

TROPHIC ANALYSES OF AN ESTUARINE MANGROVE COMMUNITY¹

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ABSTRACT

Fringing the southwest coast of Florida is a mangrove belt which supports large populations of birds, gamefishes, and invertebrate species of commercial importance. A study was conducted between 1967 and 1969 in the North River basin of this mangrove region to determine the energy basis for this large population of animals and to delineate the routes by which energy is transferred through the food web.

This is the first of three publications summarizing the results of this study. It consists of summaries of food habits for most of the fish and aquatic invertebrate species which occur in the North River mangrove ecosystem. In addition to our data, which include in excess of 10,000 analyses of stomach contents, information from other publications has been summarized where pertinent. Finally, for most species there is an estimate of relative importance in the North River system in terms of abundance.

INTRODUCTION

There is no way to ascertain from the published literature whether mangrove forests contribute significantly to the productivity of surrounding waters. Although the mangrove environment has been studied from many different aspects (summarized by Kuenzler, 1969), there have been few studies concerned with primary productivity and no mention of energy transfer to consumer trophic levels.

With this lack of information in mind we designed a program to investigate the importance of organic detritus of mangrove origin to the heterotrophic community of a south Florida estuary. We selected the North River estuary of the Everglades National Park for investigation (Fig. 1). This area presented a situation where it was possible to correlate the production of mangrove detritus within the drainage basin of the river with export of particulate matter out of the river into a coastal embayment. Moreover, due to extreme seasonal fluctuations in salinity, the fauna and flora of the North River comprise relatively few species, a feature which simplifies the task of understanding trophic relationships.

Our first objective was to estimate the annual production of organic detritus by the plants of the estuary, along with a detailed study of the

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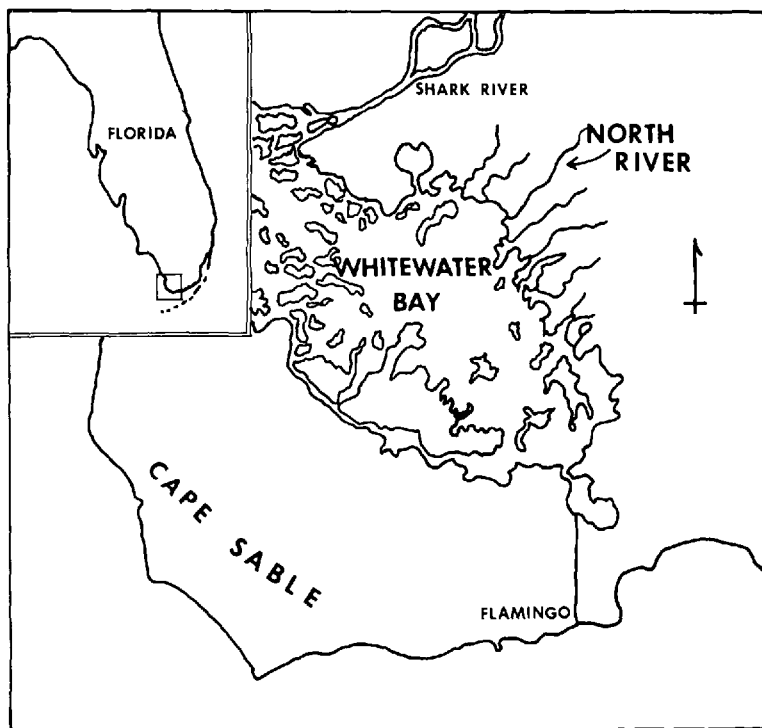


FIGURE 1. The North River study area of the mangrove-dominated estuary of the Florida Everglades.

detritus—whether it remained in the system or was exported, whether it lost or gained nutritional value as it disintegrated, and how long it took to decompose sufficiently to be available as food for detritus consumers. These aspects of the study are discussed in detail elsewhere (Heald & Odum, in press). The chief findings were that detritus production is large (in excess of 3 metric tons of dry weight per acre per year from mangrove leaf-fall alone) and that rapid decomposition by bacteria and fungi produces a plentiful food source with a high caloric value and relatively great protein content.

The second objective was to determine the apparent importance of organic detritus as a nutritional source to the heterotrophic community. Does mangrove detritus provide a broad base for most of the food webs associated with the mangrove ecosystem, or are phytoplankton, benthic algae, and their associated herbivorous food chains more important? To answer this question, it was necessary to carry out a detailed survey of the

food items ingested by organisms at all trophic levels, but with special emphasis upon primary consumers.

This paper presents the findings of this survey; it consists of summaries of food habits for each species of fish and most of the invertebrates which occur in the North River mangrove ecosystem. In addition to our own data, which include in excess of 10,000 analyses of stomach contents, information from other papers has been summarized where pertinent. Finally, for most of the species there is an estimate of relative importance in the North River system in terms of abundance.

From the trophic analyses, it is possible to reconstruct the biological pathways of energy exchange in the mangrove community and, ultimately, to assess the value of mangrove detritus to the associated animal community (for a detailed examination of trophic pathways based on these stomach analyses see Odum & Heald, manuscript in preparation).

DESCRIPTION OF THE NORTH RIVER REGION

The region on the southwest coast of Florida where the freshwater flow of the Everglades meets the sea is characterized by a broad belt of mangrove forests 10-20 kilometers wide and over 100 kilometers in length. This estuarine belt is composed of a series of small drainage basins in which the freshwater flow from the Everglades gradually mixes with the more saline waters of the Gulf of Mexico. One of these basins, the North River, is a drainage system constituting an area of 21.7 square kilometers (4100 acres), of which approximately two-thirds is covered by vegetation, principally mangroves, and one-third by open water. The open water is comprised of the river channel itself, 14 kilometers long and up to several hundred meters wide, and a series of shallow ponds which are interconnected by small winding streams ultimately emptying into the river proper. These ponds are usually less than a meter deep and range in area from a few square meters to 10 hectares. Although the pond bottoms are composed of flocculent organic mud, most of the streams and the river have exposed limestone beds and undercut mangrove peat banks.

In the upper reaches of the North River the ponds are replaced to a great extent by scattered marsh areas composed of the needlerush, *Juncus roemerianus*. These marshes are isolated from the river by a 0.2- to 0.4-meter levee, which is broken at intervals by small drainage creeks.

The headwaters of the North River are a poorly defined region ranging from the open, seasonally flooded sawgrass prairies to the enchanneled mangrove belt. Generally, it is characterized by mangrove-lined fingers intruding into the sawgrass prairie.

Because the North River area is a flooded basin, the usual zonation pattern of mangroves (Davis, 1940; Golley *et al.*, 1962) is absent. The vegetation of the river basin is dominated by the red mangrove, *Rhizophora*

TABLE 1

FISHES COLLECTED IN THE NORTH RIVER

(Unless otherwise noted, each species was collected both in this survey and that of Tabb [1966])

Species	Abundance*	Characteristic habitat†
Marsh killifish <i>Fundulus confluentus</i>	Abundant	Throughout river system
Sheepshead <i>Archosargus probatocephalus</i>	Abundant	Throughout river system
Snook <i>Centropomus undecimalis</i>	Abundant	Throughout river system
Tarpon snook <i>C. pectinatus</i>	Abundant	Headwaters and marsh pools
Tarpon <i>Megalops atlantica</i>	Abundant	Throughout river system
(‡) Ladyfish <i>Elops saurus</i>	Abundant	Throughout river system
Gray snapper <i>Lutjanus griseus</i>	Abundant	Throughout river system
Striped mojarra <i>Diapterus plumieri</i>	Abundant	Throughout river system
Silver jenny <i>Eucinostomus gula</i>	Abundant	Throughout river system
Spotfin mojarra <i>E. argenteus</i>	Abundant	Throughout river system
Gulf toadfish <i>Opsanus beta</i>	Abundant	Throughout river system
Sea catfish <i>Arius felis</i>	Abundant	Throughout river system
Atlantic needlefish <i>Strongylura marina</i>	Abundant	Throughout river system
(‡) Striped mullet <i>Mugil cephalus</i>	Abundant	Throughout river system
Bay anchovy <i>Anchoa mitchilli</i>	Abundant	Lower river and ponds
Crested goby <i>Lophogobius cyprinoides</i>	Abundant	Throughout river system
Clown goby <i>Microgobius gulosus</i>	Abundant	Throughout river system
Rainwater killifish <i>Lucania parva</i>	Abundant	Headwaters and marsh pools
Bluefin killifish <i>Lucania goodei</i>	Abundant	Headwaters region
Mosquitofish <i>Gambusia affinis</i>	Abundant	Throughout river system
Sailfin molly <i>Poecilia latipinna</i>	Abundant	Marsh pools
(‡) Goldspotted killifish <i>Floridichthys carpio</i>	Abundant	Marsh pools and river edges
Tidewater silverside <i>Menidia beryllina</i>	Abundant	Throughout river system
(‡) Spotted sunfish <i>Lepomis punctatus</i>	Abundant	Headwaters region
Great barracuda <i>Sphyrna barracuda</i>	Common	Lower river near mouth

* Estimates of abundance are based upon underwater observations, observations from above water, and catches with gear.

† Characteristic habitat refers to the area of greatest abundance and does not imply that the species is not found elsewhere in the river system at times.

(‡) = collected in this survey only.

TABLE 1 (Continued)

Species	Abundance*	Characteristic habitat†
Crevalle jack <i>Caranx hippos</i>	Common	River, larger creeks and ponds
Spotted seatrout <i>Cynoscion nebulosus</i>	Common	River, larger creeks and ponds
Red drum <i>Sciaenops ocellata</i>	Common	River, larger creeks and ponds
Scaled sardine <i>Harengula pensacolae</i>	Common	Lower river near mouth
Redfin needlefish <i>Strongylura notata</i>	Common	Throughout river system
Hogchoker <i>Trinectes maculatus</i>	Common	Lower river and ponds
Silver perch <i>Bairdiella chrysura</i>	Common	Lower river near mouth
Leatherjacket <i>Oligoplites saurus</i>	Common	Lower river and ponds
Bull shark <i>Carcharhinus leucas</i>	Common	River channel and ponds
(†)Skilletfish <i>Gobiesox strumosus</i>	Common	Lower river near mouth
(†)Least killifish <i>Heterandria formosa</i>	Common	Headwaters region
Lined sole <i>Achirus lineatus</i>	Common	Lower river and ponds
Code goby <i>Gobiosoma robustum</i>	Common	Lower river and ponds
(†)Gaftopsail catfish <i>Bagre marinus</i>	Common	Lower river and ponds
(†)Pinfish <i>Lagodon rhomboides</i>	Common	Lower river and ponds
(†)American eel <i>Anguilla rostrata</i>	Common	Throughout river system
(†)Diamond killifish <i>Adinia xenica</i>	Common	Marsh pools
(†)Gulf killifish <i>Fundulus grandis</i>	Common	River edges and marsh pools
Sheepshead minnow <i>Cyprinodon variegatus</i>	Common	River edges and marsh pools
(†)Emerald goby <i>Gobionellus smaragdus</i>	Rarely taken	Lower river and ponds
(†)Frillfin goby <i>Bathygobius soporator</i>	Rarely taken	Throughout river system
(†)Rivulus <i>Rivulus marmoratus</i>	Rarely taken	Throughout river system
Jewfish <i>Epinephelus itajara</i>	Rarely taken	River and larger streams
Bighead searobin <i>Prionotus tribulus</i>	Rarely taken	Lower river near mouth
Largemouth bass <i>Micropterus salmoides</i>	Rarely taken	Headwaters
Florida gar <i>Lepisosteus platyrhincus</i>	Rarely taken	Headwaters
Atlantic stingray <i>Dasyatis sabina</i>	Rarely taken	Lower river and ponds
(T)Warmouth <i>Lepomis gulosus</i>	Not taken in this survey	
(T)Redear sunfish <i>Lepomis microlophus</i>	Not taken in this survey	
Atlantic thread herring <i>Ophisthonema oglinum</i>	Not taken in this survey	

(†) = collected in Tabb's survey only.

mangle. The white mangrove, *Laguncularia racemosa*, is present as scattered individuals, but the black mangrove, *Avicennia nitida*, and the buttonwood, *Conocarpus erectus*, are rare. Sawgrass, *Mariscus jamaicensis*, is present in the system in the headwaters, but only in scattered clumps. This grass is characteristic of the open freshwater everglades and not of the mangrove-dominated river system.

Salinities of the rivers draining the Everglades exhibit marked seasonal variation. During the dry season, December to May, freshwater flow from the north is practically nonexistent, and saline water intrudes far up the rivers, with the result that by April salinities reach 27‰ to 29‰ in the mouth of the North River and may be as high as 20‰ in the headwaters. In late May the rainy season usually commences, and by the middle of June salinities in the entire river are uniformly "fresh" (from 100 to 300 ppm) and remain so until late fall.

The combination of the seasonal fluctuations in salinity and a scarcity of suitable habitat greatly limits the numbers of invertebrate and aquatic plant species in the North River. Characteristic residents of the high-salinity coastal mangrove swamps, such as the tree crab *Aratus pisonii*, and the pulmonate snail *Melampus coffeus*, are absent or rare. Most abundant of the permanent community are the crab *Rhithropanopeus harrisi*, the caridean shrimp *Palaemonetes intermedius*, the snapping shrimp *Alpheus heterochaelis*, and the scorched mussel, *Brachidontes exustus*. Numerous, but not as common, are the pink shrimp, *Penaeus duorarum*, and the blue crab, *Callinectes sapidus*. Also found year round are the alga *Batophora oerstedii*, and the grass *Ruppia maritima*. Neither is ever abundant; they are found only in scattered patches near the river mouth.

The late spring, summer, and fall period of low salinity is characterized by an explosive increase in numbers of the false mussel, *Congeria leucophaea*. The crayfish *Procambarus alleni* moves downstream from the headwater region and becomes relatively abundant in all parts of the river. Another downstream migrant is *Palaemonetes paludosus*, although it never becomes as abundant as *P. intermedius*. The alga *Chara hornemannii* is found during this period.

The rise of salinity in the late fall is shortly followed by the arrival of both *Acetabularia crenulata* and *Udotea wilsoni* in the plant community. The oyster *Crassostrea virginica* becomes established on mangrove roots and large pieces of debris along the shore. The intrusion of saline water is characterized by indicator organisms in the plankton, such as the chaetognath *Sagitta hispida*.

Fish populations in the North River are dominated by euryhaline species (Table 1). In addition, there are many strictly marine species which are able to remain in the river even when the water is apparently "fresh." This

phenomenon of marine fishes and crustaceans penetrating great distances into the freshwater regions of Florida has been reported and discussed by Carr (1937), Gunter (1942), H. T. Odum (1953), and Hulet *et al.* (1967). Finally, there are a few species which move downstream from the freshwater Everglades when salinities fall below 5 ‰ in the North River (*Lepomis punctatus*, *L. microlophus*, *Chaenobryttus gulosus*, *Micropterus salmoides*, *Lepisosteus platyrhincus*, *Heterandria formosa*, and *Lucania goodei*).

PROCEDURES

Collection of Organisms.—Details concerning location of sampling stations and types of sampling devices utilized have been presented elsewhere (Odum, 1970). Suffice it to say that sampling gear included bag seines, throw nets, dip nets, lift nets, various traps and pound nets, trammel nets, set lines, hook and line, fish poisons, a one-meter roller beam trawl, standard plankton nets, Van Veen grabs, and an Ockelman dredge. It was necessary to empty all of the trap devices hourly; even with these precautions, the carnivores caught in traps were not used for food studies, since their stomachs may have contained organisms obtained inside the trap.

Preservation.—Smaller organisms were preserved in buffered 10 per cent formalin. The larger fishes and elasmobranchs were dissected in the field, and only the digestive tract was retained and preserved for later examination. Selected samples of small organisms and fishes were preserved in a chilled brine solution at -4°C and transported to the laboratory for analysis within 12 hours.

Analyses of Digestive-Tract Contents.—Routine food analyses were performed in the laboratory on previously collected material. Ideally, only the stomach contents were examined; however, if the stomach was empty or only partially filled, the intestinal contents were also inspected. Because of differential digestive rates, these intestinal examinations were considered to have value only in a qualitative way and no quantitative estimates were made from them.

For caridean and penaeid shrimp, crabs, and mysids, material for examination was taken from the buccal cavity. For insect larvae, amphipods, cumaceans, and isopods, the method of Croker (1967) was used. This involves first removing the animal's head and then applying pressure to the body so that the gut contents are squeezed out onto a microscope slide.

