water.

The accumulated evidence suggests that, as a rule, young spots feed just above the bottom. With increasing size they begin to feed more upon bottom surface animals, and as they approach maturity they dig more deeply into the bottom, taking a greater quantity of burrowing forms. Bottom detritus has been shown to be consumed in quantity by spots in North Carolina and Texas. In Lake Pontchartrain this material constitutes a substantial portion of the diet of spots of all stages, and it is particularly pronounced in the food of the larger, bottom-feeding stages. Temporary specialization upon one or another type of food has been reported, but most stomachs contain a wide variety of food items.

Micropogon undulatus (Linnaeus) . Atlantic Croaker

The food of the Atlantic croaker on the south Atlantic and Gulf coasts has been investigated by Linton (1904) , Smith (1907) , Welsh and Breder (1923) , Hildebrand and Schroeder (1928), Pearson (1929), Hildebrand and Cable (1930), Gunter (1945), McLane (1948), Roelofs (1954), Reid (1955b), and Reid, Inglis, and Hoese (1956). These workers succeeded in compiling an extensive list of food items recognized in the stomachs of croakers, which may be summarized as follows : mollusks (including pelecypods and gastropods) , annelids, small crustaceans (copepods, ostracods, barnacle larvae, and amphipods) , schizopods, mud shrimp, penaeid shrimp, crabs, bryozoans, sea urchin remains, hemichordates, tunicates, fishes (menhaden, threadfin shad, anchovies, small croakers, and gobies) , unidentified fish vertebrae, diatoms, and incidental sand. It was observed that small croakers feed largely upon planktonic crustaceans and small bottom invertebrates, whereas the adults consume larger invertebrates such as annelids, clams, shrimp, and crabs as well as small fishes. Several of the workers reported the presence of large quantities of indeterminable matter and organic debris, especially among the young and medium-sized croakers. However, due to the general complexity of the food habits of this species and to geographic and seasonal differences in availability of the various acceptable items, the food relations of the Atlantic croaker have not been clearly understood to date.

In view of the obvious ecological success of the croaker in Lake Pontchartrain as evidenced by its large populations, widespread distribution, and year-around habitation of the lake (see Suttkus, 1954), and because of its importance as a food and game fish in the area, it was given special attention. Zooplankton, including calanoid copepods and a few schizopods, made up almost 70 percent of the food of the smallest size class (Table 10 and Fig. 12) . This material decreased by about one-half in each succeeding size group, and in croakers of about 100 mm. zooplankton formed an insignificant portion of the diet. Clearly the food of the young croaker is the calanoid copepod (especially Arcartia tonsa), and whereas most stomachs contained less than 40 copepods, three small individuals contained more than 125 copepods apiece.

Small bottom-inhabiting animals comprised the chief food of the 25-50 mm. group.

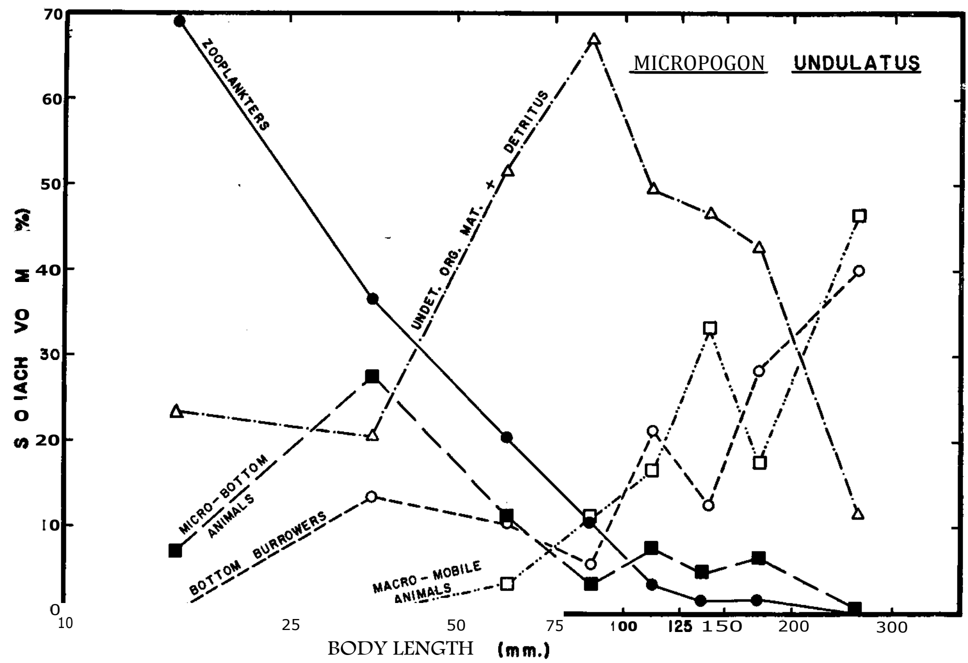


FIG. 12. Ontogenetic food progression of Micropogon undulatus.

These forms included both bottom-surface animals (harpacticoid copepods, amphipods, isopods, ostracods, minute snails, foraminiferans, and occasional coleopterans), as well as certain forms which have a greater tendency to burrow (chironomid larvae and small clams with attached mussels). Some of these bottom animals were present to a very limited extent in the smallest croakers, but they reached a peak of abundance (about 43 percent) in the 25-50 mm. size class and were present in reduced volume throughout all of the larger size groups. Occasionally the young, bottom-feeding croakers would specialize upon one form of food or another and contain up to 358 chironomids, or 10 mysids, or 46 amphipods. Most individuals in the intermediate size groups, however, exhibited a variety of food items, each present in small quantity as though general straining rather than selectivity were involved.

Detritus and undetermined organic material made up an important food category in croakers of all sizes, and this material was especially significant in croakers 50 to 200 mm. in length where it constituted over 40 percent of the stomach contents of each size group. In the 75-100 mm. group this material comprised over two-thirds of the food volume, and a decline in the utilization of this substance by the larger croakers was evident. No marked difference was noted between the detritus encountered in the stomachs of the croakers and that encountered in the stomachs of the spots. In both cases the material appeared to contain bits of shredded tissue, was sometimes flocculent in consistency, and was often greenish to dark brown in color. Furthermore, although much of the identifiable detritic material appeared to be of vegetable nature, it was generally impossible to distinguish between decomposed matter of animal and plant origin.

In the larger size groups the croaker was found to be a somewhat selective feeder, depending more upon the sorting or capture of larger discrete animals than upon filtra-

TABLE 10

Occurrence of food items in digestive tracts of 176 *Micropogon undulatus*

FOOD ITEMS	10.0-24.0 mm.		25.0-49.0 mm.		50.0-74.0 mm.		75.0-99.0 mm.		100.0-124.0 mm.		125.0-149.0 mm.		150.0-199.0 mm.		200.0-325.0 mm.	
	17 examined 15 with food		26 examined 26 with food		20 examined 20 with food		14 examined 10 with food		30 examined 28 with food		25 examined 24 with food		21 examined 18 with food		23 examined 19 with food	
	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume
Ostracoda			15.4	0.1	10.0	0.1			6.7		12.0	T	4.8			
Copepoda (undet.)			3.8						16.7	0.2						
Calanoid	82.3	52.3	69.2	24.4	35.0	4.5	7.1	0.1	6.7	0.1	4.0	0.1				
Harpacticoid	29.4	0.2	50.0	2.1	20.0	0.2			10.0	0.2						
Mysid shrimp	23.5	16.9	19.2	12.2	30.0	16.1	21.4	10.5	40.0	3.3	24.0	1.4	14.3	1.8	8.7	T
Isopoda	5.9	5.1	11.5	1.9	30.0	0.6	21.4	2.1	30.0	2.4	24.0	0.1	28.6	2.2		
Amphipoda	17.6	1.8	57.7	23.2	50.0	9.9	7.1	1.3	43.3	2.3	40.0	3.7	23.8	4.3		
Palaemonid shrimp									3.3	2.4	4.0		4.8			
Penaeus sp.													4.8	0.4		
Crabs (undet.)							21.4	1.8			4.0	0.2	14.3	1.7	8.7	4.2
Rithropanopeus harrisii									20.0	7.3	24.0	8.2	28.6	11.4	26.1	11.8
Callinectes sapidus									3.3	0.6	16.0	9.5			21.7	8.2
Insecta			3.8				7.1	0.3	20.0	0.4	4.0				4.3	
Coleoptera					5.0	0.2			23.3	2.5	32.0	1.0				
Diptera	5.9		50.0	15.1	65.0	9.8	50.0	1.5	56.7	5.8	56.0	11.6	19.0	2.5	13.0	0.2
Annelida									40.0	15.0	8.0	0.5	4.8	0.2	4.3	0.8
Mollusca																
Rangia cuneata			7.7		10.0	0.6	42.9	4.2	30.0	0.1	52.0	0.3	42.9	5.5	52.2	29.4