The following estimates were made during the examination of the contents of each organism's stomach.

1. Percentage composition of stomach contents: Estimates of the relative occurrence of materials in stomach contents are admittedly subjective

and unique to the individual investigator. For this reason it is essential that the same procedure be used consistently by one individual throughout a project to obtain good comparative data. For this project either of two methods was used, depending upon the size of the particles in the stomach contents. The first method, for larger particles, consisted of the standard practice of immersing the individual food items either in a graduated cylinder or a small-diameter, calibrated glass tube. Stomach contents of small animals containing fine particles (less than 1 mm) required a second approach. A known volume of stomach contents was pipetted onto a glass slide etched with a fine grid. With the aid of an eyepiece micrometer and the marked slide, an estimate was made of the volumetric composition of the stomach contents. This method is similar to attempts to quantify the gut contents of insects made by Jones (1950), Brown (1961), and Chapman & Demory (1963). The same technique was used for the examination of stomach contents of *Mugil cephalus* by W. E. Odum (1970b); in that paper there is a discussion of the merits and drawbacks of the method.

A third method (Mecom & Cummins, 1964) was tried but discarded. This involved filtering known volumes of stomach contents through a 0.45μ gridded millipore filter, clearing, and estimating the percentage composition of the material retained on the filter. Although basically a good method, it proved impractical for this study, because the structure of delicate particles of detritus was often altered beyond recognition on the surface of the filter during filtration.

2. Identification of food organisms: With the use of a reference collection of the common organisms of the North River it was possible to identify stomach contents accurately, even when only stray parts were present. Most food organisms were identified to species; adult and larval insects, copepods, and hydrozoans were more broadly classified.

3. Identification of organic detritus particles: At the beginning of the study a photographic atlas was compiled which included color photomicrographs of 12 different types of detritus particles at various magnifications. These photographs were made from material of known origin taken from decomposition bags and included such tissues as mangrove-leaf parenchyma, sawgrass stem, and roots of *Juncus*. With the aid of the atlas it was possible to identify most detritus particles above 30μ to 40μ in diameter from their characteristic cell structure.

4. Measurement of particle size: All stomach-content particles were measured, whether they were diatoms, small copepods, detritus particles, or entire fish. These measurements were made with an eyepiece micrometer for the smaller particles and a pair of calipers or small ruler for the larger organisms. Measurements of fish throughout this study, whether predator or prey, were standard length (i.e., from the tip of the snout with the mouth closed to the tip of the vertebral column or hypural plate). Measurements

TABLE 2

CILIATES ISOLATED FROM MANGROVE DETRITUS AND THEIR NORMAL FOOD
(As determined by Dr. Thomas Fenchel)

Ciliate	Normal diet
HOLOTRICHA	
<i>Tracheloraphis</i> sp.	ciliates, flagellates
<i>Frontonia marina</i>	diatoms
<i>Mesodinium pupula</i>	unknown
<i>Lacrynaria</i> sp.	ciliates
<i>Pleuronema</i> sp.	bacteria
<i>Helicostoma</i> sp.	dead Metazoa
<i>Prorodon</i> sp.	ciliates, flagellates
<i>Uronema</i> sp.	bacteria
<i>Cyclidium</i> sp.	bacteria
SPIROTRICHA	
<i>Parablepharisma pellitum</i>	sulfur bacteria
<i>Holosticha</i> sp.	bacteria
<i>Peritronus</i> sp.	bacteria
<i>Condylostoma</i> sp.	ciliates
<i>Strombidium</i> sp.	diatoms
<i>Uronychia transfuga</i>	ciliates
<i>Aspidisca</i> sp.	bacteria

of crustaceans were usually of the carapace length (shrimp) or width (crabs), but were total body lengths for mysids, amphipods, cumaceans, and copepods.

Terminology for Detritus.—The term “organic detritus” is used here as defined by E. P. Odum & de la Cruz (1963): “All types of biogenetic material in various stages of microbial decomposition. . . .” Implicit in such a definition is a range in particle size from, for instance, dead trees to amino acids and methane molecules.

In the present study, detritus particles in the stomachs of organisms generally ranged from a few millimeters to a few microns. When the particles reach a very small diameter, they often form aggregates or “conglomerates” and effectively increase in size. These conglomerates of fine particles commonly appeared in stomach contents, but it is not clear whether they are formed prior to ingestion or in the mucus-lined digestive tracts of the detritus consumers.

Seasonality.—Although the data were collected on a seasonal basis, most organisms did not exhibit a significant seasonal variation in diet. In most cases extreme alterations in diet reflected temporary availability of unusual food sources.

For this reason, the following summaries of stomach contents have been

pooled and expressed on an annual basis, except in a few instances where significant seasonal differences could be identified.

INVERTEBRATES

Phylum PROTOZOA

Class CILIATA

Ciliates were found in association with benthic deposits of vascular plant detritus and sediments. Presumably, these ciliates and other Protozoa are ingested by organisms which feed upon detritus and sediment particles. Ciliates identified during May (salinity 12‰) and the items which they ingest are shown in Table 2.

Phylum COELENTERATA

Class HYDROZOA

Unidentified hydrozoans became established on the rocky bottom sections of the North River when salinities were above 10‰. They were grazed by sheepshead, *Archosargus probatocephalus*.

Phylum ASCHELMINTHES

Class NEMATODA

Unidentified nematodes were observed in all samples of sediment from the North River, but rarely occurred in fish stomachs. This could be due to rapid digestion of the nematodes. Many of these nematodes had small, unarmed buccal cavities, which suggests that they were of the type which Tietjen (1967) has suggested may be important in the breakdown of plant detritus.

Extremely high numbers of nematodes were found within decaying mangrove leaves, which suggests that they play an important role in the decomposition process.

Phylum ANNELIDA

Class POLYCHAETA

Two nereid worms occurred commonly in the North River. *Nereis pelagica* was present during periods when the salinity was above 10‰; *Neanthes succinea* was much more abundant and was collected at all times of the year, even when salinities were below 1‰. Both appeared regularly in the stomach contents of fishes. Our observations suggest that both species are omnivorous consumers of fine plant detritus, algae, and occasional small crustaceans, such as harpacticoid copepods and amphipods.

Phylum MOLLUSCA

Class PELECYPODA

The common bivalve molluscs in the North River are the false mussel, *Congeria leucophaeata* Conrad; the scorched mussel, *Brachidontes exustus*

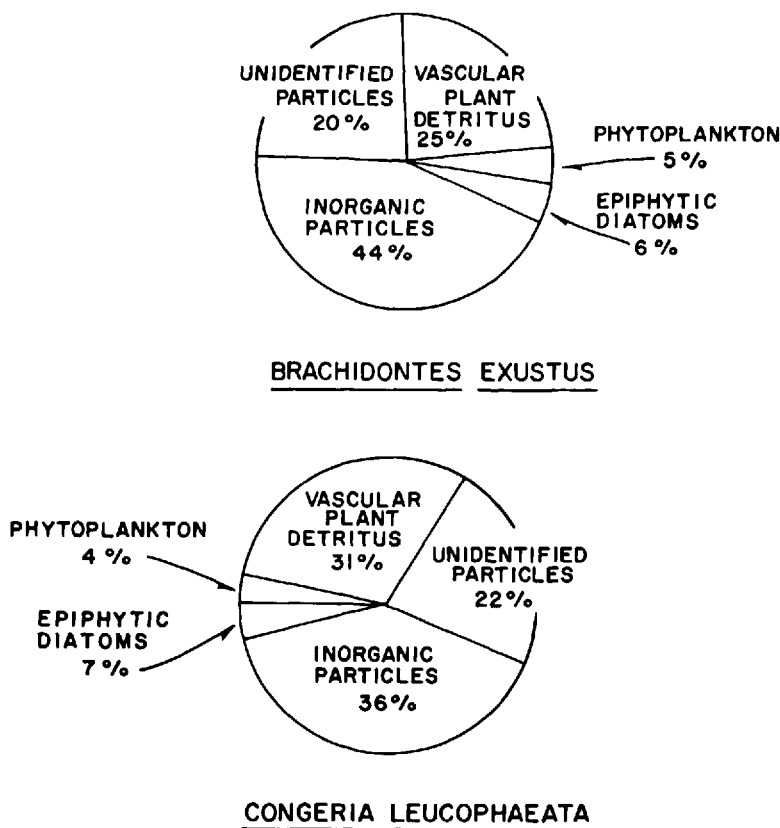


FIGURE 2. The volumetric composition (per cent) of the stomach contents of 84 false mussels, *Congeria leucophaeata*, 6-18 mm long, and 63 scorched mussels, *Brachidontes exustus*, 4-24 mm long. *C. leucophaeata* was collected between July and December 1968, and *B. exustus* between January and July 1968.

Linnaeus; the pointed venus, *Anomalocardia cunimeris* Conrad; and the eastern oyster, *Crassostrea virginica* Gmelin. All, except *C. leucophaeata*, are most numerous from January to May when salinities are above 10‰. *C. virginica* and *A. cunimeris* disappear completely during the remainder of the year, but *B. exustus* maintains low-level populations during most of the freshwater period. Conversely, *C. leucophaeata* is present during most of the year, except for February through April when salinities are too high.

C. leucophaeata and *B. exustus* are the most important bivalves in the food web, serving primarily as food for the sheepshead, *Archosargus probatocephalus*. The percentages of materials filtered from the water and

ingested into the stomachs of these two molluscs are shown in Figure 2. Both ingest very fine particles, usually of less than 50μ . *C. virginica* and *A. cunimeris* are less abundant and therefore of limited importance in the food web.

Phylum ARTHROPODA

Class CRUSTACEA

Subclass OSTRACODA

Ostracods were often encountered in fish stomachs, but were not identified to genus or species. Ostracods eat bacteria, molds, algae, and fine plant detritus (Pennak, 1953).

Subclass COPEPODA

Harpacticoid copepods were collected throughout the year, but reached their greatest abundance between January and May, when salinities were above 10‰. They are an important food source for many small fishes and invertebrates. Harpacticoids are primarily bottom browsers, which eat small algal cells and bits of detritus (Green, 1968).

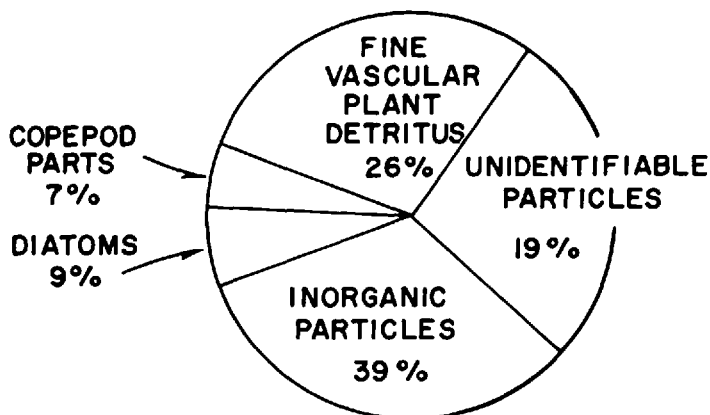
Cyclopoid and calanoid copepods were present in sufficient numbers in the plankton to support the larval fish which were present. These copepods are presumed to be filter feeders that ingest phytoplankton and small bits of detritus. Examination of *Acartia* sp., *Labidocera* sp., and *Cyclops* sp., the three most common copepods in the plankton, revealed masses of particles of vascular plant detritus in their digestive tracts along with a few phytoplankters and epiphytic diatoms.

Subclass MALACOSTRACA

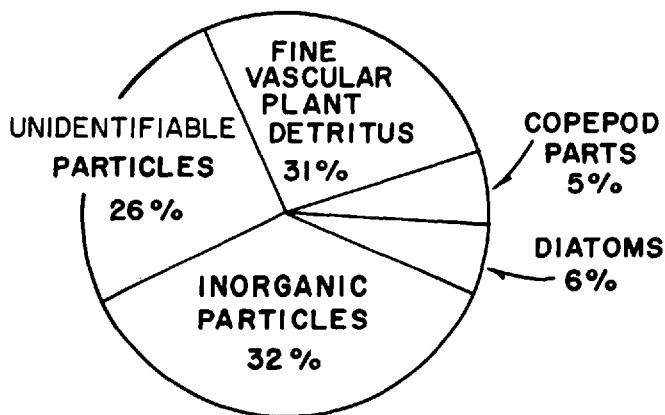
Order MYSIDACEA

Mysids are abundant in the North River and are an important source of food for many fishes. Four species were collected routinely. *Mysidopsis almyra* Bowman was the most common mysid, occurring in all habitats and at all times of the year in water which ranged from less than 1‰ to 26.2‰. *Taphromysis bowmani* Bacescu occurred under the same conditions as *M. almyra*, but was outnumbered three to one in Ockelman dredge tows. *Mysidopsis bahia* Molenock was less common than the other two and was never taken in water of less than 9‰; this is not conclusive evidence that it does not occur at lower salinities. *Gastrosaccus dissimilis* Coifmann was common when salinities were above 15‰, but was definitely not present at salinities below 10‰.

Most mysids are filter feeders (Barnes, 1963), which ingest small particles such as diatoms and finely divided detritus (Pennak, 1953; Cannon & Manton, 1927). Mauchline (1969) identified particles of silt, fragments of leaves, spores, and other terrigenous materials in *Leptomysis*. In addi-



TAPHROMYSIS BOWMANI



MYSIDOPSIS ALMYRA

FIGURE 3. The volumetric composition (per cent) of the digestive-tract contents of 120 specimens of *Taphromysis bowmani* and 153 specimens of *Mysidopsis almyra* collected throughout the year.

tion, Green (1968) has pointed out that mysids often function as omnivores, feeding on copepods and dead amphipods.

We examined the digestive-tract contents of 120 specimens of *Taphromysis bowmani* and 153 specimens of *Mysidopsis almyra* (Fig. 3) and

found essentially the same types of particles as described in the quoted literature.

Order CUMACEA

The only two cumaceans which were present in the North River were *Cyclaspis varians*, which was more abundant, and *Oxyurostylis* sp., which was rare. We collected both of these with the Ockleman dredge in the river between January and May, when salinities were above 20‰. They were eaten by a number of fishes, but in small amounts. Examination of the digestive tracts of 15 specimens of *C. varians* revealed particles of inorganic sediment, particles of vascular plant detritus, and a few benthic diatoms.

Order ISOPODA

Only two isopods are of any importance in the North River food web. A species of *Limnoria*, which was often collected from burrows in dead mangrove logs, occasionally turned up in the stomachs of small, benthic, predacious fishes, such as *Eucinostomus gula*. The digestive tract of this isopod contained microalgae and detritus particles which had been scraped off the surfaces of submerged logs and decaying leaves. Individuals captured during the day were empty, indicating nocturnal feeding.

A tanaidacean isopod of the genus *Leptochelia*, species undetermined, was abundant and frequently preyed upon by most of the small carnivorous fishes. Its diet consisted of fine plant detritus and particles of inorganic sediment, along with a few benthic diatoms.

Order AMPHIPODA

Amphipods are exceedingly numerous throughout the North River system and serve as an important link in the plant-detritus-based food chain, since they assimilate bacteria and fungi attached to detritus, and in turn are fed upon by higher consumers. Although seven species were collected regularly, only three were numerous enough to be considered essential in the detritus-based food web.

Amphipods are generally regarded as omnivores that feed on all types of plant and animal matter, both living and dead. Hargrave (1970) has demonstrated the ability of the freshwater amphipod *Hyalella azteca* to assimilate bacteria and algae of the sediment while having little success with elm leaves. Although amphipods may feed heavily upon decaying leaves and leaf particles, it is probable that nutrition from such a diet comes from absorbed microorganisms (Kaushick, 1969).

Melita nitida

This was the most common amphipod in our samples, but the least common of the three major species in fish stomachs. This apparent contradiction is caused by the preference of *M. nitida* for very shallow water,

where it is easily collected by the ecologist, but is difficult for fish to reach. It was found in water shallower than a meter and usually only a few centimeters deep, along the shoreline where leaves and other mangrove debris accumulate. Glass plates placed in this environment required only a few days to acquire a microbial scum before they became covered with *Melita*. During the daytime this amphipod occurs under decaying mangrove leaves, where it grazes the bacteria-laden organic scum off the undersides of the leaves. Digestive-tract contents during the day include fine particles of inorganic matter and vascular plant detritus, along with bacteria and Protozoa. Few microalgae are present. Nocturnal grazing occurs also on the exposed upper surfaces of decaying leaves and other smooth surfaces, so that, in addition to detritus particles, a small percentage (5 to 10 per cent) of microalgae is consumed. Particles in the digestive tract averaged 18μ , but ranged up to 200μ .

In addition to feeding upon small particles, *Melita* tears apart large pieces of decaying leaves. Judging from observations in the laboratory and upon nylon litter bags placed in the environment, *Melita* is responsible to a great extent for the fragmentation of mangrove leaves once they have been in the water for 2 or 3 months. Litter bags placed in water of intermediate and high salinity had greater numbers of *Melita* than those in low salinities; these greater numbers of amphipods were accompanied by an accelerated leaf fragmentation rate (see Heald & Odum, manuscript in preparation).

Grandidierella bonnieri

Grandidierella was by far the most commonly encountered amphipod in fish stomachs, being eaten in large numbers by all of the small carnivorous fishes (i.e., *Eucinostomus*, *Anchoa*, *Menidia*, *Bairdiella*, etc.). Its natural habitat is the beds of small streams and the shallow bottom a few meters from the shoreline of the river. The food of *G. bonnieri* was composed of very fine detritus particles, largely of mangrove-leaf origin, along with associated microorganisms. In contrast to *Melita nitida*, this amphipod was never observed fragmenting pieces of leaf material; particles in the digestive tract rarely exceeded 30μ in diameter.

Corophium lacustre

The digestive tract contents of this amphipod resembled those of *Grandidierella*, suggesting that it also is a small-particle grazer with questionable ability to fragment entire leaves.

OTHER AMPHIPODS

Cymadusa compta and *Gammarus mucronatus* were routinely collected in plankton-net and Ockelman-dredge tows, but seldom occurred in the stomachs of North River fishes. *C. compta*, however, was commonly eaten

by juvenile fishes in Whitewater Bay. Two other amphipods, *Elasmopus* sp. and *Gitanopsis* sp., appeared in samples at times, but were not numerous.

Order DECAPODA
Family Palaemonidae

Caridean shrimp of the genus *Palaemonetes* were abundant throughout the year in all environments of the North River system. During the saline period from January to June, *P. intermedius* Holthuis occurred almost exclusively, except in the headwaters region where *P. paludosus* Gibbes was occasionally taken. With the onset of the rainy season and freshwater conditions in the river, *P. paludosus* moved downstream as far as the mouth, but never was taken in as great numbers as *P. intermedius*. Two other carideans, *P. pugio* Holthuis and *Periclimenes americanus* (Kingsley) appeared occasionally in samples, the former during freshwater conditions and the latter during April when salinities exceeded 20‰.

The food of the members of the family Palaemonidae has received little attention from ecologists, both because of the small size of the shrimp and the very fine nature and difficulty of identification of the contents of their digestive tracts. Hunt (1953) examined 49 specimens of *P. paludosus* from the Tamiami Canal, Dade County, Florida, and concluded that plants provided the primary source of food in the form of algae and vascular plant fragments. Animal remains (rotifers, copepods, ostracods, chironomid larvae, and snails) occurred in only 16 per cent of the digestive tracts examined. Kawanabe *et al.* (unpublished manuscript) regarded algae and vascular plant fragments as the food of *P. pugio* in small pools in the *Spartina* marshes of Georgia.

The material from the buccal cavities of 229 specimens of *P. intermedius* from the North River is summarized in Figure 4. Fifty-two specimens of *P. paludosus* contained almost identical substances—so similar that we consider the diets of the two species to be the same. In both cases there was little variation in ingested substances between sampling stations, although there was often great variation between individuals of the same species in the same sample.

Almost all buccal cavities contained a high percentage of fine particles. Some of these were completely unrecognizable and could have been organic or inorganic in origin. A large percentage of the particles which could be identified were inorganic (clay, quartz, broken bits of calcium carbonate) and probably served a twofold purpose in the digestive tract. First, their presence in the gastric mill greatly facilitates the grinding and reduction of resistant tissues to a digestible form. Second, the high percentage of clay-sized particles supplies the shrimp with a source of dissolved organic substances which were sorbed onto and into the particle.

Other than inorganic particles, the next most commonly ingested ma-

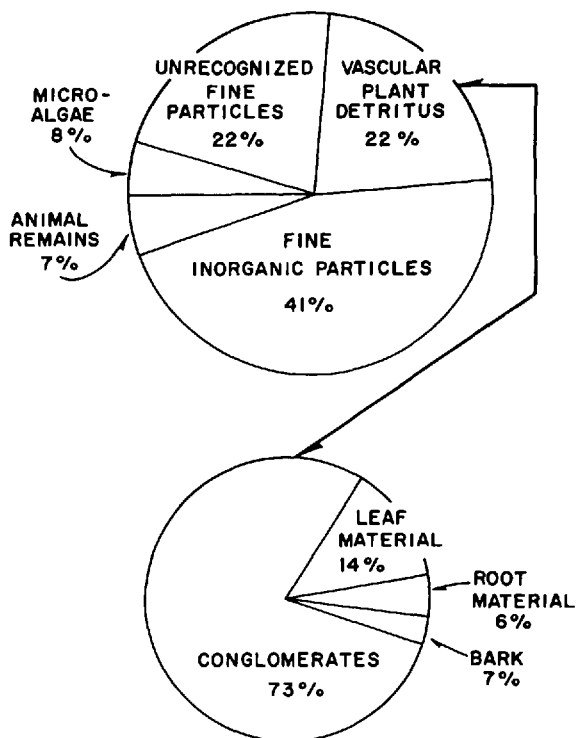


FIGURE 4. The volumetric composition (per cent) of the buccal-cavity contents of 229 specimens of *Palaemonetes intermedius* collected throughout the year.

terials were bits of vascular plant detritus, which were identified by their characteristic color and cell structure. Most of this material appears to be passed through the digestive tract in an unaltered form. Examination with both phase and fluorescence microscopy with acridine orange stain indicated that bacteria, Protozoa, and fungi were removed from the particles during passage down the digestive tract.

Usually there was a small percentage of algal material present in the digestive tract; this paucity of algae in the diet reflected the general scarcity of benthic algae in the North River system. Specimens of *Palaemonetes* that we have examined from other regions of south Florida, where periphyton and benthic algae are more abundant, contained proportionally more algae and less vascular plant detritus than in the North River.

Occasionally the caridean shrimp ingested large amounts of animal materials. These opportunistic meals included benthic and planktonic copepods, amphipods, chironomid larvae, ostracods, and snails.

In summary, *Palaemonetes*, an important link in certain North River food chains, ingests five types of materials: (1) inorganic particles (largely calcium carbonate), which are used as a grinding paste in the gastric mill, (2) clay-sized particles (both inorganic and organic), which probably contain sorbed dissolved organic substances that can be utilized by the shrimp, (3) benthic diatoms, desmids, dinoflagellates, and filamentous green and blue-green algae, (4) particles of vascular plant detritus originating from mangroves and *Juncus*, and (5) pieces of animals such as ostracods, amphipods, and copepods. Except for animal fragments which occasionally exceeded 1.5 mm, most particles were less than 50 μ and averaged 13 μ in diameter. Fungi, bacteria, and Protozoa ingested along with the fine inorganic and organic particles must be included as an important food source. In brief, *Palaemonetes* is an opportunistic omnivore.

Family Penaeidae

Penaeus duorarum Burkenroad

Pink shrimp

Pink shrimp are common, but not abundant, in the North River. This is in marked contrast to the large population present in nearby Whitewater Bay. Bernard Yokel (personal communication) has suggested that the limited numbers of pink shrimp in the North River may be the result of the weak or nonexistent counterflow of water up the river during the incoming tide. Such a water movement appears necessary for the distribution of postlarval penaeid shrimp.

The food of penaeid shrimp has been summarized by Dall (1968). He concluded that penaeids are opportunistic omnivores which feed upon easily captured animals along with algal cells and filaments and sediment particles, all obtained by browsing the surface of estuarine muds. He believes that most of the energy from this diet is derived from bacteria, small algae, Protozoa, harpacticoid copepods, and nematodes. Idyll *et al.* (1967) also mentioned the importance of films of bacteria, yeast, and slime molds which exist on mud particles.

Eighteen specimens of *P. duorarum* contained food (Fig. 5) which was similar to that described by Dall (1968). There was a large percentage of inorganic particles, which must contribute food value in the form of adsorbed microorganisms and absorbed organic compounds which were previously dissolved in the water.

Family Alpheidae

Alpheus heterochaelis Say

Big-Clawed Snapping Shrimp

This snapping shrimp was collected in large numbers along the banks of the North River and in the small drainage creeks which flow out of the

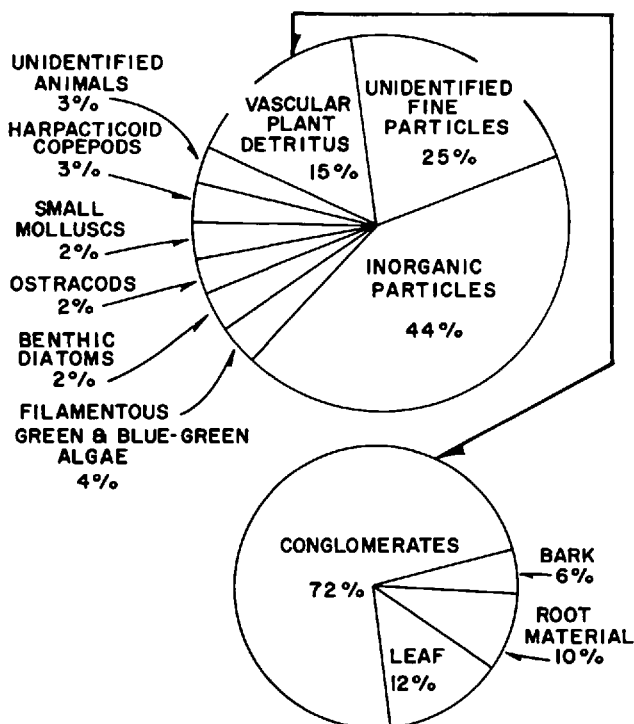


FIGURE 5. The volumetric composition (per cent) of the buccal-cavity contents of 18 pink shrimp, *Penaeus duorarum*, 6-19 mm carapace length, collected in September, November, and December 1968.

mangrove ponds and *Juncus* marshes. Individuals were collected in water of salinities ranging from less than 1‰ to 27.5‰. *A. heterochaelis* is heavily preyed upon by several species of fish.

Gary Hendrix (personal communication) notes that *A. heterochaelis* is an omnivore which feeds upon a variety of animal and plant material including decaying leaves. The contents of the digestive tract of 24 specimens of *A. heterochaelis* are shown in Fig. 6. Particles ingested ranged up to 400 μ in diameter and averaged 42 μ . Feeding appeared to be predominantly nocturnal.

Family Portunidae
Callinectes sapidus Rathbun
 Blue Crab

Large populations of *Callinectes sapidus* exist in areas of the Everglades estuary such as Hell's Bay and Coot Bay Pond which lie adjacent to shallow-

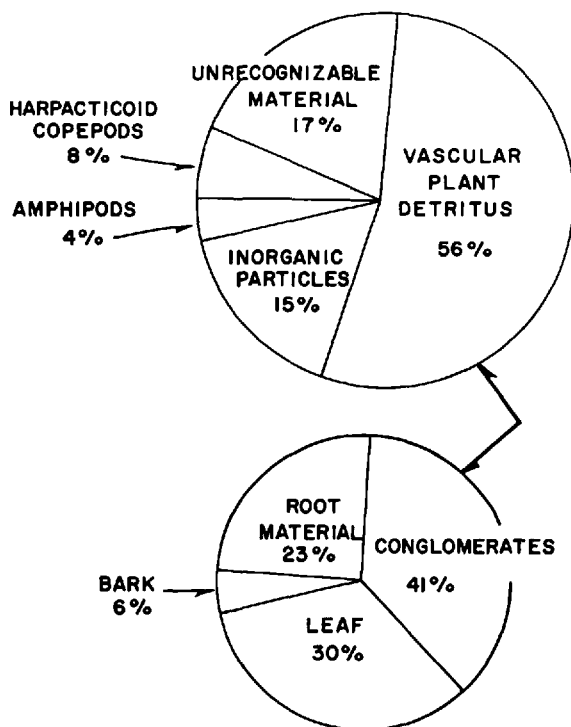


FIGURE 6. The volumetric composition (per cent) of the buccal-cavity contents of 24 snapping shrimp, *Alpheus heterochaelis*, 24-46 mm total length, collected throughout the year.

water marshes. Other regions including the North River basin have relatively sparse populations of blue crabs. Durbin Tabb (personal communication) has suggested that it is the combination of a scarcity of suitable shallow marshes and the further reduction of marsh areas during the seasonal lowering of water level in the dry season that limits blue crab production in the North River. Tagatz (1968) found juvenile blue crabs of less than 40-mm carapace width inhabiting the type of shallow-water habitat that virtually disappears from the North River system during the dry season, due to the drop in water level.

Whatever the reason for the shortage of blue crabs in the North River system, it is not caused by a lack of suitable food material. In Lake Pontchartrain, Louisiana, they were found by Darnell (1958) to feed primarily upon molluscs, crabs, and detrital material. The extensive work of Tagatz (1968), which was done in the St. Johns River, Florida, showed a similar

diet. His examinations of 668 crabs which contained food material revealed 39.0 per cent of the total stomach contents to be made up of molluscs, 19.4 per cent of fish, and 15.9 per cent of crustaceans. The molluscs included clams and mussels of less than 15 mm length; the preferred size was 1.5-5.0 mm. Amphipods and crabs (*Rhithropanopeus harrisii*) were the preferred crustaceans. Other foods included plants, annelids, insects, and bryozoans. Generally, blue crabs of all sizes ate the same things, although ostracods were important to very small crabs. Tagatz (1968) did not indicate that organic detritus was of much importance as food to *Callinectes* in the St. Johns River, although it occurred in many crabs.

Only eight specimens of *Callinectes sapidus* were collected from the North River. They ranged in carapace width from 122 to 180 mm and contained the following items in order of frequency: the mussels *Congeria leucophaeata* and *Brachidontes exustus*, the crab *Rhithropanopeus harrisii*, amphipods, unidentified fish remains, grains of sand, and a small volume of plant detritus (bark and root hairs). All mussels were less than 15 mm in length.

In summary, *Callinectes sapidus* is much less numerous in this estuarine system than might have been supposed prior to intensive collecting, apparently because of a lack of suitable habitat for the juveniles. The moderately small population which is present is concentrated in the mangrove-lined ponds where they feed principally on mussels, *R. harrisii*, and amphipods.

Family Xanthidae

Rhithropanopeus harrisii (Gould)

This little euryhaline crab was abundant at all stations in the North River system and is an extremely important component of the food web. It was collected at salinities which ranged from less than 1‰ to 27.5‰. Quantitative samples from the bed of a small stream draining the *Juncus* marshes revealed more than 40 specimens of *R. harrisii* per square meter, hiding in holes, under logs, leaves, shells, and other debris.

Examination of the buccal-cavity contents of 141 specimens of *R. harrisii*, 3 to 14 mm in carapace width, revealed an omnivorous diet dominated by mangrove leaf detritus (Fig. 7). Crustaceans, such as small amphipods and harpacticoid copepods, were eaten more often by small crabs (2.5-5.0 mm carapace width). Detritus particles averaged 72 μ and ranged up to 800 μ in width; often they appeared to be the result of mechanical reduction of larger pieces by the crab, or even pieces nibbled from entire dead leaves. This leaf detritus is fragmented into very fine material (mean width = 16 μ) by additional grinding in the buccal cavity, so that fecal material contains few large particles.