Mytilopsis leucopheata							7.1		3.3		12.0	0.3	19.0	20.3	39.1	9.7
Gastropoda					5.0	0.2							4.8		8.7	0.8
Hydroids											8.0				4.3	
Sponges									3.3	0.2						
Foraminifera	5.9	0.1	7.7	0.3												
Vertebrata																
Anchoa mitchilli											4.0	2.7	4.8	1.3	4.3	2.0
Cyprinodon variegatus									3.3	1.6						
Gambusia affinis									**3.3**	1.1						
Gobiosoma bosci							7.1	9.1			4.0	4.5				
Micropogon undulatus															4.3	9.2
Myrophis sp.															4.3	9.4
Syngnathus sp.											4.0	1.8	4.8	1.3		
Fish remains					5.0	3.3	14.2	T	13.3	3.5	12.0	6.5	14.3	1.5	4.3	1.4
Algae-Filamentous									3.3	0.2	8.0		9.5	0.4	13.0	0.2
Vascular plants									16.7	1.9	20.0	0.4	28.6	2.3	8.7	T
Eggs and Cysts	5.9	0.3	3.8													
Organic mat. (undet.)	58.8	23.2	61.5	16.3	80.0	43.3	85.7	40.5	83.3	35.1	88.0	41.9	71.4	36.0	52.2	8.9
Detritus	11.8		65.4	4.3	90.0	8.7	71.4	26.5	43.3	14.1	60.0	4.7	47.6	6.6	65.2	2.8
Sand			26.9	0.2	15.0	2.2	35.7	1.8			12.0	0.2	14.3		8.7	
SUMMARY																
Copepoda		52.5		26.5		4.7		0.1		0.5		0.1		0.0		0.0
Mysid shrimp		16.9		12.2		16.1		10.5		3.3		1.4		1.8		0.0
Isopoda, Amphipoda		6.9		25.1		10.5		3.4		4.7		3.8		6.5		0.0
Insecta		0.0		15.1		10.0		1.8		8.7		12.6		2.5		0.2
Mollusca		0.0		0.0		0.8		4.2		0.1		0.6		25.8		39.9
Fishes		0.0		0.0		3.3		9.1		6.2		15.5		4.1		22.0
Crabs, Shrimp		0.0		0.0		0.0		1.8		10.3		17.9		13.5		24.2
Miscellaneous		0.1		0.4		0.1		0.0		17.3		0.9		2.9		1.0
Incidental, undet.		23.5		20.8		54.2		68.8		49.2		46.8		42.6		12.9

* Stomach and intestine included.

tion of microscopic creatures or consumption of detritus. This trend of selectivity becomes progressively more noticeable above 100 mm., and in croakers above 200 mm. larger animals constituted over 85 percent of the total food volume. Among the animals consumed by adult croakers the following made up significant percentages in some size classes: annelids, up to 15 percent in one class, palaemonid and penaeid shrimp made up less than 3 percent in any of the adult classes, crabs (Callinectes sapidus and ***Rithropanopeus*** harrisii) up to 20 percent, mollusks (chiefly the clam, Rangia cuneata) up to 40 percent, and small fishes (including Anchoa mitchilli, Cyprinodon variegatus, ***Gambusia affinis, Gobiosoma*** bosci, young Micropogon undulatus, Myrophis sp., Syngnathus sp., and remains of other species) up to 22 percent. Undoubtedly, size is an important factor determining the utilization of a particular food item by the adult croaker, and even young croakers as large as 67 mm. are not free from predation by adults over 300 mm. in length. Miscellaneous items encountered in the stomachs of some croakers included sponge, hydroids, eggs and cysts, worm burrows, adult insects, filamentous algae (Cladophora sp.) , and sand.

On the basis of the above information it is clear that, whereas the croakers of Lake Pontchartrain consume a great variety of different food items, from young to adult they pass through a succession of four overlapping, but distinctly recognizable food stages. They specialize successively upon (1) zooplankton, (2) micro-bottom animals, (3) detritus, and (4) larger animals, the latter group including burrowers, crawlers, and swimmers.

As a rule, small croakers displayed only one or two types of food within a given stomach with little variation from one croaker to the next. Intermediate-sized individuals, however, feeding upon small bottom invertebrates exhibited a wide variety of foods within any given stomach, and differences between one individual and another were common. Adults, as a group, continued to display a varied diet, but since the food items consumed were individually much larger, the variety of items within a given stomach tended to decrease.

Study of the percent fullness of the stomachs and intestines reveals a clear picture of the daily pattern of feeding of the young and adult croakers (Fig. 13). In the young plankton-feeding and bottom-browsing individuals (11.5-74 mm.) feeding intensity is low during the early morning and increases to a peak by early afternoon which gradually tapers off toward evening. This may be related to a presumed vertical migratory pattern of the calanoid copepods which constitute a major element of the diet of these small croakers. Presumably, during the hottest and lightest portion of the day these copepods would be most concentrated near the bottom, and, therefore, most available as food for the young fishes. Intermediate-sized croakers (75-150 mm.) which feed upon detritus together with a general mixture of animals from the bottom water and bottom surface appeared to feed moderately throughout the day, increasing their feeding activity somewhat toward evening (the dip in the curve during the late afternoon appears to be an artifact resulting from small numbers in that particular time class) . Large adult croakers (150-325 mm.) exhibit two distinct feeding periods during the day. An early peak in mid-morning is followed by a period of low feeding intensity throughout the afternoon with some indications of increased feeding activity toward the evening. This bimodality may be associated with periodic availability of its molluscan, crustacean, and vertebrate food, with its own necessity of escaping mid-day predation, or with general physiological inactivity during the warmest and lightest portions of the day.

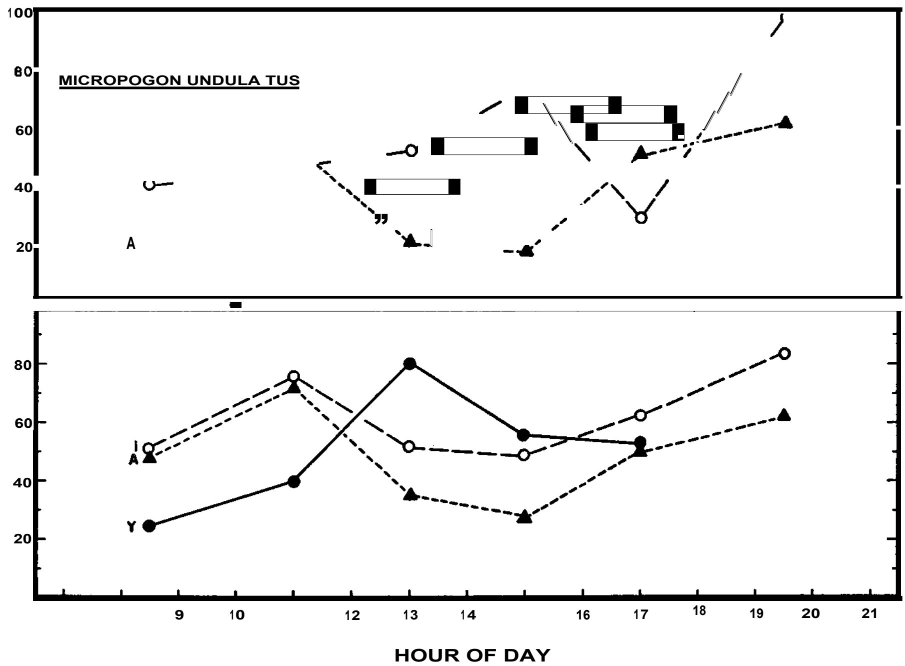


FIG. 13. Hourly pattern of percent-fullness of stomach and intestine of Micropogon undulatus (young, intermediate, and adult).