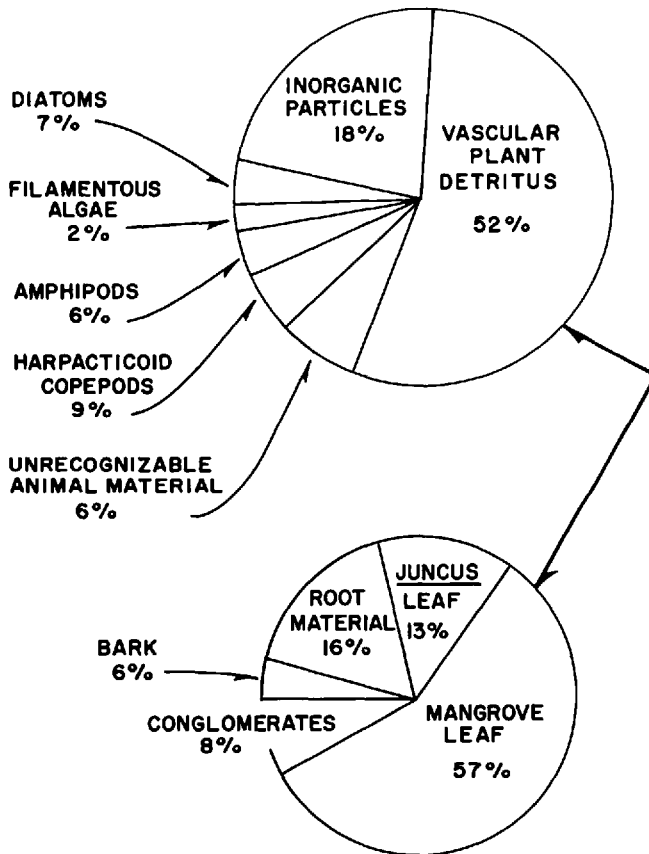


FIGURE 7. The volumetric composition (per cent) of the buccal-cavity contents of 141 specimens of *Rhithropanopeus harrisii*, 3-14 mm carapace width, collected throughout the year.

Class INSECTA
Order DIPTERA
Family Chironomidae

Chironomid midge larvae are present in all habitats of the North River system throughout the year. Although populations of larvae are somewhat reduced during the period from February to May when salinities are usually above 20‰, at least two species are present (*Chironomis* sp. and *Cricotopus* sp.). During freshwater conditions of the remainder of the year, additional species become established (notably *Chironomis decorus*) creating a significant source of food for predatory fishes and crustaceans.

Chironomid larvae are generally regarded as herbivores which consume algae, higher plants, and organic detritus (Pennak, 1953). Feeding may consist of: (1) ingestion of bottom deposits of organic detritus and algae (Thienemann, 1954), (2) grazing of green algae and diatoms (Jansson, 1967), (3) indiscriminate filtering of suspended particles with a mucous net (Walshe, 1947), and (4) tunneling through leaf material or leaf-mining (Walshe, 1951). Hunt (1953) found chironomid larvae from the Tamiami Canal, Florida, filled with diatoms and masses of fine debris, apparently of plant origin.

Since the chironomid larvae from the North River were not identified to species, information concerning digestive-tract contents of individual species was not obtained. We examined the digestive-tract contents from 120 larvae of at least four species, including *Chironomis* sp., and *Cricotopus* sp., and always found very fine material (less than 50μ ; average particle = 8μ). Included in this fine material was usually a small percentage (less than 5 per cent) of diatoms, with the remainder of the volume composed of varying amounts of inorganic particles and organic detritus. About one-third of the detritus could be recognized as originating from mangrove leaves; the remainder was completely unidentifiable. Although in some cases the leaf material appeared to have been torn from dead leaves, a large percentage was composed of decaying detritus particles which had not been macerated by the larvae. Detrital material taken from the digestive tracts of larvae which had been preserved for a few hours in a chilled brine solution was examined both with phase and fluorescence microscopy, which revealed numerous bacteria and ciliates and a few flagellates. Fungi were also present in the gut contents.

It seems probable that most of the nutrition in the diet of the chironomid larvae originates from bacteria and fungi attached to detritus particles. Careful examination of the digestive tract revealed that these two components, along with diatoms, were readily digested, but particles of vascular plant detritus were not noticeably altered.

VERTEBRATES

Phylum CHORDATA

Class CHONDRICTHYES

Family Carcharhinidae

Carcharhinus leucas (Valenciennes)

Bull Shark

Clarke & von Schmidt (1965), while examining the stomach contents of large bull sharks, found remains of *Archosargus probatocephalus*, *Caranx* sp., *Centropomus undecimalis*, *Euthynnus alletteratus*, *Galeichthys felis*, *Lactophrys tricornis*, *Megalops atlanticus*, *Mugil* sp., *Prionotus* sp.,

crustaceans, molluscs, and parts of other sharks. Schwartz (1960) mentioned a number of additional species of fish eaten by adults of *C. leucas* in Chesapeake Bay. Miles (1949) examined five juveniles (100-150 cm) caught in Texas bays and found remains of *Cynoscion arenarius*, *Alosa pseudoharengus*, and *Penaeus setiferus* in their stomachs. Darnell (1958) examined three juveniles of the same size from Lake Ponchartrain, Louisiana, and found a large *Mugil cephalus* (255 mm), a number of small *Brevoortia patronus* (66-103 mm), a *Micropogon undulatus* (67 mm), *Penaeus setiferus*, and a small crab (probably *Callinectes sapidus*). Fishes made up 90 per cent of the ingested food.

We observed young bull sharks in the upper reaches of the North River in October 1967, and May and June 1968, but none was captured. An individual measuring 102 cm, total length, was caught in a trammel net at the pond station in November 1968. In February 1969, 12 individuals ranging in length from 110 to 162 cm were taken in three days in the same manner at the same location. Seven of the 13 sharks were females. Since the young of *C. leucas* are born in Florida in April, May, and June and are about 74-75 cm in total length at birth (Clarke & von Schmidt, 1965), these were probably all yearlings.

Only six of the 13 sharks from the North River pond contained food. Four had eaten individuals of *Galeichthys felis*, which ranged in size from 200 to 250 mm. Two of these specimens of *G. felis* had been bitten into two pieces just behind the dorsal and pectoral spines, and only the posterior portion of the fish had been ingested. Of the two remaining sharks containing food, one had ingested a *Penaeus duorarum* (10-mm carapace), and one a *Lophogobius cyprinoides* 42 mm long.

Class OSTEICHTHYES

Family Lepisosteidae

Lepisosteus platyrhincus DeKay

Florida Gar

Hunt (1953) has written a complete and definitive account of the food chain which supports the Florida gar in the freshwater Everglades. He examined 448 gar, 106 of which contained food. This food was made up of 76.4 per cent fishes and 23.6 per cent invertebrates, by volume. *Gambusia affinis* was the most commonly encountered fish in the stomachs; others included *Lucania goodei*, *Jordanella floridae*, *Heterandria formosa*, *Poecilia latipinna*, and small centrarchids. The most important invertebrate (16.5 per cent of total stomach contents) was *Palaemonetes paludosus*. Chironomid and *Chaoborus* larvae and dragonfly and damselfly nymphs were also ingested by gars.

We examined no gars from the North River. Several were observed

during July and August, and one was caught in a trammel net, but subsequently lost. Although uncommon in the North River, at least during the time of this survey, the species becomes abundant in other basins of the Everglades mangrove belt during the rainy season.

Family Elopidae
Megalops atlantica Valenciennes
Tarpon

We observed moderately large populations of juvenile tarpon in the North River basin. However, a limited amount of suitable habitat in the form of shallow, dark-colored, brackish ponds, as described by Wade (1962), prevents larger populations such as those found in the nearby Roberts River headwaters. In general, the brackish mangrove belt should be regarded as an important habitat for young tarpon.

No tarpon were taken in this survey. From the recent summary of Rickards (1968), young tarpon appear to be strictly carnivorous and predominantly piscivorous. He found that in Georgia marshes *Gambusia* predominated in the stomach contents of tarpon in the size-range 19 to 273 mm; ostracods and *Palaemonetes* were of some importance. Tarpon of larger sizes also consumed *Fundulus heteroclitus* and *Mugil cephalus*. Harrington & Harrington (1960, 1961) examined 214 tarpon between 16 and 45 mm SL and found cyclopoid copepods dominant in the diet, indicating that the very young fish are plankton feeders. Adults prey upon a wide variety of fishes, crabs, shrimp, and even ctenophores (Randall, 1967).

Elops saurus Linnaeus
Ladyfish

Darnell (1958) reviewed the papers of Linton (1904), Gunter (1945), Hiatt (1947), Knapp (1949), and Reid (1954), and concluded that *Elops saurus* feeds on penaeid shrimp and fishes. Springer & Woodburn (1960) agreed that the same diet is consumed by fish in Tampa Bay, Florida, as did Cervigón (1966) for Venezuelan *E. saurus*. From the data of Harrington & Harrington (1961), it can be concluded that the diet of young ladyfish in marsh communities is based upon copepods until the fish reach a size of about 45 mm. At this point they begin feeding upon small fishes and *Palaemonetes*.

Juvenile ladyfish are found abundantly throughout the brackish mangrove belt. In the North River basin they first appear at a length of about 20 mm; the largest specimen collected was 346 mm. Larger fish are found in the deeper sections of Florida Bay and the mouth of the Shark River (Tabb & Manning, 1961).

Our analyses of the food of *E. saurus* in the North River agree with the

quoted literature. Five of six fish ranging from 19 to 38 mm were filled with copepods and a few crab zoeae; the sixth was empty. Of 28 fish measuring between 223 and 346 mm, only nine contained food; this food by volume was composed of 44 per cent caridean shrimp and 56 per cent small fishes (*Poecilia latipinna*, *Eucinostomus gula*, *Menidia beryllina*, and *Anchoa hepsetus*). The larger individuals of *E. saurus* appeared to feed primarily from dusk to dawn.

Family Clupeidae

Harengula pensacolae Goode & Bean Scaled Sardine

Reid (1954) listed planktonic crustaceans as the food of *Harengula pensacolae* near Cedar Key, Florida. Mysids, amphipods, copepods, ostracods, and small molluscs were removed from a large number of fish taken from Tampa Bay by Springer & Woodburn (1960).

Small schools of juveniles of *H. pensacolae* (60-100 mm) visit the lower North River and mangrove ponds during the winter months when salinities are above 15‰. Scrutiny of 45 stomachs of fish from 64-96 mm revealed 32 that contained food (Fig. 8). Amphipods were the chief food and probably made up most of the "unidentified residue" category. Twenty-two smaller fish (16-30 mm) collected in the Little Shark River contained planktonic copepods, zoeae, nauplii, and a few fish larvae.

Family Engraulidae

Anchoa mitchilli (Valenciennes) Bay Anchovy

The food of *Anchoa mitchilli* was described by Hildebrand & Schroeder (1928) as mysids and copepods. Springer & Woodburn (1960) concluded from the stomach contents of 42 specimens of *A. mitchilli* from Tampa Bay, Florida, that the principal foods are copepods, ostracods, mysids, pelecypods, gastropods, small fishes and crustacean larvae. From his work in Lake Pontchartrain, Louisiana, Darnell (1958) suggested that this anchovy passed through two ontogenetic feeding stages. Young individuals (no size specified) are plankton strainers consuming large quantities of microzooplankton and suspended detritus. At larger sizes the fish are more selective and prey upon planktonic mysids, postlarval shrimp, and larval fishes in addition to mysids, amphipods, isopods, ostracods, harpacticoid copepods, small snails, and clams obtained from the benthos.

The bay anchovy is the most abundant fish in the brackish bays of the Everglades estuary (Tabb & Manning, 1961; Roessler, 1967). It is not, however, particularly numerous in the North River system; this indicates that this fish may prefer to remain in more open waters.

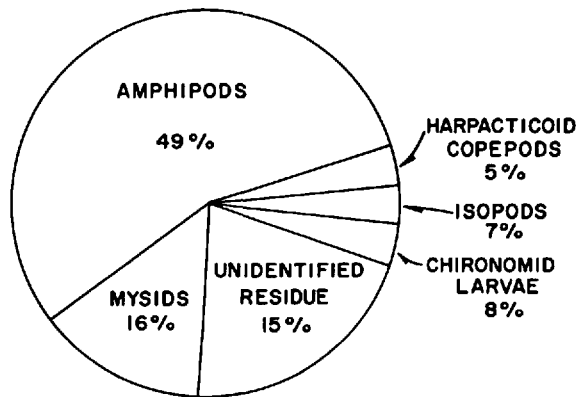


FIGURE 8. The volumetric composition (per cent) of the stomach contents of 32 scaled sardines, *Harengula pensacolae*, 64-96 mm long, collected between December 1967, and March 1968.

Examination of *A. mitchilli* from the North River did not completely support Darnell's conclusions about the Lake Pontchartrain population of *A. mitchilli*. Seventeen larval and young juveniles of less than 25 mm had fed solely upon microzooplankton (copepods, copepodites, nauplii) which did not appear to have been ingested as the result of simple straining of the water but rather as the product of selective capture of the appropriately-sized organisms. Further evidence against simple filtration was provided by the complete absence in the fish's stomach of detritus particles of the same size as the microzooplankton. Charles A. Mayo (personal communication) has observed larvae of *A. mitchilli* in the laboratory and is convinced that feeding is a process of intentional, visually aided capture of individual zooplankters.

Twenty-seven larger bay anchovies (31-62 mm) were dissected and found to have consumed material similar to that described by Darnell for anchovies of this size (Fig. 9); little of this food originated from the plankton. Seventy-five specimens of *A. mitchilli* were collected in July from the Turkey Point shrimp-rearing ponds of the University of Miami, a system in which planktonic copepods are very numerous. All of these anchovies had fed upon planktonic copepods (*Acartia* sp.) to the exclusion of benthic organisms. The predominantly benthic feeding in the North River is probably encouraged by the abundance of benthic organisms and the meager supply of zooplankton; this scarcity could explain the relatively low populations of anchovies in the North River system.

Anchoa hepsetus, which is most abundant in Florida Bay (Tabb & Manning, 1961) and other areas of higher salinity, was encountered infrequently in the North River.

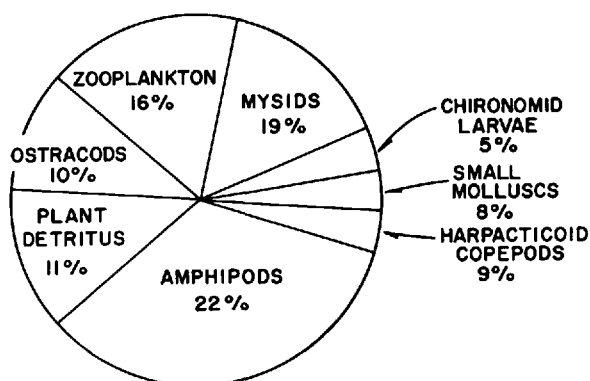


FIGURE 9. The volumetric composition (per cent) of the stomach contents of 27 bay anchovies, *Anchoa mitchilli*, 31-62 mm long, collected throughout the year.

Family Synodontidae
Synodus foetens (Linnaeus)
 Inshore Lizardfish

Smith's (1907) description of *Synodus foetens* ably characterizes its feeding: "It is a voracious feeder; small fish constitute its principal food, but crabs, shrimp, worms and other animals are eaten." This description is supported by the data of Hildebrand & Schroeder (1928), Reid (1954), and Springer & Woodburn (1960).

S. foetens occasionally enters the lower portion of the North River and associated mangrove ponds during late winter and early spring when salinities exceed 15‰. Only two specimens (189 and 112 mm) were taken during this survey, and neither contained food.

Family Ariidae
Arius felis (Linnaeus)
 Sea Catfish

Darnell (1958) has summarized the extensive literature on *Arius felis* and concluded, from this and from examination of catfish from Lake Pontchartrain, Louisiana, that three feeding stages exist. For fish of less than 100 mm, copepods and other zooplankton appear to be most important. Above this size, benthic invertebrates become more important until, finally, catfish above 200 mm eat larger crabs and fishes (this final stage is apparently not the case for *A. felis* in the North River). Although other authors have not emphasized it, "bottom detritus" was noted by Darnell in a large proportion of the catfish stomachs in Louisiana. He suggested that the presence of only the hard parts of fishes in the catfish stomachs was traceable to straining of bottom sediments and not actual capture of live fish

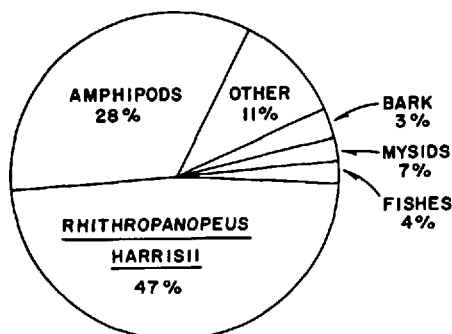


FIGURE 10. The volumetric composition (per cent) of the stomach contents of 62 sea catfish, *Arius felis*, 205-331 mm long, collected throughout the year.

(this is not true for *A. felis* in the North River, as fresh fishes were found in their stomachs).

Both Knapp (1949) and Harris & Rose (1968) have emphasized the ability of *A. felis* to consume large quantities of commercial penaeid shrimp. Of 468 catfish examined by Knapp in Texas, 87 per cent had eaten shrimp. Harris & Rose presented data which estimated a potentially significant loss to the shrimp fishing industry from catfish predation.