Studies to date suggest that the food of the croaker is roughly similar throughout its geographic range, but local differences in detail may be pointed out. Along the Atlantic coast polychaetous annelids are of considerable importance as food, and quantities of echinoderms and some ascidians and hemichordates are consumed in that area. Along the Gulf coast these items appear to be of less importance, whereas quantities of shrimp, fishes, and crabs are substituted. On the Atlantic coast the staple food mollusk of the adult croaker appears to be the razor clam, which is replaced in Lake Pontchartrain by Rangia cuneata and Congeria leucopheata, and in east Texas by Macoma mitchelli. Several investigators on the Atlantic coast have encountered quantities of debris or undeterminable organic matter in the stomachs of young and medium-sized croakers and have generally been inclined to consider such material as "incidental" or simply annelid or other large food digested beyond recognition. Reid (1955b) , working in Texas, appears to have been the first to point out that organic debris may constitute an important energy source for the croaker as well as for other species of sciaenid fishes. This point is reemphasized by the food contents from Louisiana specimens.

Regarding adaptations of the croaker for obtaining its food, Welsh and Breder (1923) noted that this fish possesses a flattened profile and sensitive, pendant mandibular barbels typical of bottom feeders. Roelofs (1954) reported that when feeding in laboratory aquaria, croakers dive into the bottom with some force, digging as they feed, and thus they are able to obtain subsurface animals for food. He also studied the gill rakers of this fish, pointing out that they tend to be short and stout with relatively few setae. Hence, the gill structure of the adult croaker forms a coarse basket rather than a fine straining mechanism and tends to retain only the larger particulate matter. This knowledge aids in understanding the food habits of the species and in explaining the observed differences between the food habits of the adult croaker and those of the adult spot. The croaker shovels more deeply while the spot scoops the surface; also, the latter retains what the former discards. As a matter of fact, although the adults of the two species appear not to be in keen competition for food, there does exist a great deal of overlap in the food of the intermediate-sized croaker and that of the adult spot.

Pogonias cromis (Linnaeus) . Black Drum

Smith (1907) mentioned that the black drum is a bottom feeder taking mainly crustaceans and various mollusks including oysters. Welsh and Breder (1923) agreed, emphasizing depredations of the black drum upon oyster beds. Reporting on the food of 117 black drums (80-990 mm.) from Texas, Pearson (1929) found that young individuals (80-200 mm.) feed a great deal upon what he termed "soft foods" (including fish and annelids) as well as upon crustaceans and mollusks. With increasing size the "soft foods" were dropped from the diet, and older drums were found to feed largely upon mollusks (74 percent) and crabs (16 percent). The mollusks included mainly *Mulinia transversa corbuloides* with some *Mytilus* sp. and *Ostrea* sp.

Gunter (1945) examined the stomach contents of 124 black drums (205 460 mm.) from southern Texas, only 96 of which contained recognizable material. He found that crustaceans, molluskc, and fishes were the most abundant foods. The crustaceans included large numbers of amphipods, as well as blue crabs, penaeid shrimp, palaemonid shrimp (*Palaemonetes sp.),* pistol shrimp (*Cargo* sp.) , and oyster crabs (*Panopeus* sp). The mollusks included small gastropods, and pelecypods (*Donax* sp. and razor clams) , and the only identifiable fish was the goby (*Gobiosoma bosci)* which appeared in the stomachs of at least 12 individuals and which numbered as high as 23 in a single stomach. Reid (1955b) examined seven young black drums from East Bay, Texas, and in the six which contained food he found masses of pelecypod shell debris.

Among the small drums examined from Lake Pontchartrain, mollusks made up over 65 percent of the food material, and mud crabs *(Rithropanopeus harrisii)* made up about 12 percent (Table 11). A few other small invertebrates were noted. While the quantity of detritus present in the stomachs was very small, more than one-fifth of the food consisted of organic material which was not positively identifiable. This material frequently took on the appearance of a milky sludge and was probably composed of the partially-digested bodies and mucus of the many pelecypods consumed. Among the three large black drums examined, the stomach of one was empty while the remaining two were about half full of the clam (*Rangia cuneata*). In addition to the above, a number of large black drums were examined qualitatively in the field. These generally contained only the remains of *Rangia cuneata,* supporting the conclusion that all sizes of black drum above 100 mm. in length are primarily dependent upon this clam as the staple food while in Lake Pontchartrain. Welsh and Breder (1923) pointed out that the black drum exhibits the flattened profile and mandibular barbels typical of bottom-feeding fishes. Pearson (1929) correlated the food with the environment in which the fish feeds. He noted that the pelecypod food of the black drum (in this case, the clam, *Mulinia)* lives in shallow muddy lagoons and bays, and that the black drum is most abundant where the water is always turbid, highly saline to brackish, shallow (4ft.), and characterized by temperature extremes. Reid (1955a) mentioned that this species, like the redfish, *Sciaenops ocellata,* has a characteristic habit of grazing in the salt marshes when these marshes are under water.

Commercial fishermen have pointed out to the writer that black drums frequently dig for mollusks in shallow water, and in so doing they literally stand on their heads waving the caudal fins aloft. Where the water is very shallow the caudal fins may clear the surface and be visible for some distance. This phenomenon of "flagging frequently enables the commercial fisherman to locate the black drum among the marshes and tidal flats of the Louisiana coast. Apparently the phenomenon of head-standing is not limited to shallow waters. Mr. Percy Viosca, Jr. (in personal conversation and correspondence) has indicated that while flying over Lake Pontchartrain on a still summer day he noted on the surface what appeared to be the result of large black drums feeding singly or in groups through the western sector of the lake. Digging and flagging, each drum created an upwelling of turbid water resembling smoke pouring from a chimney. These fish were undoubtedly digging for the clam, Rangia ***cuneata***, the only abundant large pelecypod in that area of the lake.

Indirect evidence indicates that the adult black drum can easily crush and discard the hard shells of adult rangia clams retaining only the soft bodies as food. In the field it was repeatedly observed that freshly-caught specimens with shell fragments in the buccal cavity contained only a milky mush in the stomach. Although a number of authors have noted shell fragments occurring in the stomach of this fish, such material appears to have been derived from small or more fragile mollusks.

It is generally accepted that the black drum is a bottom feeder, but details of the food habits of the species are still poorly known. Individuals less than 100 mm. have not been well investigated, and larger individuals have generally been lumped into a single group. On the basis of the existing knowledge of the food habits of the species two feeding stages are distinguishable, and from what is known of related sciaenids, a third may be postulated. The very young undoubtedly feed upon planktonic or bottom-dwelling mi-

TABLE 11

Occurrence of food items in digestive tracks of 24 *Pogonias cromis*

	116.0-218.0 mm.	
	24 examined 20 with food	
FOOD ITEMS	Percentage of **tracts*** containing item	Percentage of total stomach volume
Isopoda	8.3	0.4
Amphipoda	4.2	
Crabs		
Rithropanopeus harrisii	20.8	12.2
Insecta		
Dipter—larvae	16.7	0.1
Mollusca		
Rangia cuneata	75.0	55.5
Mytilopsis leucopheata	12.5	9.9
Gastropoda	20.8	0.1
Fish scales	4.2	
Algae—filamentous	4.2	
Organic mat. (undet.)	41.7	21.7
Detritus	41.7	T
Sand	12.5	
SUMMARY		
Crabs		12.2
Mollusks		65.5
Misc. Invertebrates		0.5
Organic mat. (undet.)		21.7

* Stomach and intestine included.

crocrustaceans. Following this stage, larger bottom invertebrates must enter the diet, individuals within the 100-200 mm. class being dependent primarily upon small mollusks, crustaceans, and "soft foods" (fish and annelids) . Larger individuals (over 500 mm.) subsist chiefly upon mollusks. In Lake Pontchartrain the primary food of the middle-sized as well as the adult black drums, appears to be the clam, *Ran gia cuneata.*

Sciaenops ocellata (Linnaeus) . Red Drum, Redfish

The food of the redfish on the Atlantic coast has been reported by Linton (1904) and Hildebrand and Schroeder (1928), and food habits of this species on the Gulf coast of Texas have received the attention of Pearson (1929), Gunter (1945), Knapp (1949), and Reid (1955b). The smallest redfishes examined (30 mm. and over) have been found to consume small crustaceans such as schizopods and amphipods. Food of the larger size groups has been found to include primarily penaeid shrimp *(P. aztecus* and *P. setiferus),* blue crabs *(Callinectes sapidus)* and fishes *(Brevoortia* sp., *Galeichthys felis, Anchoa mitchilli, Cyprinodon variegatus, Fundulus* sp., *Lucania parva, Mugil cephalus, Menidia* sp., *Syngnathus* sp., *Leiostomus xanthurus, Lagodon rhomboides, Symphurus plagiusa, Gobiosoma bosci,* and *Myrophis punctatus,* as well as a number of unidentified species). In addition, a variety of other organisms has been encountered in the stomachs of large redfish with less frequency. These include the following: bivalves, squids, annelids, crustaceans including grass shrimp *(P. vulgaris)*, mud crabs *(Neopanope t. texana,* and *Panopeus herbstii),* snapping shrimp *(Crago* sp.), mud shrimp *(Callianassa jamaicense louisiananum),* a large marsh rat, algae, and vascular plant matter.