Arius felis is abundant at all times of the year throughout the North River, including the mangrove-lined ponds and small creeks that drain the *Juncus* marshes in the headwaters region. Figure 10 summarizes the food of 62 catfish (205 to 331 mm) from the North River. Included in the miscellaneous category are 11 types of food, each of which made up less than five per cent of the fish's diet: nematodes, crayfish, dragonfly larvae, tarpon and other fish scales, adult insects, *Brachidontes exustus*, isopods, algal strands, *Penaeus duorarum*, *Palaemonetes* spp., and *Alpheus heterochaelis*. It is this utilization of a number of food sources which probably explains the ability of *A. felis* to adapt successfully to different habitats.

The stomach contents of 14 young of *A. felis* (52-74 mm) from White-water Bay were dominated by amphipods; other foods were mysids, chironomid larvae, isopods, and small crabs.

Bagre marinus (Mitchill) Gafftopsail Catfish

There is a hint in the literature that the diet of *Bagre marinus* may be different from that of *A. felis*. Gudger (1916) stated that the blue crab, *Callinectes sapidus*, is the staple food of *B. marinus* in North Carolina waters (quoted from Gunter, 1945). Gunter examined five gafftopsails from Texas and found blue crabs in all five. Miles (1949) looked at 85 fish from

Texas and found six species of crabs, 11 species of fishes, and penaeid shrimp in their stomachs. Cervigón (1966) stated that *B. marinus* in Venezuela feeds on crabs, shrimp, and small fishes.

Bagre marinus was outnumbered eight to one by *Arius felis* in our catches from the North River. These data agree closely with the ratio of 10 to 1 found by Tabb & Manning (1961) after a large fish-kill in White-water Bay.

Of eight gafftopsail catfish (262-445 mm) that we examined from the North River, five contained food. Three had eaten small individuals of *Callinectes sapidus*, whose carapace width was 40-50 mm; the remaining two contained remains of unidentified fish. In contrast to *A. felis*, no amphipods or mysids were found in their stomachs. Although this is an extremely small sample, it does suggest a possible difference in diet compared to *A. felis*. Specimens of the latter species from the same samples as those of *B. marinus* rarely were found without amphipods or with fishes or *Callinectes* in their stomachs.

Family Anguillidae

Anguilla rostrata (LeSueur)

American Eel

Hildebrand & Schroeder (1928) regarded large American eels as omnivorous consumers of crustaceans, annelids, fish, echinoderms, molluscs, and eelgrass. Small eels, 50-200 mm long, feed on amphipods and isopods. De Sylva *et al.* (1962) listed a number of food items removed from the stomachs of 47 specimens of *A. rostrata* from the Delaware River estuary. Included were polychaetes, mysids, larvae and eggs of *Limulus*, *Menidia* sp., and insect remains.

During rotenone sampling in the North River, we commonly collected *Anguilla* from beneath the undercut banks of the river channel and small streams. Although eels taken in our survey ranged from 181 to 472 mm, Tabb & Manning (1961) reported several of 1000 mm from the Everglades estuary.

Eight eels (181-472 mm) examined from North River daytime samples were empty, indicating nocturnal feeding. Four of the same size-range taken at night contained *Rhithropanopeus harrisi*, *Palaemonetes intermedius*, *Alpheus heterochaelis*, and *Lophogobius cyprinoides*.

Family Cyprinodontidae

Fundulus confluentus Goode & Bean

Marsh Killifish

Harrington & Harrington (1961) analyzed the stomach contents of 88 specimens of *Fundulus confluentus* from a Florida salt marsh and found that when mosquito instars and pupae were present in the environment they dominated the fish's diet. At other times they consumed *Palaemonetes*,

isopods, amphipods, fishes, insects, nematodes, gastropods, ostracods, and a small amount of plant material. In a *Spartina* marsh pool at Sapelo Island, Georgia, *Spartina* detritus and algae composed 30 per cent of the stomach contents of three marsh killifish (Kawanabe *et al.*, unpublished manuscript).

E. confluentus is one of the most common fishes from the brackish marsh areas of the Everglades estuary (Tabb & Manning, 1961), although its abundance evidently fluctuates. In 1965-66, the marsh killifish was listed by Tabb (1966) as the fifth most common fish taken in the entire North River basin, with more than 500 collected. Sampling at the same stations with the same gear in 1968-69 yielded only 16 specimens of *F. confluentus*. These had fed upon chironomid larvae and amphipods. The fish collected in 1965-66 (examined by W. Drummond) had ingested chironomid larvae, adult insects, amphipods, small bivalve molluscs, and a few isopods. Fish (primarily *Gambusia affinis*) occurred in stomachs of killifish more than 55 mm long, but most often in those longer than 70 mm.

Fundulus grandis Baird & Girard
Gulf Killifish

Springer & Woodburn (1960) reported a varied diet for *Fundulus grandis* from the Tampa Bay, Florida, region. The diet included hermit crabs, pelecypods, unidentified arthropods, and small fishes such as *Poecilia latipinna*. Harrington & Harrington (1961) found the stomach contents of the gulf killifish to be composed of *Palaemonetes*, mosquitoes, and small fishes.

Fundulus grandis is a small predator of the marsh pools, small streams, and shoreline areas of the North River. Of 27 fish that we examined, those between 29 and 45 mm had eaten amphipods, isopods, small specimens of *Rhithropanopeus harrisii* (2-4 mm, carapace width), chironomid larvae, terrestrial insects, small snails, and filaments of algae. Above this length, they included fishes and larger specimens of *R. harrisii* (up to 12 mm, carapace width) to the exclusion of the smaller components of the diet. One killifish of 68 mm had managed to swallow a *Gambusia affinis* of 25 mm.

Cyprinodon variegatus Lacépède
Sheepshead Minnow

Cyprinodon variegatus is generally regarded as an herbivore that ingests algae, plant detritus, and sand particles (Hildebrand & Schroeder, 1928; Reid, 1954; Springer & Woodburn, 1960), although Harrington & Harrington (1961) found that they fed upon mosquito instars and pupae when available in the environment.

Although the sheepshead minnow may at times be abundant in the *Juncus*-lined pools and along the shallow edges of the North River (Tabb,

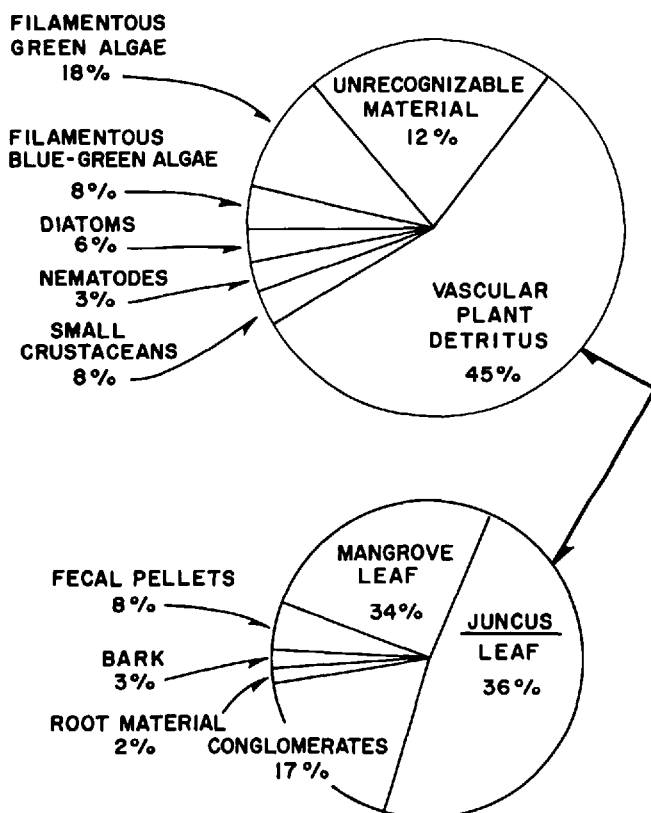


FIGURE 11. The volumetric composition (per cent) of the digestive-tract contents of 44 sheepshead minnows, *Cyprinodon variegatus*, 15-53 mm long, collected throughout the year.

1966), during the period of this survey we captured relatively few individuals and these were greatly outnumbered by *Floridichthys carpio*. The food of 44 specimens of *C. variegatus* (15-53 mm) that we collected from the *Juncus* marsh pools is indicated in Figure 11. There was little variation from a predominantly detritus-algal diet, although fish ranging from 10 to 15 mm had eaten a few harpacticoid copepods and small amphipods.

Floridichthys carpio (Günther)
Goldspotted Killifish

This species was considered by Tabb & Manning (1961) to be rare in the Everglades estuary. During the present survey we collected *Floridichthys carpio* routinely throughout the year in water which ranged from less than 1‰ to 26.5‰. In the *Juncus* marsh pools it was taken in ap-

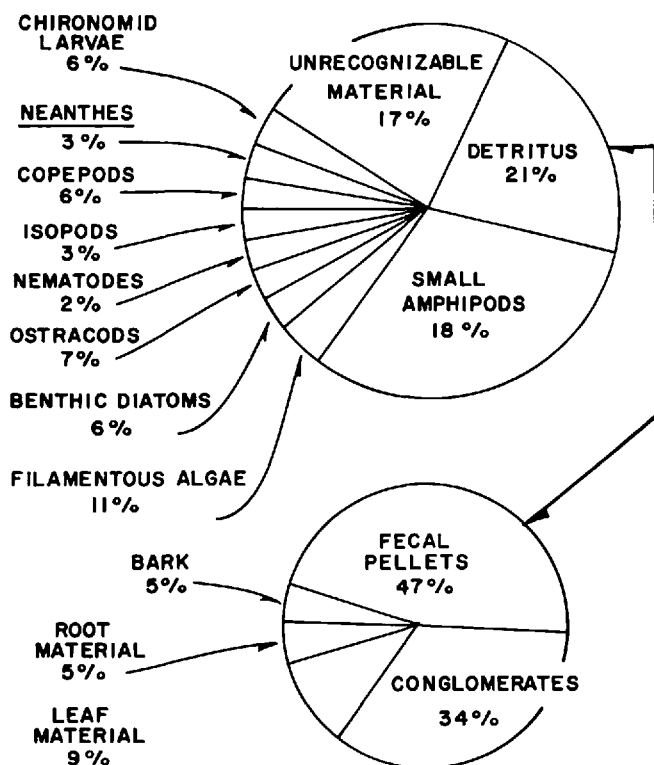


FIGURE 12. The volumetric composition (per cent) of the digestive-tract contents of 81 goldspotted killifish, *Floridichthys carpio*, 14-59 mm long, collected throughout the year.

proximately the same numbers as *Cyprinodon variegatus*, but outnumbered the latter 20 to 1 in samples from the shallow waters adjacent to the shore of the North River.

Little information exists concerning the food of *F. carpio*. Springer & Woodburn's data (1960) from Tampa Bay, Florida, indicated a diet of tiny crustaceans, molluscs, and annelids. This indication of a more carnivorous diet than that of *C. variegatus* is supported by our data from the North River (Fig. 12). At least 45 per cent of the food material was of animal origin, compared to 11 per cent for *C. variegatus* (Fig. 11).

Adinia xenica (Jordan & Gilbert)
Diamond Killifish

This little fish was collected in every season from the *Juncus* marsh pools, but never were more than two or three taken in the same sample.

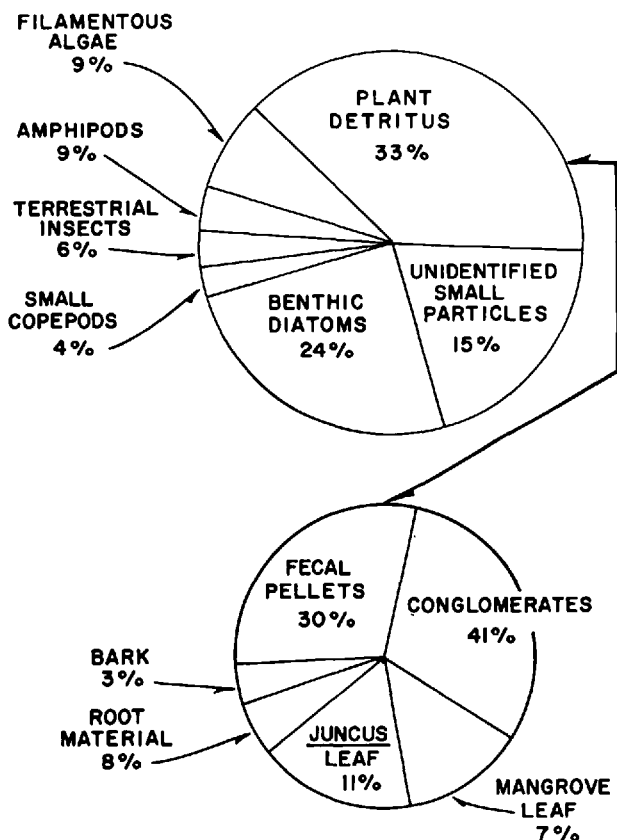


FIGURE 13. The volumetric composition (per cent) of the digestive-tract contents of 28 diamond killifish, *Adinia xenica*, 26-33 mm long, collected throughout the year.

We could find no information in past literature which referred to its food. Examination of 28 fish (26-35 mm) from the *Juncus* marsh station indicated a diet (Fig. 13) that was based primarily upon plants, both living and detrital. Almost all of this ingested plant material was very fine, either tiny detrital particles or diatoms. When animal material was consumed, it was eaten to the exclusion of plant material.

Lucania parva (Baird)
Rainwater Killifish

Hildebrand & Schroeder (1928) considered the diet of *Lucania parva* to be small crustaceans. Harrington & Harrington (1961) found cyclopoid

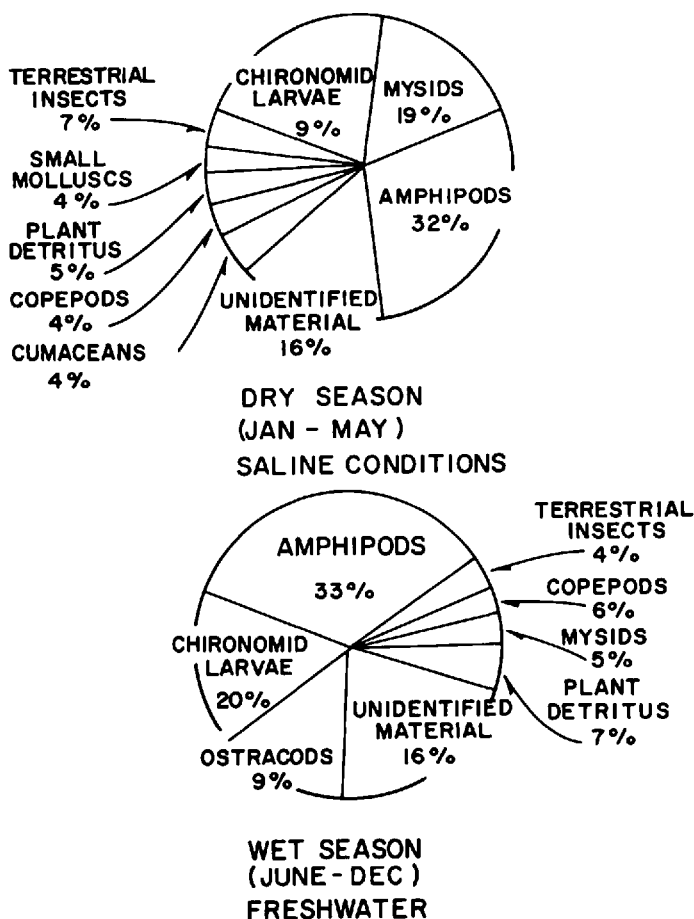


FIGURE 14. The volumetric composition (per cent) of the stomach contents of 74 rainwater killifish, *Lucania parva*, 21-37 mm long, collected throughout the year.

and harpacticoid copepods dominant in the diet, except during periods when mosquito instars and pupae were present in the environment and were consumed in large numbers. Plant material was found infrequently.

Together with *Gambusia affinis* and *Menidia beryllina*, this is one of the most abundant, small, carnivorous, forage fishes in the North River. It serves as an intermediate step between the detrital-algal feeders and the top carnivores. Forty-eight specimens of *L. parva* (less than 20 mm) from the North River had eaten planktonic copepods almost exclusively. The diet of fish measuring 21 to 37 mm is shown in Fig. 14.