Stomach contents of 17 redfish (184-625 mm.) from Lake Pontchartrain were examined. Among the 12 which contained recognizable food, crabs predominated and included both the blue crab *(Callinectes sapidus)* and the mud crab *(Rithropanopeus harrisii)* which together made up 62 percent of the food. Other important categories included fish remains (17 percent) and unidentified organic material (15 percent) . Vascular plants made up five percent of the stomach contents, and amphipods, palaemonid shrimp, and hydroids constituted less than one percent each. Within the above size range, large living invertebrates and fishes made up four-fifths of the material consumed by the redfish, and especially heavy predation upon blue crabs was indicated.

Available information indicates that young redfish subsist mainly upon a diet of small crustaceans including amphipods and schizopods, with larger individuals shifting to larger crustaceans and fishes. In inside waters, as pointed out by Gunter *(op. cit.)* and borne out in the Pontchartrain series, the principal food of the adult redfish is the blue crab, whereas in marine waters penaeid shrimp achieve greatest significance. In both habitats a wide variety of different invertebrates is utilized as supplementary food. As pointed out by Pearson *(op. cit.)* and Gunter *(op. cit.)* this predatory fish consumes both bottom-living and free-swimming forms, and the former author noted that in its feeding habits the redfish is intermediate between the bottom-feeding black drum and the pelagic predator, the speckled trout. It has been reported by Reid (1955a) that the redfish, like the black drum, frequently grazes in flooded salt marshes, a habit which appears to be of considerable significance in the ecology of the species in the marshy areas of southeastern Louisiana.

SPARIDAE

Archosargus oviceps Ginsburg. Gulf Sheepshead

In 1894 Brooks discussed the food of the sheepshead, and on the basis of personal observations concluded that although this fish browses among algae, its food is "exelusively animal", including barnacles and young oysters. Linton (1904) examined the stomach contents of two specimens and found crustaceans (including hermit crabs), sea urchin fragments, shells, and gorgonian spicules. Smith (1907) mentioned that the sheepshead feeds chiefly upon mollusks and crabs, a statement which was repeated by Hildebrand and Schroeder (1928) apparently without further verification. Gunter (1945), however, examined the food of 18 specimens (190–365 mm.) from southern Texas, and he found that in most individuals the long guts were distended with great quantities of plant material ("grass" and algae). Crabs (including Callinectes sapidus), gastropods, and unidentified shells were encountered in only a few individuals. Gunter concluded, therefore, that regardless of previous statements, the adult sheepshead is largely herbivorous. Gunter (1954) later reported observing the clumsy but successful attack by an adult sheepshead on a half grown blue crab swimming at the surface.

Viosca (1954) drawing upon years of personal experience indicated that in Louisiana the sheepshead feeds both upon "grass" in the beds of aquatic vegetation and upon small invertebrates inhabiting oyster reefs and other hard surfaces. As invertebrate food items, he listed sessile forms such as barnacles, mussels, small oysters, and hydroids, as well as small mobile species including crabs, shrimp, and snails. Reid, Inglis, and Hoese (1956) stated that four sheepshead (230–400 mm.) from East Bay, Texas had consumed crabs, pelecypods, and vegetable matter.

In the present study 11 specimens of the gulf sheepshead (218–410 mm.) from Lake Pontchartrain were analyzed, and all contained identifiable food. Vegetation was the most abundant material encountered and included filamentous algae (*Cladophora* sp.) together with vascular plants (V allisneria spiralis and Ruppia maritima) which constituted over 54 percent of the stomach volume. Invertebrates included mussels (Congeria leucopheata and Mytilus recurvus) 19 percent, clams (Rangia cuneata) 8 percent, sponge (Spongilla 1. lacustris) 10 percent, and mud crabs (Rithropanopeus harrisii) 1.5 percent. Young croakers and remains of other small fishes constituted three percent of the food, and blue crabs (Callinectes sapidus), amphipods, isopods, barnacles (Balanus spp.), small gastropods, and hydroids made up less than one percent each. A small quantity of undetermined organic material also was present.

The food of young sheepshead apparently has not been investigated. Larger individuals employ the well-formed, incisor-like teeth for cropping vegetation, for picking up small active invertebrates, and for scraping sessile animals from hard surfaces. The sheepshead's habit of nibbling the invertebrate epifauna from vertical posts and pilings appears to be widely recognized among sport fishermen of the Gulf area. Individuals collected from inshore shallows such as Lake Pontchartrain and the bays of southern Texas were found to have fed chiefly upon vegetation. This species is further remarkable in its occasional utilization of sponge as food.

Lagodon rhomboides (Linnaeus). Pinfish

Linton (1904) and Smith (1907) mentioned that the food of the pinfish is quite varied, including primarily mollusks, worms, crustaceans (amphipods and small shrimps and crabs), small fishes, and vegetation ("sea weed", "sea lettuce", and "vegetable detritus"). A variety of other animal remains also was present. Hildebrand and Schroeder (1928) found that the food of 13 specimens included (in decreasing order of abundance) vegetable debris, crustaceans, mollusks, and annelids. Gunter (1945) reported the food of eight large pinfish (150–285 mm.) from Texas. One fish had consumed razor clams, and the remaining individuals all contained plant material including algae and "grass". Because of the stomach contents and the presence of large, incisor-like teeth, the pinfish was regarded by Gunter as being a "grazer". Reid (1954) provided information on the food of 65 young pinfish (15-128 mm.) from Florida. His data indicate that the smallest fish (15-50 mm.) fed most frequently upon copepods, amphipods, and shrimp. The next larger size group (51-100 mm.) contained (in decreasing order of occurrence) copepods, shrimp, organic detritus and mud, amphipods, mollusks, crabs, fishes, and plant detritus. The largest pinfish group (101-128 mm.) contained only copepods, amphipods, shrimps, and mollusks, each occurring in 18-25 percent of the stomachs. Although dealing primarily with smaller individuals, Reid's study seems to suggest that if invertebrates are sufficiently abundant, less vegetation is consumed by the pinfish.

In the Lake Pontchartrain study micro-bottom animals constituted the principal food of the two smallest size classes (40-64 mm. and 65-74 mm.), making up from 60 to 80 percent of the ingested material in each class (Table 12 and Fig. 14).

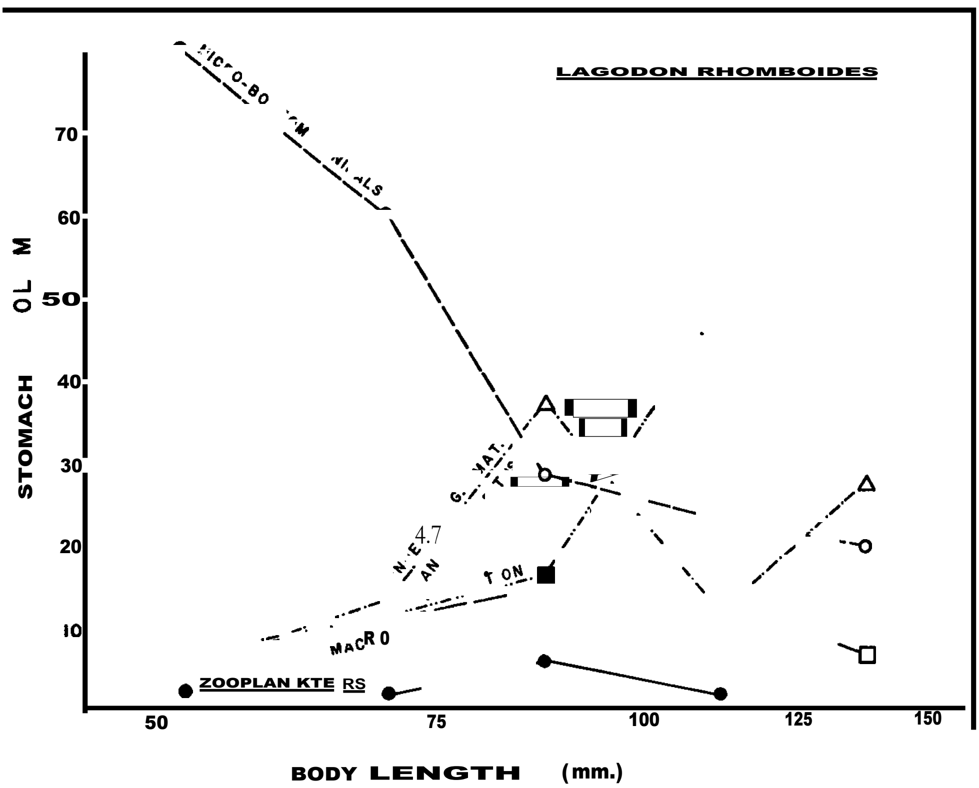


FIG. 14. Ontogenetic food progression of *Lagodon rhomboides.*

Bottom amphipods (including *Corophium* spp., *Cerapus* sp., and various grammarids) made up the bulk of this material. Also included were bottom sopepods, isopods, and dipteran (chironomid) larvae and pupae. Although larger pinfish concentrated primarily upon other food materials, micro-bottom animals continued to be consumed, and these forms made up 20-30 percent of the food volume in each of the upper size classes.

Pinfishes of all sizes consumed some vegetation. In the 40-64 mm. group this ma-

TABLE 12

Occurrence of food items in digestive tracts of 101 *Lagodon rhomboides*

FOOD ITEMS	40.0-64.0 mm.		65.0-74.0 mm.		75.0-99.0 mm.		100.0-124.0 mm.		125.0-150.0 mm.	
	20 examined 20 with food		21 examined 21 with food		25 examined 24 with food		20 examined 19 with food		15 examined 15 with food	
	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume
Ostracoda							5.0			
Copepoda (undet.)			4.8	0.1	4.0	0.2				
Arguloid	5.0	0.3	4.8	0.3						
Calanoid			4.8	0.3			5.0			
Harpacticoid	10.0	0.1	4.8	0.1			20.0	1.6	33.3	2.0
Mysid shrimp	5.0	2.4	19.0	1.6	28.0	5.8	10.0	1.8	13.3	0.6
Isopoda	25.0	0.3	42.9	2.2	48.0	2.7	40.0	2.8	60.0	3.2
Amphipoda	90.0	64.5	81.0	47.6	60.0	24.3	45.0	17.7	40.0	13.0
Palaemonetes sp.							5.0	3.4		
Macrobrachium ohione	5.0	4.1								
Crabs (undet.)			4.8	2.8	4.0		10.0	1.4		
Rithropanopeus harrisii	5.0	2.4	9.5	2.5	20.0	10.5	20.0	8.6	26.7	6.4
Callinectes sapidus			9.5	0.3						
Insecta (Diptera)	50.0	12.0	33.3	10.6	20.0	0.5	15.0	0.3	20.0	0.9
Annelida	10.0	2.7	4.8	0.1	8.0	1.9	10.0	0.9		
Mollusca										
Rangia cuneata					8.0					
Mytilopsis leucopheata					4.0				6.7	0.5
Gastropoda					4.0					
Hydroids					16.0	1.1				
Vertebrata										
Gobiosoma bosci			4.8	5.7					6.7	
Fish remains	10.0		23.8	3.3	40.0	5.8	10.0			
Bottom Diatoms	5.0	0.1					10.0	0.1	6.7	0.2
Algae-filamentous	15.0	5.8	14.3	11.2	28.0	14.1	70.0	40.3	66.7	34.5
Vascular plants			4.8	0.2	16.0	2.3	40.0	8.0	53.3	11.1
Organic mat. (undet.)	80.0	2.8	90.5	6.9	84.0	20.0	40.0	7.8	40.0	18.9
Detritus	25.0	2.7	47.6	3.3	60.0	10.1	45.0	4.0	40.0	8.5
Sand	10.0		9.5		32.0	0.6	45.0	1.3	13.3	0.1
SUMMARY										
Microcrustacea (excl. Amphipoda)		3.1		4.6		8.7		6.2		5.8
Amphipoda		64.5		47.6		24.3		17.7		13.0
Diptera		12.0		10.6		0.5		0.3		0.9
Macrocrustacea		6.5		5.6		10.5		13.4		6.4
Fishes		0.0		9.0		5.8		0.0		0.0
Vegetation		5.8		11.4		16.4		48.3		45.6
Misc. Invertebrates		2.7		0.1		3.0		0.9		0.5
Incidental and Undet.		5.6		10.2		30.7		13.2		27.7

* Stomach and intestine included.

terial made up 6 percent of the food volume, and it increased thereafter so that in both groups over 100 mm., vegetation constituted almost half of the total food volume. Most of this vegetation was composed of filamentous green algae, especially *Cladophora* sp., although species of *Oedogonium, Rhizoclonium,* and *Spirogyra* were also represented. Vascular plants were of significance only in the two larger size classes where they constituted about 10 percent of the food volume. These included *Vallisneria spiralis* and probably also *Ruppia maritima.* There is no question of the algae being an "incidental" item in the food of this fish, although small invertebrates were frequently found entangled in the balls of filamentous algae.

A few zooplankters, including schizopods and planktonic copepods, were represented in the food of each size class. This material appeared in greatest abundance in the food of the intermediate-sized fish and dropped to less than one percent in the largest size class. Pinfish of all sizes also consumed some macro-mobile animals including crabs (*Callinectes sapidus* and *Rithropanopeus harrisii),* shrimp (*Palaemonetes* sp. and *Macrobrachium ohione),* and fishes (*Gobiosoma bosci* and others) . Contrary to expectations, the macro-mobile animals achieved their most important food status in the intermediate size groups, and adult pinfish appeared to consume somewhat less of this material. Undetermined organic material and detritus seemed to be of little importance in the food of the smaller pinfish. This material, however, made up more than one-third of the food volume in the intermediate size group, decreasing somewhat in the larger individuals.

The Pontchartrain data indicate that small pinfish (50-75 mm.) consume primarily micro-bottom animals. In large pinfish (above 100 mm.) the primary food is filamentous algae. During the transition stage (75-100 mm.) there seems to be no specialization, and as though the fish were having difficulty obtaining enough to eat, increased volumes of detritus and decaying organic material were taken in. Zooplankton and macro-mobile animals were included to some extent in the food of all size classes.

The pinfish is a very selective feeder, and the number of different types of food items per stomach is generally small. With increasing size there does occur, however, a noticeable increase in the average number of identifiable types of food per stomach, from an average of 2.1 in the smallest size group to 3.1 in the largest. This increase is associated with the fact that small invertebrates often accompany the ingested filamentous algae. As indicated by Figure 15, both young and adult pinfish are daytime feedv's, beginning in the morning and continuing to feed throughout the afternoon.

Gunter (1945) and Reid (1954, 1955b) have remarked on the association of the pinfish with beds of aquatic vegetation, and they have explained the relative scarcity of the species from the Gulf beaches of northern and southern Texas on the basis of sparsity or absence of aquatic vegetation in the area. The same association undoubtedly holds true in southeastern Louisiana since, as mentioned earlier, the vegetation is of significance directly as food for the adults, and indirectly as a source of small invertebrates which are consumed by both the young and adults. The distribution of their food items in Lake Pontchartrain suggests further that whereas adult pinfish must browse among the vegetation of the limited grassy shallows, the young probably feed on the bottom in much the same habitat.