Lucania goodei Jordan

Bluefin Killifish

Hunt (1953) studied the diet of *Lucania goodei* in the Tamiami Canal and found that 95 per cent of the volume of the stomach contents was composed of animal matter (chironomid larvae, ostracods, copepods, cladocerans, mayfly nymphs, Hydracarina, and snails). The bluefin killifish exhibits little tolerance for saline water and moves into the mangrove belt of the Everglades estuary only during the summer period of freshwater influx. As Tabb & Manning (1961) have pointed out, it is common at such times, but never abundant. We examined the stomach contents of 12 specimens of *L. goodei* (18 to 23 mm) from the North River; eight contained food that included copepods, cladocerans, ostracods, and chironomid larvae.

Family Poeciliidae

Gambusia affinis (Baird & Girard)

Mosquitofish

Hunt's (1953) review of the literature demonstrates that although *Gambusia affinis* is considered a surface feeder with a predilection for insects and insect larvae, it is quite capable of switching to an almost completely herbivorous diet based on benthic and epiphytic algae. For instance, Harrington & Harrington (1961) found over 70 per cent of the stomach contents of mosquitofish from a south Florida salt marsh to be composed of mosquito larvae and pupae, along with other arthropods, and only 8 per cent of the volume to be made up of plant material. On the contrary, Barney & Anson (1920), Ward (1931), and Hiatt (1947) have mentioned the importance of algae in the diet. Hunt (1953) estimated that 174 specimens of *Gambusia* from the Tamiami Canal in the Florida Everglades had fed upon algal material (60 per cent) and animal material (40 per cent). The algae originated from the periphyton and were not phytoplankton; the animals which had been consumed included chironomid larvae, Entomostraca, ants, and many insects and small crustaceans. Mosquito larvae were found in only two stomachs.

Gambusia affinis is a ubiquitous fish found in every type of aquatic habitat in the North River basin; it reaches its greatest abundance in the headwater creeks and *Juncus* marsh pools. Of 107 individuals (14 to 41 mm) that we examined, 87 contained food (Fig. 15). In contrast to Hunt's data from the freshwater Everglades, algal material was of little importance, occurring in only 22 per cent of the stomachs examined. This may be explained, in part, by the scarcity of algae in the mangrove sector compared to the periphyton-encrusted canal in which Hunt collected his fish. The "other" category in Figure 15 includes harpacticoid copepods, small snails, ants, adult insects, *Neanthes*, ostracods, and mosquito pupae. The

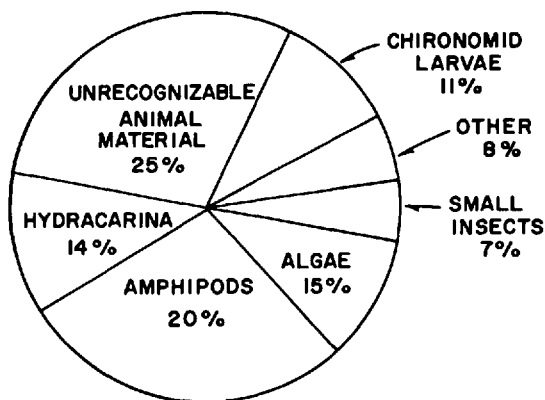


FIGURE 15. The volumetric composition (per cent) of the stomach contents of 87 mosquito fish, *Gambusia affinis*, 14-41 mm long, collected throughout the year.

latter were found in only three fish. There were no discernible seasonal trends in change of diet, nor were there differences in the fish's diet between the sampling stations. Any changes in food ingested from one sample to the next reflected the opportunistic nature of this fish.

Poecilia latipinna (Lesueur)
Sailfin Molly

The food of *Poecilia latipinna* has been investigated by several authors. Hiatt (1947) found mollies feeding upon periphyton and plant debris in Hawaiian fish ponds. Hunt's data (1953) from Florida's Tamiami Canal indicate a similar diet, although a few small ostracods and rotifers were consumed. Harrington & Harrington (1961) stated that vascular plant detritus was the item ingested in the greatest quantities by mollies in a high tidal marsh. They also noted feeding upon mosquito instars and pupae when available.

In the North River system, this fish is abundant throughout the year in the flooded *Juncus* marshes and associated pools. The greatest numbers were captured between February and April, but this was because water levels are lowest at this time and the fish are concentrated in the shallowest depths. Two hundred twenty-four mollies (29-54 mm) had fed almost exclusively upon fine particles, most of which were of vascular plant origin (Fig. 16). Particles larger than 800μ were seldom ingested. Filamentous algae were rarely eaten and fecal pellets and animal material were not found in the digestive tract.

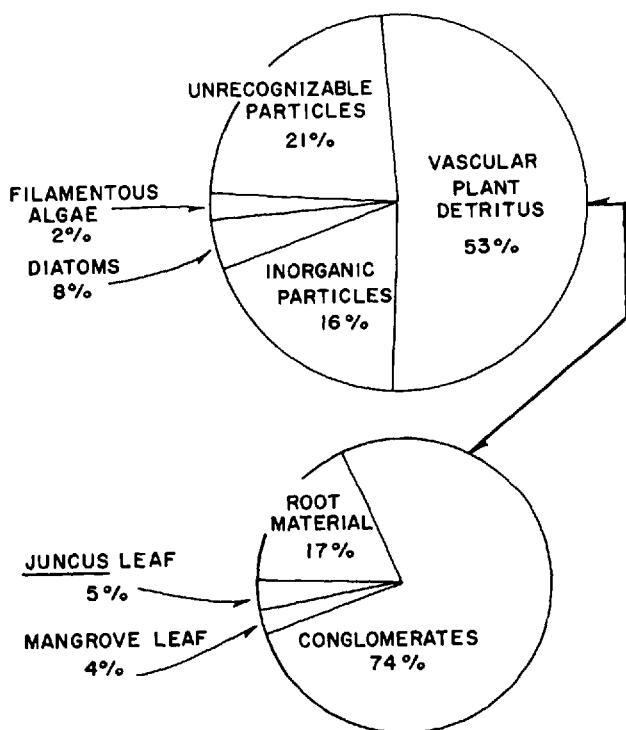


FIGURE 16. The volumetric composition (per cent) of the digestive-tract contents of 224 sailfin mollies, *Poecilia latipinna*, 29-54 mm long, collected throughout the year.

Heterandria formosa Agassiz
Least Killifish

Seal (1910), Mellen (1927), and Hunt (1953) all considered *Heterandria formosa* to be omnivorous, although the first two authors regarded the fish as primarily carnivorous. Hunt's investigation in the Tamiami Canal revealed a diet of 80 per cent plant material (green algae, diatoms, and detritus) and 20 per cent of animal origin (rotifers, copepods, cladocerans, chironomid larvae, and Hydracarina).

The least killifish is common, but not abundant in the headwaters of the North River. Surprisingly, we collected it there all year, even when salinities were as high as 23‰. The stomach contents of 22 fish (11 to 18 mm) are summarized in Figure 17. They normally feed upon epiphyte-encrusted surfaces of mangrove roots and drooping limbs.

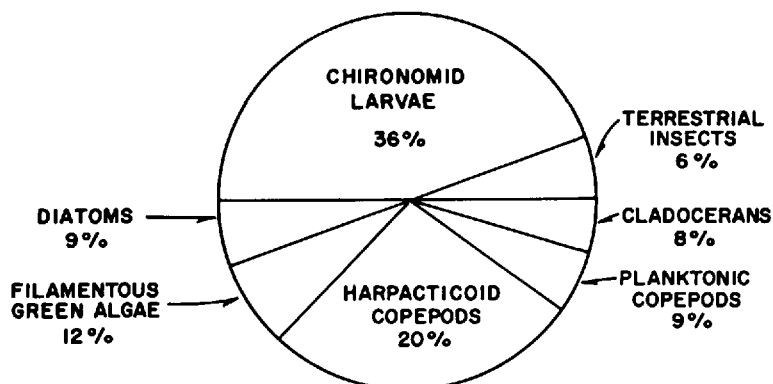


FIGURE 17. The volumetric composition (per cent) of the stomach contents of 22 least killifish, *Heterandria formosa*, 11-18 mm long, collected throughout the year.

Family Centropomidae
Centropomus undecimalis (Bloch)
 Snook

Although they occur elsewhere in Florida, snook are found principally in the brackish-water mangrove habitat. During the years when commercial snook fishing was legal, the greatest catches came from the mangrove belt of southwest Florida (Marshall, 1958). *Centropomus* sp. was often observed in the North River during the course of this survey, but none was captured. Small specimens occur in the *Juncus* marsh pools and small drainage streams in the headwaters; older fish are found in the main river channel and in the mangrove-lined ponds near the mouth.

Since we do not have data on stomach contents of snook, it is necessary to base the analysis of their trophic position upon other sources. Marshall (1958) obtained 128 fish ranging from 230-851 mm in length from the nearby Ten Thousand Islands and found food in 61. Fish were the most important food (occurred in 57.3 per cent of those examined); they included *Eucinostomus* sp., *Mugil cephalus*, *Lagodon rhomboides*, *Anchoa* spp., *Poecilia latipinna*, and *Gambusia affinis*. Other foods were caridean and penaeid shrimp (occurred in 41 per cent), crabs (in 18 per cent), and crayfish (in 8.2 per cent). Thomas H. Fraser (personal communication) has suggested that crayfish and *Macrobrachium* sp. may be of importance as freshwater food, along with fishes such as *Menidia beryllina*, *P. latipinna*, and *M. cephalus*. Cervigón (1966) stated that *C. undecimalis* in Venezuelan lagoons feeds on small shrimp, anchovies, and small catfish (*Bagre* sp.). Springer & Woodburn (1960) found snook in Tampa Bay, Florida,

feeding principally upon fish. Those of less than 56 mm had eaten small crustaceans.

Snook less than 100 mm long are found in marginal habitats, such as marsh edges, ponds, and ditches (Marshall, 1958). Harrington & Harrington (1961) found specimens of this size in a Florida east-coast marsh feeding on fishes and to a lesser extent on caridean shrimp. Linton & Rickards (1965) reported juveniles from Georgia marshes consuming caridean shrimp and a few specimens of *Gambusia*.

Family Serranidae

Epinephelus itajara (Lichtenstein)

Jewfish

Young jewfish occur seasonally along the north shore of Whitewater Bay and in the mouth of the North River, although not in the numbers found in the Shark River estuary. Their presence in the North River is dependent upon salinity values above 25‰ (Tabb & Manning, 1961). For this reason, *Epinephelus itajara* should not be considered a significant component of the North River system.

Little information exists concerning the food of juvenile jewfish. Smith (1961) stated that *E. itajara* feeds chiefly on crustaceans. Randall (1967) found adults on West Indian reefs feeding on lobsters (68.9 per cent of volume), crabs (12.2 per cent), fishes (13.3 per cent), and sea turtles (5.6 per cent). Two specimens of *E. itajara* (191 and 232 mm), which we captured in the mouth of the North River, contained both *Penaeus duorarum* and *Rhithropanopeus harrisii*.

Family Lutjanidae

Lutjanus griseus (Linnaeus)

Gray Snapper, Mangrove Snapper

As shown by Springer & Woodburn (1960), juveniles of *Lutjanus griseus* spend their first few months in grass communities such as those found in Florida and Whitewater bays. The young fish feed during daylight hours (Randall, 1967; also supported by our data), primarily upon small crustaceans. At a length of about 50 mm, the snappers begin to leave the grass beds and move into areas of rocky bottoms or mangrove shores, as found in the North River system. This change of habitat is accompanied by a change of diet to fishes and larger crustaceans.

Crocker (1962) concluded that juveniles of *L. griseus* in the Everglades estuary feed on grapsid crabs and penaeid shrimp and to a lesser degree on fish such as *Anchoa* spp. He could not detect a significant difference in the diet from month to month or among snappers ranging from 130 to 475 mm in length. Tabb & Manning (1962) recorded shrimp, crabs, and various small fish from snappers in the Whitewater Bay region. Longley &

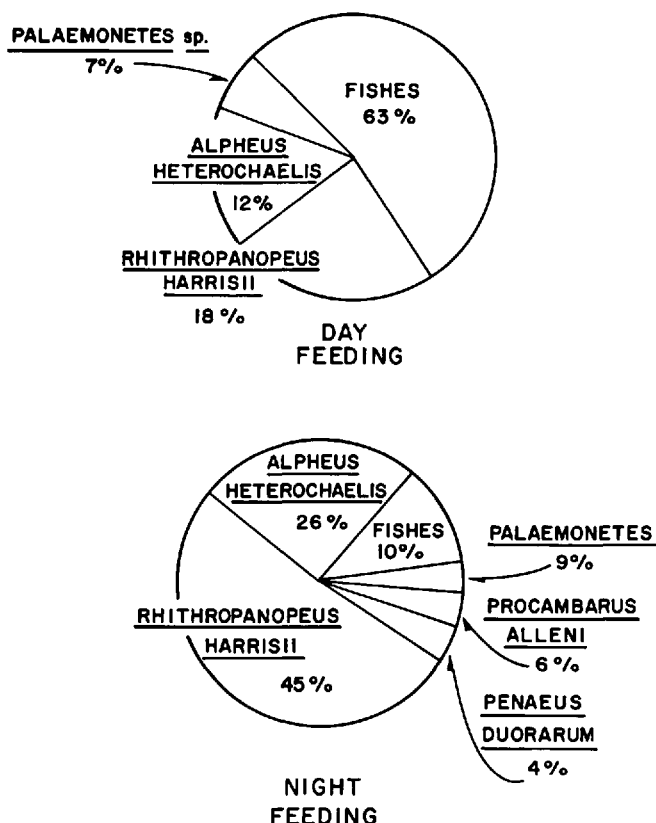


FIGURE 18. The volumetric composition (per cent) of the stomach contents of gray snappers, *Lutjanus griseus*, 95-254 mm long, collected throughout the year. Of 74 fish captured during the day, 60 contained food; 36 of 38 from the night samples contained food.

Hildebrand (1941) found *L. griseus* in the vicinity of the Tortugas feeding on crabs, shrimp, squid, and annelids. Springer & Woodburn (1960) discovered only fishes in the stomachs of gray snappers from Tampa Bay, Florida. Randall (1967) stated that adults on the offshore reefs eat more fish than crustaceans.

Of 112 mangrove snappers that we captured in the North River, none was shorter than 85 mm or longer than 254 mm. This suggests that almost all North River snappers are in the I and II year-classes (Croker, 1962). There appears to be a movement of late II and III year-class snappers out of brackish areas such as the North River into Florida Bay, since the modal size of the North River fish was considerably smaller (192 mm, fork length)

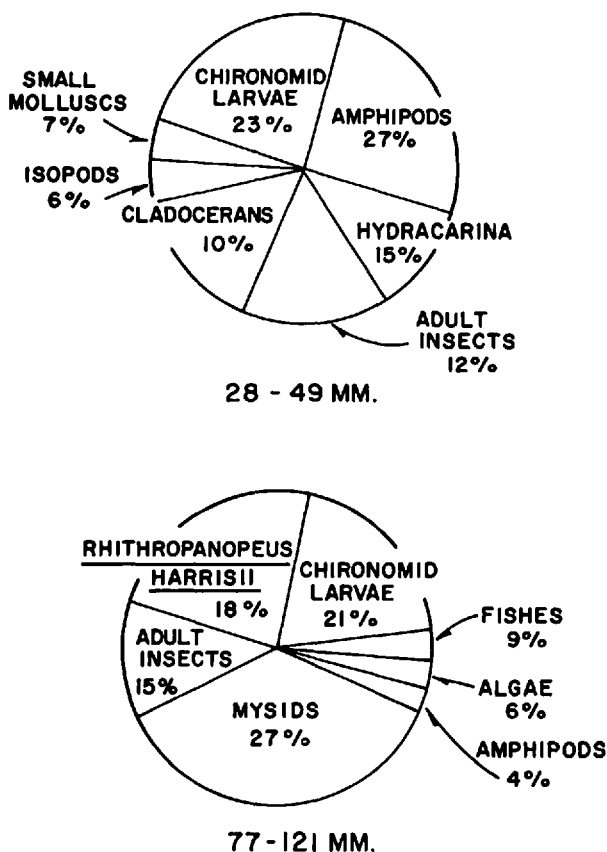


FIGURE 19. The volumetric composition (per cent) of the stomach contents of spotted sunfish, *Lepomis punctatus*, taken between May 1968, and February 1969. Of 32 fish ranging from 28-49 mm long, 27 contained food; 19 of 23 in the range 77-121 mm contained food.

than for snappers collected by Croker in the vicinity of Flamingo (250 mm, fork length). Mature mangrove snappers are found on offshore reefs.