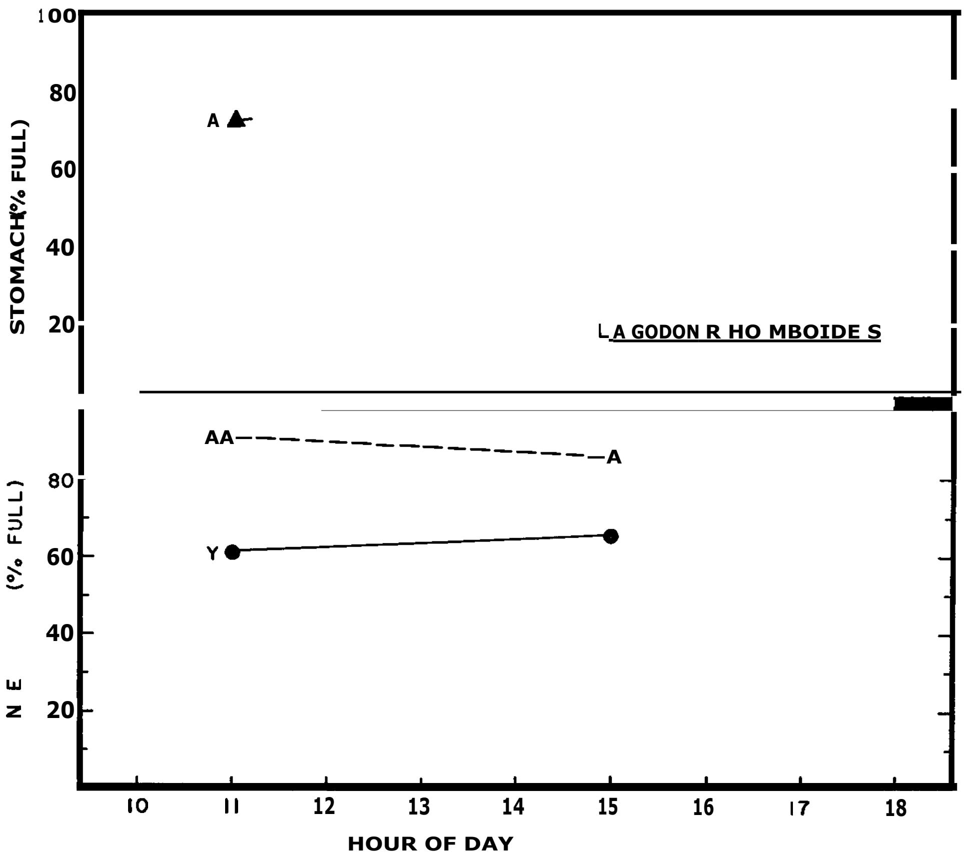


FIG. 15. Hourly pattern of percent-fullness of stomach and intestine of Lagodon rhomboides (young and adult).

Like its relative, the sheepshead, the pinfish exhibits a row of incisor-like teeth which are employed for grazing upon vegetation, picking up small invertebrates, and, perhaps, scraping invertebrate epifauna from solid surfaces. Size differences seem to preclude much overlap in food requirements of the adults of the two species. Competition of adult pinfish with young sheepshead appears to be avoided largely by differences in habitat utilization.

BOTHIDAE

Paralichthys lethostigma Jordan and Gilbert. Southern Flounder

Gunter (1945) reported the examination of 16 large flounders (240-490 mm.) from southern Texas, eight of which contained food. Seven had consumed fishes including mullet, anchovies (Anchoa mitchilli diaphana), pinfish (Lagodon rhomboides), mojarra, and other unidentified species. In addition, three flounders contained penaeid shrimp (P. aztecus and P. *setiferus*) and a stone crab. McLane (1948) mentioned that in the St. Johns River of Florida, the southern flounder consumes large numbers of the locally abundant shad, Signal osa petenensis vanhyningi. Knapp (1949) examined 24 specimens from Texas and found that fishes, including the menhaden, were present in over 40 percent of the stomachs, shrimp were present in 50 percent, and miscellaneous invertebrates occurred in less than five percent. In northern Texas, Reid (1955b) examined the stomachs of seven specimens (159-265 mm.) and found fish in three of the stomachs while shrimp occurred only once.

A total of 19 specimens (113-380 mm.) from Lake Pontchartrain were examined, of which only 14 contained recognizable food. Fishes constituted 89 percent of the total food volume and included anchovies (Anchoa mitchilli diaphana) (41 percent), small croakers, (Micropogon undulatus) (2 percent), and a large quantity of unidentifiable fish remains (46 percent). Crabs made up about seven percent of the food and included Callinectes sapidus as well as Rithropanopeus harrisii. Schizopods, clams (Rangia cuneata), small gastropods, and undetermined organic material made up less than two percent each.

The above studies indicate that adult southern flounders are highly predaceous consuming large quantities of small fishes and smaller amounts of crabs and shrimp, which they apparently attack either upon or near the bottom. The relative percentages of fishes and shrimp utilized, however, appears to vary from one environment to another and may be related to availability. Young flounders probably prey upon small bottom invertebrates.

SOLEIDAE

Trinectes maculatus *fasciatus* (Lacépède). Hogchoker

Hildebrand and Schroeder (1928) examined the stomachs of 17 hogchokers from Chesapeake Bay and concluded that the species feeds primarily upon annelids supplemented by occasional small crustaceans and strands of algae. Reid (1954) mentioned that all stomachs which he inspected were devoid of food, although they usually contained quantities of sand.

Ten hogchokers (61-74 mm.) from Lake Pontchartrain were examined, but the stomachs of only three contained recognizable food. Amphipods of the genus Corophium were present in all three stomachs and made up about 50 percent of the contents. Undetermined organic matter and detritus comprised the remainder. Examination of the intestinal contents revealed that the hogchokers had also consumed other microcrustaceans, dipteran (chironomid) larvae, foraminifera, and seeds. Although quite meager, the above data suggest that the hogchoker subsists largely upon a diet of small bottom-living invertebrates supplemented by quantities of organic detritus and other materials which it gleans from the surface of the bottom.

INVERTEBRATES

MACTRIDAE

Rangia cuneata Gray. Common Rangia, Clam

Three specimens of the common rangia (35-38 mm.) from Lake Pontchartrain were examined, and all of the stomachs contained food. Unidentifiable detritus made up about 70 percent of this material, and sand constituted 10 percent. Enormous numbers of small, regular, round bodies were observed in two of the clams, and these made up an estimated 17 percent of the total food volume. These bodies, which were barely distinguishable at 1000x magnification, were assumed to be minute protozoans or individual cells derived from disintegrated colonies of blue green algae (Anabaena spp. or *Microcystis* spp.). Additional material present in trace amounts included eggs (or cysts), a variety of bottom diatoms, foraminifera, and bits of vascular plant material.

In Lake Pontchartrain the common rangia is most abundant on the muddiest bottoms in waters of maximum turbidity. As indicated by the above analyses and by observations in laboratory aquaria, the species is a typical "filter feeder", and in view of the high percentage of detritus ingested a simple straining action with very little selectivity is suggested.

Penaeus setiferus (Linnaeus) . White Shrimp

Williams (1955) reported on stomach analyses of 184 young and adult penaeid shrimp from the estuaries of North Carolina. He found that the stomachs were generally filled in the summer and fall, but were nearly always empty in winter. Williams listed the most abundant food materials as follows (in order of decreasing frequency of occurrence), unrecognizable debris (probably a mixture of digesting tissue and organic deposit from the bottom) , chitin fragments (from crustaceans), setae (probably from annelids), worm jaws (annelid), plant fragments, and sand. Other materials occurring in smaller quantities included foraminifera, minute gastropods and lamellibranch shells, squid suckers, complete small fishes, fish parts (scales, muscle fibers, remains of gut, mandible, ribs, eye lens) , eggs, seed pods, and other materials. Williams emphasized that most of the remains which he encountered were either large or very hard, in either case, materials which would not readily pass through the straining apparatus of the pyloric stomach. Since such materials might accumulate over a period of time, he suggested that unrecognized, softer, more digestable matter could easily form the bulk of the shrimp diet.

Flint (1956) studied the food of penaeid shrimp from Grande Isle, Louisiana and Biloxi, Mississippi (localities verified by personal correspondence). Small shrimp *(ca.* 10 mm.) contained chiefly cropped filaments of blue green algae and such diatoms as ordinarily would have been found adherent to them in the natural habitat. Adult shrimp, however, were found to have consumed large quantities of bryozoans, some algae, and a few small pieces of sponge and coral. The algae included primarily lithophytic diatoms which may have been taken in incidentally, adherent to other materials. A few fragments of roots and stems of vascular plants and bits of sawdust also were encountered. Flint noted that partial or complete digestion of the algal protoplasts had taken place. He concluded that in the turbid coastal waters (of Mississippi and Louisiana), blue green algae which thrive in low light intensities probably serve as a major food for both young and adult shrimp, although the latter consume a diversity of materials among which bryozoans, lithophytic algae, and diatoms appear to be outstanding.

In the present study the stomach contents of ten white shrimp (91-142 mm.) were examined, all of which contained food. Detritus and ground organic matter made up 58 percent of this material. Mollusks, comprising 12 percent included many minute clames *(Rangia cuneata)* and a few small gastropods. Microcrustacea made up less than four percent of the stomach contents and included ostracods and harpacticoid copepods. Insect remains were evidenced by traces of dipteran and coleopteran larvae. Numbers of foraminiferans were present in six of the stomachs, and traces of vascular plants were noted twice. In addition to the above materials, all shrimp contained quantities of sand.

Pearson (1939) successfully reared post-larval white shrimp (5-35 mm.) in laboratory aquaria. He found that green algae were consumed in quantity, but alone this material seemed insufficient to satisfy the hunger of the young shrimp. When placed in aquaria containing a shallow layer of estuarine bottom deposits of sand and organic debris, however, the young shrimp fed well and thrived on this material. At a length of about 15 mm. other food was introduced such as raw fish, angleworms, and shrimp meal which also were taken readily as food. More recently, Johnson and Fielding (1956) reported success in rearing adult white shrimp on a diet of fish meal and also upon fresh fish. In special growth experiments shrimp were found to consume as much as 10 percent of their body weight of fresh fish per day.

The accumulated evidence suggests that, whereas both young and adult white shrimp are omnivorous, they feed largely upon organic detritus of the estuarine bottom. This substance is supplemented with more concentrated food material of animal and vegetable origins, both fresh and decaying, from a great variety of immediate sources. In Lake Pontchartrain large concentrations of white shrimp were sometimes observed feeding in shallow mud flats on hot summer days, especially in the rich deltaic deposit areas of tidal streams which drain the north shore marshes. Much feeding must also take place in deeper waters since shrimp captured a mile or more from shore generally exhibited full stomachs.

PALAEMONIDAE

Macrobrachium ohione (Smith). River Shrimp

Ten specimens of the river shrimp (48-81 mm.) from Lake Pontchartrain were examined, and all contained food material. Finely-ground detritus and bits of organic material made up over one-half of the diet, and sand constituted almost 20 percent of the stomach contents. Of the remaining identifiable material, clams *(Rangia cuneata)* made up the highest percentage. These were frequently broken, although the stomach of one river shrimp contained a total of 33, mostly unbroken clams, the largest of which measured 1.5 mm. Miscellaneous items included ostracods, bits of arthropod integument, minute gastropods, hydroid "stems", sponge spicules, tintinnids, foraminiferans, filamentous algae *(Cladophora* sp.) , diatoms (species of *Cymbella, Navicula,* and *Pinnularia),* eggs and cysts, and remains of vascular plants. Three of the river shrimp contained fish remains including eye lenses, vertebrae, ribs, otoliths, scales, and macerated fibers which appeared to be muscle tissue. Several individuals contained quantities of minute round bodies similar to those encountered in stomachs of *Rangia cuneata* (mentioned earlier).

These analyses indicate that the river shrimp is a general bottom scavenger feeding upon bits of animal and vegetable material which it sifts from the bottom surface material. The bottom detritus itself forms a significant portion, if not the bulk, of the diet of this species. The nature of the stomach contents further suggests that the river shrimp and the white shrimp were for the most part feeding on different types of bottoms.

PORTUNIDAE

Callinectes sapidus Rathbun. Blue Crab

In his discussion of the life history of the blue crab, Hay (1904) considered the food and the feeding habits of the species. He noted that in shallow back-waters the blue crab often stalks and consumes small fishes and that occasionally it nibbles at tender shoots of eel grass and other aquatic vegetation. He considered the "favorite" food of the blue crab, however, to be decaying flesh and other putrid matter and noted that large numbers of crabs were attracted to the offal from stables and water closets overhanging the water. Hay also indicated that injured crabs, small crabs, and soft crabs are sometimes eaten by stronger individuals, and he concluded that while the blue crab consumes a variety of foods, it is preeminantly a scavenger and a cannibal.

In the Lake Pontchartrain study a great variety of materials was encountered in the stomachs of all sizes of crabs, although food differences between young and adults were not pronounced (Table 13 and Fig. 6). Crustacean remains constituted the most abundant material in the stomachs of small individuals, making up over one-third of the food in the 30-74 mm. group. This material decreased to 10 percent of the food volume in the largest individuals. Included in this material were the remains of both the blue crab *(Callinectes sapidus)* and the mud crab *(Rithropanopeus* harrisii), as well as unidentified pieces of crustacean exoskeletons. Greatest utilization of the mud crabs occurred in the 75-124 mm. class where they made up 16 percent of the food volume, and small blue crabs achieved a maximum of 13 percent in

TABLE 13

Occurrence of food items in stomachs of 124 *Callinectes sapidus*

	30.0-74.0 mm.		75.0-124.0 mm.		125.0-147.0 mm.		148.0-197.0 min.	
	29 examined 24 with food		31 examined 27 with food		24 examined 23 with food		40 examined 29 with food	
FOOD ITEMS	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume	Percentage of tracts° containing item	Percentage of total stomach volume	Percentage of tracts* containing item	Percentage of total stomach volume
Crabs (undet.)	13.8	2.7	12.9	4.9	16.7	5.7	12.5	4.3
Rithropanopeus harrisii			16.1	15.6	4.2	0.2	5.0	0.1
Callinectes sapidus	10.3	1.4	3.2	2.5	8.3	13.0	7.5	5.0
Cirripedia			6.5	0.1				
Crustacea (undet.)	31.0	31.7	9.7	2.0	20.1	3.5	10.0	1.0
Odonata			3.2	0.2	4.2	0.2		
Annelida			6.5	0.1	4.2	T		
Mollusca								
Rangia cuneata	41.4	32.4	45.2	20.2	70.8	30.0	57.5	46.5
Mytilopsis leucopheata			6.5	0.3	25.0	19.4	20.0	11.9
Gastropoda	13.8	1.9	12.9	9.0	29.2	5.5	25.0	5.0
Hydroids	3.4	0.3	6.5	0.2	8.3	0.5	2.5	T
Vertebrata								
Fish remains	3.4	0.5	6.5	0.4	16.7	1.6	17.5	5.4
Bottom Diatoms			3.2	0.1				
Algae-filamentous			12.9	3.0	4.2	T	2.5	0.3
Vascular plants	6.9	0.4	25.8	8.1	20.8	0.8	10.0	2.0
Organic mat. (undet.)	17.2	7.7	35.5	13.9	25.0	5.9	17.5	8.8
Detritus	37.9	12.1	32.3	12.8	33.3	12.7	15.0	9.7
Sand	37.9	9.1	41.9	6.4	29.2	1.7	2.5	T
SUMMARY								
Crabs, Undet. Crusts		35.8		25.0		22.4		10.4
Mollusks		34.3		29.5		54.9		63.4
Fish remains		0.5		0.4		1.6		5.4
Vegetation, misc.		0.7		11.8		1.5		2.3
Detritus, undet.		19.8		26.7		18.6		18.5
Sand		9.1		6.4		1.7		T

* Stomach only.

the diet of the 125-147 mm. size group. Following a molt the blue crab may consume its own shed exoskeleton, and it is likely that much of the blue crab shell encountered in the stomachs was simply obtained in this manner. The evidence here indicates that some cannibalism does occur, however, since fresh muscle fibers were frequently found still attached to the consumed shell fragments. *Callinectes sapidus* is known to be cannibalistic when confined in "holding" pens, especially if hard and soft individuals are confined together (Benedict, 1940; Cargo and Cronin, 1951) , and the present work bears out the suggestion of Hay *(op. cit.)* that cannibalism is also of widespread occurrence in the natural population.

Mollusks also appeared as an important elment in the diet of the blue crabs, constituting one-third of the food of the smallest individuals and increasing to almost two-thirds of the food volume of the largest size class. These mollusks included small clams *(Rangia cuneata),* mussels *(Congeria leucopheata),* and gastropods *(Melampus coffeus* and *Neritins virginico,* both of which are inhabitants of the marginal
pus coffeus and *Neritina virginica,* both of which are inhabitants of the marginal

Fish remains were not significant in the diet of the smaller size groups, and even in the largest blue crabs they made up only 5 percent of the food. Vegetation was