The contents of the 112 specimens of *L. griseus* from the North River are summarized in Figure 18. There was no detectable difference in diet between times of the year or between snappers of different sizes in the range 95-254 mm. Snappers taken at night or in the early morning had fed almost exclusively on crustaceans, while fishes predominated in daylight feeding. By far the most commonly ingested fish was *Lophogobius cyprinoides*; others included *Microgobius gulosus*, *Anchoa hepsetus*, *A. mitchilli*, *Gambusia affinis*, *Poecilia latipinna*, *Fundulus grandis*, and

Anguilla rostrata. One 141-mm snapper had managed to swallow a specimen of *A. rostrata* 210 mm long.

Family Centrarchidae

Tabb & Manning (1961) listed five centrarchids which are normally found in the freshwater regions of the Everglades but move into the mangrove zone during the rainy season. The list was composed of the warmouth, *Lepomis gulosus*; the bluegill, *L. macrochirus*; the redear sunfish, *L. microlophus*; the spotted sunfish, *L. punctatus*; and the largemouth bass, *Micropterus salmoides*. All of these probably stray into the North River at times of low salinities, but only *L. punctatus* was collected commonly in our survey; *L. macrochirus* and *M. salmoides* were occasionally observed in the headwater creeks, but in very limited numbers.

Lepomis punctatus (Valenciennes) Spotted Sunfish

Hunt (1953) reported on the stomach contents of 20 spotted sunfish from the Tamiami Canal in the freshwater Everglades. Principal components of the diet of these fish were copepods, ostracods, chironomid larvae, and cladocerans. The sunfish also ate rotifers, mayflies, damselflies, nymphs, Hydracarina, and snails in lesser quantities.

We took 67 specimens of *Lepomis punctatus* from the North River between May and February, a period when salinities did not exceed 15‰ to 20‰. They occurred first at the headwater station in May and had penetrated to the river mouth by June. The occurrence of individuals as small as 14 mm in the *Juncus* marsh pools in November indicates that spawning probably takes place in the mangrove belt.

Eight spotted sunfish (14-18 mm) taken in November had eaten cladocerans exclusively. Four other fish between 18 and 29 mm had eaten insects, cladocerans, chironomid larvae, isopods, and amphipods. The diet of two size-classes of the larger fish is depicted in Figure 19.

Family Carangidae *Caranx hippos* (Linnaeus) Crevalle Jack

Darnell (1958) classified the crevalle jack as a predator which feeds on fishes, crabs, squids, shrimp, and smaller invertebrates. Hildebrand & Schroeder (1928) and Reid (1954) found only fish in crevalle jack stomachs. De Sylva *et al.* (1962) took 40 specimens of *C. hippos* ranging from 30 to 160 mm long from Delaware Bay; they found mysids most important to fish of less than 70 mm, and *Palaemonetes* spp. eaten by those

between 100 and 150 mm. The few fishes which had been consumed by these young jacks included gobies, anchovies, and atherinids.

Twenty-two specimens of *Caranx hippos* ranging from 147 to 241 mm long were collected from the North River, but we saw much larger fish of at least 600 mm as far inland as the small streams of the headwaters. Only six of the captured jacks contained food (penaeid shrimp) in their stomachs. Since all six fish were captured in traps, we regard the data as inconclusive.

Oligoplites saurus (Bloch & Schneider)

Leatherjacket

This fish was listed by Tabb & Manning (1961) as common in White-water Bay, but only near tidal inlets. It does, however, penetrate the North River system during April and May when salinities exceed 25‰. In the same publication, Tabb & Manning mentioned that leatherjackets measuring 30 to 120 mm from the Everglades estuary feed on *Alpheus heterochaelis*, small individuals of *Penaeus duorarum*, and larval fishes.

We captured 24 specimens of *Oligoplites saurus* (162 to 247 mm) from the North River and its mangrove-lined ponds; none contained food. One juvenile fish (29 mm) was taken in June. Its stomach was full and contained a larval fish 5 mm long and three young of *Palaemonetes* sp.

Family Gerreidae

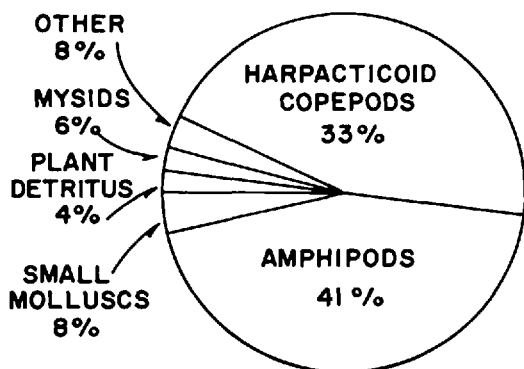
Eucinostomus gula (Quoy & Gaimard)

Silver Jenny

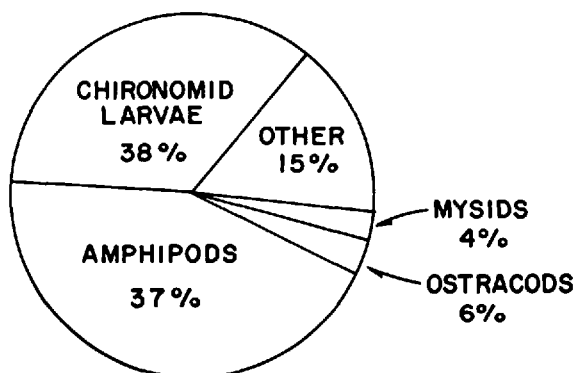
The abundance of this species in the Everglades estuary is reflected by its dominance in the biomass of Roessler's (1967) catches from Buttonwood Canal. Tabb (1966) found it the fourth most abundant fish in the North River; in our catches it occurred in equal numbers with *E. argenteus* and was outnumbered only by *Menidia beryllina*, *Gobiosoma robustum*, and *Lophogobius cyprinoides*. Waldinger (1968) discussed aspects of the biology of this and other species of gerreids from the Everglades mangrove region.

Springer & Woodburn (1960) found copepods, polychaetes, ostracods, amphipods, and small pelecypods eaten by *E. gula* from Tampa Bay, Florida. They found no copepods in fish larger than 45 mm.

The percentages for the stomach contents of 38 specimens of *E. gula* (35-70 mm) taken during the saline period from January to May, and 74 fish (19-54 mm) from the freshwater period during the remainder of the year are shown in Figure 20. Harpacticoid copepods, small molluscs, and *Nereis* disappear from the diet with the arrival of freshwater conditions and are replaced by chironomid larvae, which are of little importance during the saline period. Amphipods are eaten in equal numbers throughout the year.



**DRY SEASON (JAN-MAY)
SALINE CONDITIONS**



**WET SEASON (JUNE-DEC)
FRESHWATER**

FIGURE 20. The volumetric composition (per cent) of the stomach contents of the silver jenny, *Eucinostomus gula*, 19-70 mm long. Thirty-eight of 46 fish from the dry-season samples contained food, as did 74 of 87 from the wet season.

Eucinostomus argenteus Baird & Girard
Spotfin Mojarra

This species and *E. gula* were collected in equal numbers and usually in the same habitats. This combination of the two species in the same

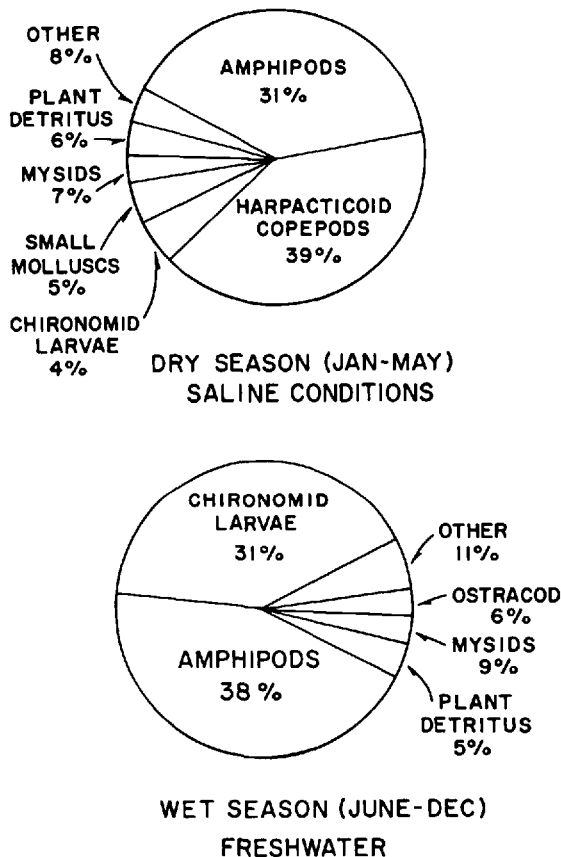


FIGURE 21. The volumetric composition (per cent) of the stomach contents of spotfin mojarra, *Eucinostomus argenteus*, 19-63 mm long. Fifty-one (42 contained food) were examined during the dry season, and 66 (53 contained food) during the wet season.

samples is in contrast to the findings of Kilby (1955), Reid (1954), and Springer & Woodburn (1960), all of whom found *E. argenteus* primarily in brackish estuarine areas and *E. gula* in sandy regions of higher salinity. Springer & Woodburn found *E. argenteus* in Tampa Bay, Florida, feeding on polychaetes, copepods, unidentified crustaceans and their larvae, and small molluscs.

The percentages of the stomach contents of *E. argenteus* (19-63 mm) taken from the North River during the two seasons are shown in Figure 21. The diet is nearly identical to that of *E. gula*; when fish of the same size-

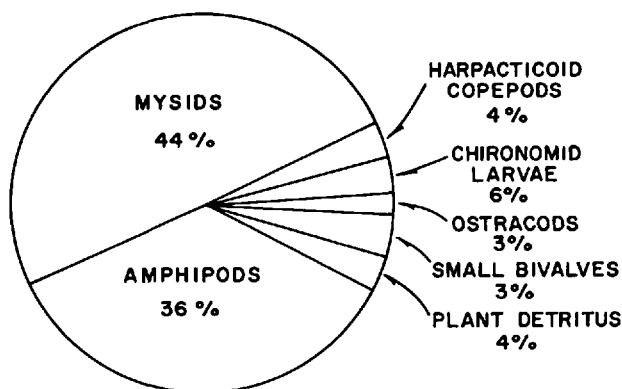


FIGURE 22. The volumetric composition (per cent) of the stomach contents of 12 striped mojarra, *Diapterus plumieri*, 35-172 mm long, taken in January, May, July, August, and November 1968.

range were examined from the same sample no difference could be detected between the food of the two species.

We examined 18 young of *Eucinostomus* sp. (probably *E. argenteus*). Eight, measuring nine to 13 mm, had eaten planktonic organisms such as larval copepods, nauplii, and zoeae. The remaining ten, 16-19 mm long, had decreasing amounts of these organisms and quantities of small amphipods and chironomid larvae.

Diapterus plumieri (Cuvier)
Striped Mojarra

There is little information on either the biology or diet the *Diapterus plumieri*. Springer & Woodburn (1960) recorded it from Tampa Bay in salinities ranging from 3.7‰ to 24.8‰, but reported specimens from the St. Lucie River in water of less than 1‰. One fish (175 mm) from Tampa Bay had eaten polychaetes, while two from the St. Lucie River (71 and 77.7 mm) contained copepods. The food of very young individuals of *D. plumieri* (5-35 mm) which were found in a shallow marsh was reported by Harrington & Harrington (1961) to consist of copepods (86 per cent of volume) and mosquito instars (9 per cent). The closely related *Diapterus rhombeus* was reported in Venezuela to feed on algae, *Thalassia*, sponges, polychaetes, bivalves, and crustaceans such as ostracods and copepods (Cervigón, 1966).

This fish is abundant throughout the North River. During the summer months when the water was clear, it was possible to move slowly upstream in a boat and see several hundred striped mojarras in a 100-meter stretch of the river.

We collected 14 individuals ranging in length from 35 to 172 mm, although fish as large as 359 mm occur in the region (Tabb & Manning, 1961). The food removed from 12 stomachs is summarized in Figure 22. Surprisingly, there was no detectable difference in diet between the smallest and largest fish in this size-range; one individual 35 mm long had consumed 18 specimens of *Taphromysis bowmani* 3 to 5 mm long, while another fish 170 mm long had consumed approximately 50 mysids of the same size.

Family Sciaenidae

Sciaenops ocellata (Linnaeus)

Red Drum, Channel Bass

Yokel (1966) studied the life history of *Sciaenops ocellata* in the Everglades estuary. This work included extensive data on stomach contents and a review of the papers of Pearson (1929), Gunter (1945), Miles (1949, 1950), Knapp (1949), Kemp (1949), Reid (1954), Breuer (1957), Darnell (1958), Springer & Woodburn (1960), and Simmons & Breuer (1962). From the results of these investigations, the red drum in the range 100-800 mm S.L. emerges as a carnivore which consumes crabs, penaeid shrimp, and fishes such as *Mugil cephalus* and *Cyprinodon variegatus*; in most instances either crabs or shrimp were the most important food item. Data on very small juveniles are scarce. Springer & Woodburn (1960) examined three specimens (31.0 to 46.3 mm S.L.) which had eaten mysids and polychaete worms. Hildebrand & Schroeder (1928) found redfish of this size-range feeding principally upon *Gammarus* and *Mysis*.

Yokel's (1966) study was based on 585 fish obtained from the waters of higher salinity in Florida Bay, Whitewater Bay, and the Ten Thousand Islands and not from brackish areas such as the North River system. His data show red drum in the 100-500 mm range to be heavily dependent (about 70 per cent by volume) upon penaeid shrimp and xanthid and portunid crabs. Penaeids predominated in the diet during the summer months when smaller sized shrimp are available, and crabs were most numerous in the diet during the remainder of the year. Fishes, which were the only other significant food source, were important only to the smaller redfish and were replaced by xanthid crabs in the diet of larger individuals.

We took seven redfish, ranging from 308-403 mm, from the North River and its associated ponds. Six contained remains of *Rhithropanopeus harrisi* exclusively; the seventh contained an additional small fraction of chironomids (10 per cent) and bits of mangrove bark (5 per cent). Forty-seven larval redfish were captured. Those of 6-8 mm S.L. contained copepods (mostly *Acartia* sp. of 500 μ -700 μ length). One larva 8 mm long contained 30 copepods. At about 10 mm in length, the fish begin incorporating crab zoeae (1.0-1.5 mm) and other larval fish (2-4 mm)

into their diet. Two individuals of 34 and 42 mm had eaten mysids, amphipods, and *Palaemonetes intermedius*.

Cynoscion nebulosus (Cuvier)
Spotted Seatrout

Moody (1950) conducted a detailed study of the food of *C. nebulosus*; from examinations of 954 fish (511 contained food) at Cedar Key, Florida, he concluded that the seatrout passes through four recognizable feeding stages. The first stage, made up of fish less than 50 mm, feeds predominantly upon copepods and other planktonic Crustacea. Caridean shrimp were most important to the second stage of fish, which measured from 50 to about 150 mm. Penaeid shrimp dominated the food of the third group (150 to 275 mm) and were replaced to a great extent by fishes in the fourth and largest group. Although fish were most important as food to these large trout, they were ingested by trout of all sizes over 25 mm. Tabb (1966) mentioned a number of fishes consumed by trout, including *Mugil cephalus*, *Lagodon rhomboides*, *Eucinostomus gula*, *E. argenteus*, *Cyprinodon variegatus*, and *Gobiosoma robustum*.

Environmental variations in the diet of spotted seatrout were suggested by Darnell (1958), who reviewed the extensive literature and compared it with his own data from Lake Pontchartrain, Louisiana. Due to peculiarities of the lake's environment there is a relative scarcity of penaeid and caridean shrimp so that young trout must feed upon mysids and benthic amphipods. In addition they begin to exploit the lake's enormous populations of anchovies and larval fish at an early age.

Springer & Woodburn (1960) looked at the stomach contents of 322 young seatrout (11 to 96 mm) from Tampa Bay, Florida, and found mysids, copepods, and carideans. Stewart (1961) studied the diet of trout over 150 mm long from Florida and Whitewater bays in the Everglades estuary and found pink shrimp, *Penaeus duorarum*, the most important food (60.2 per cent by volume). Fishes were next in importance (32.9 per cent), followed by porcellanid crabs (3.6 per cent), and caridean shrimp (0.3 per cent).