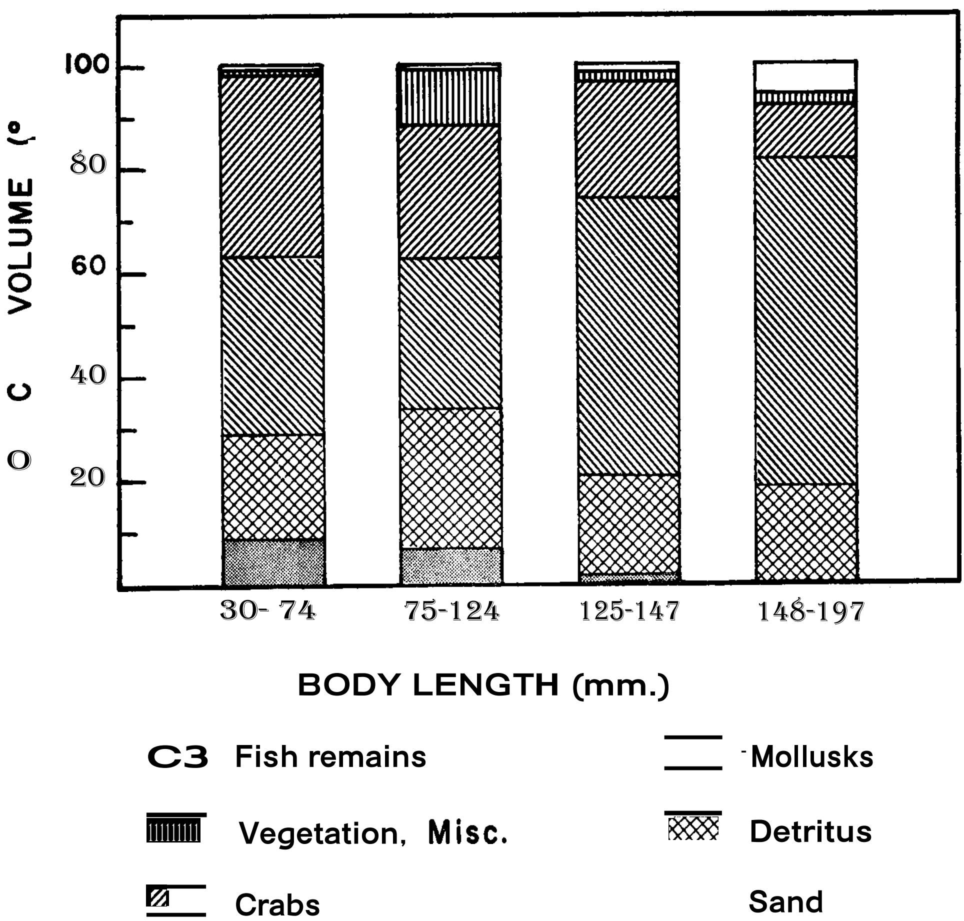


Fig. 16. Ontogenetic food progression of *Callinectes sapidus.*

seldom encountered except in the 75-124 mm. group where it made up 11 percent of the consumed material. Detritus and undetermined organic material, however, were of considerable importance throughout the size range investigated, constituting from one-sixth to one-fourth of the stomach contents within each size class. Sand made up nine percent of the contents of the smallest size group and declined thereafter to less than one percent.

As indicated for the white shrimp, small or easily-digested soft tissues may comprise a larger percentage of the food of the blue crab than is evident from routine stomach analyses. The general types of food seem clear, however, even if quantitative aspects may be somewhat distorted. As a detritivore, this crab consumes large quantities of bottom debris and decomposing organic matter. As a bottom predator, it takes in numbers of small crabs (including its own kind), clams, mussels, and snails, as well as occasional aquatic insects, barnacles, and probably other small invertebrates and fishes. As a general scavenger, this species is attracted to decaying flesh in baited nets and traps, and undoubtedly the blue crab consumes large quantities of decaying fishes and other animals under natural conditions. Benedict (1940) mentioned that blue crabs are attracted to nets and lines baited with the flesh of many species of fishes. Cargo and Cronin (1951) listed fish as the main item in the diet of the blue crabs in Chesapeake Bay, adding that the species also takes in a wide variety of animal and plant matter including seaweeds and marsh plants. In Lake Pontchartrain this species is a detritivore, bottom predator, and general scavenger; any less complete designation would seem inadequate.

The stomachs of young blue crabs tend to be most full in the morning hours, and it appears that most of their feeding takes place either at night or during the early morning with less feeding activity in the afternoon (Fig. 17). Adults, on the other hand, exhibit the fullest stomachs in the middle of the afternoon, indicating that they are primarily daytime feeders. The significance of this difference in feeding time is not clear. It might be supposed that the young, living in shallowest waters, are faced with the necessity of avoiding extreme temperatures or excessive predation during the daylight hours, and that the adults feeding chiefly in deeper more turbid waters, are less limited by these factors. In partial substantiation of this idea, Lambou (1952) recorded the presence of immense numbers of crabs of all sizes in the shallow, brackish-water lagoons north of Lake Pontchartrain, and he indicated that the small crabs were especially abundant at night when the shallow water appears to be alive with them. In view of information presented elsewhere in this paper, selective factors due to predation pressure on this species must be enormous.

Discussion

Ignoring details, the food studies reveal two primary food chains within Lake Pontchartrain. The first pathway proceeds from copepods *(Acartia)* through small fishes *(Anchoa, Brevoortia,* very young sciaenids, etc.), to larger predators. The second proceeds from small benthic invertebrates through larger invertebrates and small bottom-dwelling fishes (catfishes, young sciaenids, etc.) , to the same large predators. Organic detritus, which was prominent in the food of the fishes and larger invertebrates, probably also serves as an important source of nutrition for the cope.

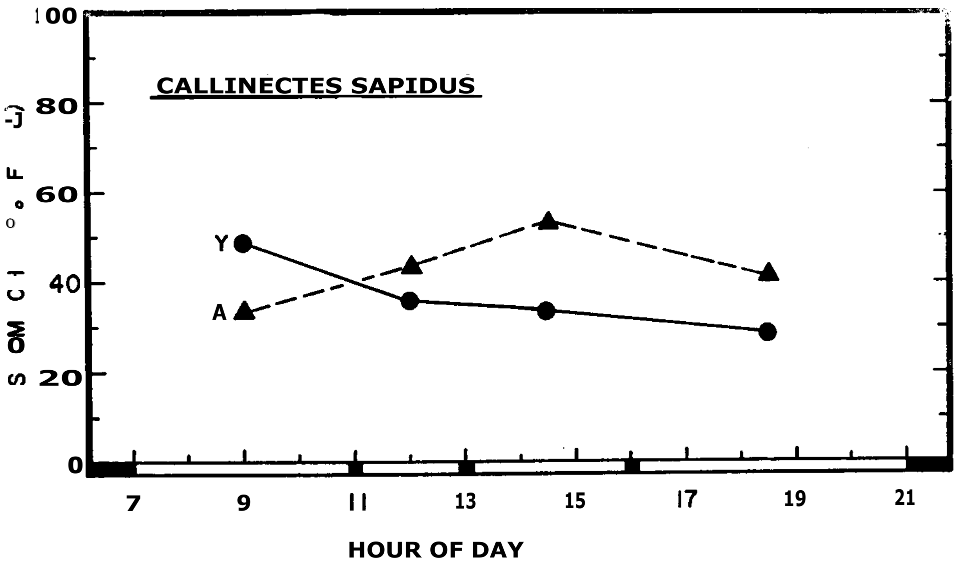


FIG. 17. Hourly pattern of percent-fullness of stomach and intestine of Callinectes sapidus (young and adult).

pods and small benthic invertebrates of this turbid estuary. Such detritus has a very complex origin (cf. Gneri and Angelescu, 1951), and it has been shown by other workers to be rich in bacteria (Baier, 1935; ZoBell and Feltham, 1938, 1942; Burkholder and Bornside, 1957) .

An ontogenetic progression of food stages was clearly demonstrated for several of the well studied species, and for one species (Atlantic croaker) as many as four distinct nutritional stages were recognized. Within a given stage considerable substitution of food items was of ten observed. In some cases it was possible to correlate ontogenetic changes in food utilization with changes in morphology, habitat, feeding time, and behavior. As a result of their highly varied diets including much detritus, most, if not all, of the species examined are considered to be omnivorous. Distinct trophic levels (in the sense of Lindeman) were not recognizable in this estuarine community.

Summary

The physical environment of Lake Pontchartrain was found to be characterized by moderate temperature, generally low salinity, and very high turbidity, although considerable variations in these factors were noted. Food studies, including 1,399 quantitative and about 100 qualitative stomach analyses, were carried out on thirty-five of the most important species comprising the estuarine community. These included the following: bull shark, longnose gar, spotted gar, alligator gar, bigeye herring, gulf menhaden, gizzard shad, threadfin shad, southern bay anchovy, gaff-topsail catfish, sea catfish, blue catfish, channel catfish, Atlantic needlefish, striped mullet, silverside, yellow bass, largemouth bass, common jack, freshwater drum, silver perch, sand squeteague, spotted squeteague, spot, Atlantic croaker, black drum, red drum, gulf sheepshead, pinfish, southern flounder, hogchoker, common rangia (clam) , white shrimp, river shrimp, and blue crab.

A definite ontogenetic progression of food stages was recognizable in many species, and most were considered to be omnivorous. Organic detritus was prominent in the diet of most species. Two partial food chains (planktonic and benthonic) were found to support the top predators, but distinct "trophic levels" among the consumers were not recognizable.

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