Spotted seatrout are exceedingly common in Whitewater and Florida bays (Tabb & Manning, 1961) and rank as one of the three gamefish most sought by anglers (Higman & Stewart, 1961). In the North River, *C. nebulosus* is found primarily in the open waters of the mangrove-lined ponds and rarely in the river itself. Eleven trout ranging from 92 to 382 mm long were taken at the mangrove-pond station between the months of October and March. Eight contained food in their stomachs, which included *Anchoa mitchilli*, *Eucinostomus gula*, and caridean shrimp. This was too small a sample upon which to base a conclusion. Twenty-four juveniles (68 to 112 mm) from Whitewater Bay had fed upon mysids,

amphipods, chironomid larvae, carideans, and small fishes, in that order of importance.

Bairdiella chrysura (Lacépède)

Silver Perch

Darnell (1958) summarized the literature that mentions the food of the silver perch. The smallest fish feed primarily upon copepods; this is supplemented by ostracods, cladocerans, mysids, and amphipods. As the fish grow larger they consume proportionally more mysids, amphipods, isopods, small shrimp, and crabs. The largest fish include other fishes in their diet. Darnell found mysids, *Palaemonetes*, and fishes to constitute approximately one-quarter each of the volume of stomach contents of *B. chrysura* (70 to 143 mm) from Lake Pontchartrain, Louisiana.

We collected a few specimens of *Bairdiella chrysura* in the lower portion of the North River and mangrove ponds during periods when saline conditions existed. In addition, large numbers of larvae (9 to 17 mm) were captured in the lower river between April and September, regardless of salinity. Of 34 larvae which contained food, copepods and larval fish made up approximately equal halves of the stomach contents. The larvae of *Menidia beryllina* appeared most frequently in their stomachs. The proportionally large mouth of *B. chrysura* allows it, even when only 9 mm long, to feed upon other larval fishes. A series of 14 larger fish (127 to 181 mm) were taken from the mangrove-pond station where they had been feeding upon *Anchoa mitchilli* and mysids.

Family Sparidae

Lagodon rhomboides (Linnaeus)

Pinfish

Caldwell (1957) concluded from his own observations and from the literature that *L. rhomboides* is "completely catholic" in its choice of diet, but that the bulk is composed of small crustaceans. He explained the occurrence of plant material in pinfish stomachs as probably incidental to the capture of crustaceans. This opinion was not shared by Darnell (1958) or Springer & Woodburn (1960), who pointed out that adult pinfish often contain only vegetation, such as *Diplanthera*, in their stomachs. Hansen (1967) presented feeding data for pinfish of up to 150 mm from the Pensacola estuary, Florida, which show a seasonal progression from predominantly a plant diet in the summer to a carnivorous diet in the late fall. Large pinfish tended to consume vascular plants and filamentous algae, while small pinfish contained more diatoms.

Pinfish are abundant in the seagrass and *Udotea*-covered areas of White-water Bay, but only occasionally stray into the lower section of the North River. This may be due to the sparseness of aquatic plants in the river.

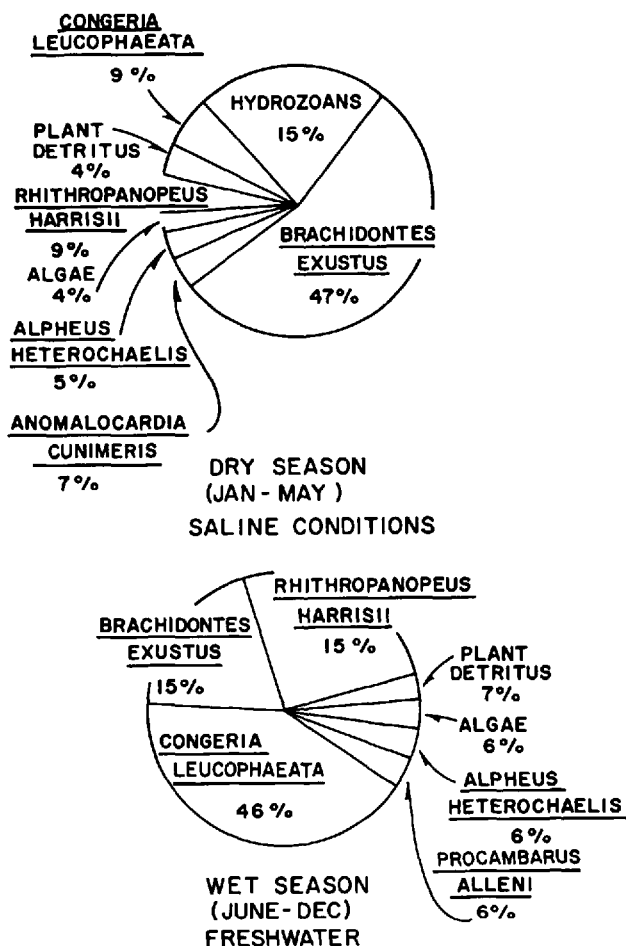


FIGURE 23. The volumetric composition (per cent) of the stomach contents of sheephead, *Archosargus probatocephalus*, 48-267 mm long, collected throughout the year. Sixty-four of 69 fish examined from the dry season contained food; 50 of 52 from the wet season contained food.

Twelve pinfish (39-61 mm) were collected in June and September from the island station. They contained animal food exclusively; this included *Brachidontes exustus*, mysids, amphipods, and *Conger leucophaeata*. Pinfish from nearby Whitewater Bay, however, often contained pieces of algae and vascular plants along with crustaceans and molluscs. Every specimen of *Lagodon* taken in night samples had an empty stomach, con-

firming Caldwell's (1957) observation that the species is strictly a diurnal feeder.

Archosargus probatocephalus (Walbaum)
Sheepshead

The sheepshead is one of the five important gamefish produced in quantity in the North River system. Judging from our catches and underwater observations, it is second to the grey snapper in abundance among the five species.

There has been some disagreement in past publications concerning the trophic position of *Archosargus probatocephalus*. Smith (1907) and Hildebrand & Schroeder (1928) originally suggested that the fish was a carnivore which fed primarily upon molluscs and crustaceans. Gunter (1945) examined 18 specimens (190 to 365 mm) from the Texas coast and concluded that sheepshead were herbivorous. This opinion was based on the fish's very long intestine and the discovery of "grass" and algae in most stomachs examined. Darnell (1958) quoted Viosca (1954) as concluding from many years' experience that sheepshead feed on both aquatic vegetation and upon invertebrates found around oyster reefs, such as mussels, hydroids, crabs, and small oysters. Darnell's data for 11 sheepshead (218 to 410 mm) from Lake Pontchartrain, Louisiana, indicated approximately equal amounts of vegetation (*Ruppia*, *Cladophora*, *Vallisneria*) and invertebrates (mussels, sponges, clams, crabs) in sheepshead stomachs. Springer & Woodburn (1960) found young individuals of *A. probatocephalus*, smaller than 50 mm, living in seagrass beds and feeding upon amphipods, copepods, and polychaetes. Larger fish ate molluscs, barnacles, and algae.

In the Everglades estuary, the first few months of the sheepshead's life is spent in the grass beds of Florida and Whitewater bays where the diet is restricted first to copepods and then to amphipods, chironomids, and mysids, along with a few strands of algae. At a length of about 35 to 40 mm, very small molluscs become incorporated into the diet and some of the fish begin to move into regions of hard substrate, such as the North River. This influx of small sheepshead begins at the mouth of the river in June and continues until the late fall. As the fish work their way upstream into the scoured rocky bottom headwaters region, the diet switches from amphipods and mysids to a more diversified array of items, most of which are encrusting forms which are nibbled off the rocky stream bed (Fig. 23). Seasonally there is a slight difference in diet, primarily due to the presence of hydroids and *Anomalocardia cunimeris* during the winter-spring period of higher salinity. *Brachidontes exustus* is of primary importance during this same period, but is outnumbered by *Congerina leucophaea* during the freshwater months.

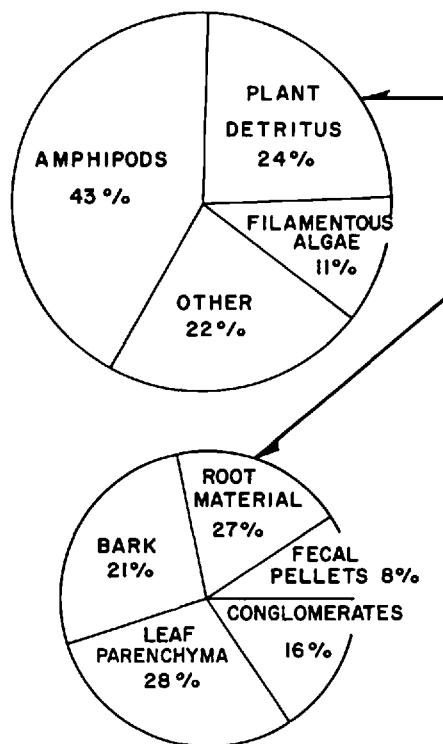


FIGURE 24. The volumetric composition (per cent) of the stomach contents of 154 crested gobies, *Lophogobius cyprinoides*, 24-73 mm long, collected throughout the year.

Family Gobiidae
Lophogobius cyprinoides (Pallas)
 Crested Goby

In terms of numbers this was the second most common goby taken in the North River by rotenone sampling; in terms of biomass it was the most important goby present. While poisoning small streams it was not uncommon for us to take 150 specimens of *Lophogobius* in a 100-m stretch of stream (and 200 specimens of *Gobiosoma robustum*), which indicated a population density in excess of one crested goby per square meter. Such a dense population is facilitated by the diverse feeding habits of this fish, apparently the most omnivorous species in this estuarine system.

Examination of 174 specimens of *L. cyprinoides* (24-73 mm) revealed 154 which contained 14 categories of food in their stomachs. Although

amphipods, mangrove detritus, and filamentous algae dominated the stomach contents (Fig. 24), a great range of other items were ingested, including mysids, caridean and penaeid shrimp, *Neanthes*, ostracods, small bivalves, chironomid larvae, harpacticoid copepods, isopods, *Rhithropanopeus harrisi*, and snails. There was little seasonal difference in diet, but a great contrast often existed between two individuals of the same size from the same sample. Crested gobies over 60 mm long ate more small crabs and caridean shrimp than those less than 60 mm. At times, vascular plant detritus and filamentous algae were eaten almost exclusively. These components occurred in 78 per cent of the filled stomachs that were examined; amphipods and other small crustaceans occurred in 76 per cent of the stomachs.

The occurrence of plant detritus particles in the stomachs of *Lophogobius* appears to be more than incidental. In many cases, fish which had been confined in glass jar traps were observed to have stomachs filled with detritus particles that had settled into the trap.

Three specimens of *Lophogobius* (45-55 mm) were maintained in the laboratory for over a year on a diet consisting solely of aged and ground mangrove leaves, with no animal material other than microorganisms present. Although none of the fish grew in length or gained weight, they were in excellent condition at the termination of the project. Detritus and algae must be a secondary food source, which is used to supplement the primary food of small crustaceans and insect larvae or to carry the animal through periods when the primary food source is difficult to obtain.

Gobiosoma robustum Ginsburg
Code Goby

Reid (1954) looked at the stomach contents of 18 specimens of *G. robustum* from Cedar Key, Florida, and found "shrimp," amphipods, molluscs, and copepods. In Tampa Bay the diet is composed of copepods, isopods, amphipods, tiny pelecypods, and decapod shrimp (Springer & Woodburn, 1960).

The code goby was listed by Tabb & Manning (1961) as the most abundant goby of the Everglades estuary; this proved to be the case in the North River. It was collected in great numbers in all seasons and in all habitats, but seemed to prefer shallower water along the river banks and in the smallest creeks.

The stomach contents of 66 specimens of *G. robustum* (15-35 mm) from the North River are shown in Figure 25. There was little seasonal change in the diet, except for the presence of cladocerans and large numbers of chironomid larvae between August and December, and a lack of cladocerans and fewer chironomids during the remainder of the year. Cumaceans exhibited just the opposite pattern of occurrence. Six smaller code gobies

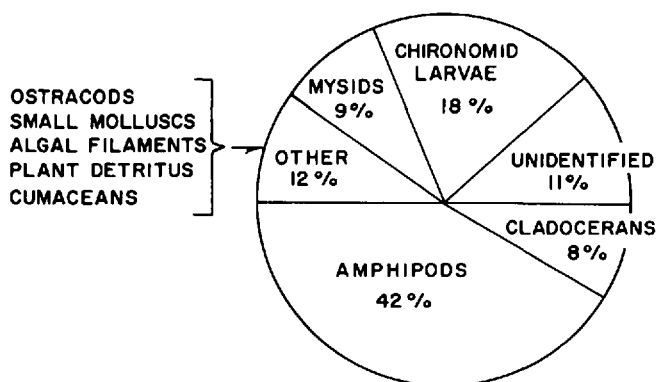


FIGURE 25. The volumetric composition (per cent) of the stomach contents of 66 code gobies, *Gobiosoma robustum*, 15-35 mm long, collected throughout the year.

(7 to 15 mm) had eaten harpacticoid copepods, juvenile mysids, cumaceans, and many pennate diatoms.

Microgobius gulosus
Clown Goby

Microgobius gulosus exhibited similarities to *Gobiosoma robustum*, in choice of both habitat and food, but was outnumbered 15 to 1 by the latter in our North River samples. Reid (1954) found clown gobies (45-57 mm) feeding upon copepods, mysids, and amphipods. Springer & Woodburn (1960) listed the same food items plus polychaetes, small bivalves, and algae. The diet of 18 specimens of *M. gulosus* (18-32 mm) from the North River is summarized in Figure 26. No clown goby smaller than 18 mm was collected.

Bathygobius soporator (Valenciennes)
Frillfin Goby

Although frillfin gobies were captured in the North River only during periods when salinities exceeded 10‰, their occurrence was too sporadic to conclude that they are not present during freshwater conditions. They were taken from the same type of habitat as *Lophogobius cyprinoides*, but were outnumbered by that species in our samples 30 to 1.

Springer & Woodburn (1960) examined one specimen of *B. soporator* (53 mm) from Tampa Bay, Florida, and found insect larvae and caridean shrimp in its stomach. Eleven specimens taken from the North River ranged from 38 to 86 mm long. Of six which contained food, five had eaten

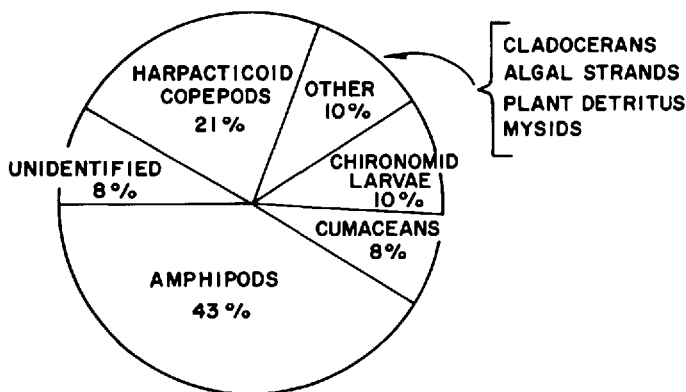


FIGURE 26. The volumetric composition (per cent) of the stomach contents of 20 clown gobies, *Microgobius gulosus*, 18-32 mm long, collected throughout the year.

Palaemonetes intermedius along with a few chironomids and amphipods. The sixth had eaten chironomids exclusively.

Family Sphyraenidae
Sphyraena barracuda (Walbaum)
Great Barracuda

Young barracuda appear occasionally near the mouth of the North River and in the mangrove ponds, but only during periods when the salinity is above 10‰. We do not consider this species as a factor of much significance in the trophic scheme of the North River.

De Sylva (1963) analyzed the stomach contents of 901 barracuda from Florida and the Bahamas and found fishes almost exclusively. Randall (1967) made similar findings from the West Indies.

Six barracuda ranging from 135 to 369 mm long were taken from the North River. All contained remains of fish; identifiable species were *E. gula* (five specimens), *Menidia beryllina* (two), and *Archosargus probatocephalus* (one).

Family Mugilidae
Mugil cephalus Linnaeus
Striped Mullet

Schools of striped mullet move up and down the North River, penetrating into the mangrove-lined ponds and far up the smallest headwater streams. They were observed primarily in areas where soft, flocculent sediments are covered by shallow water.

Since one author has already conducted an extensive study of this fish's feeding in a number of different habitats including a mangrove system (W. E. Odum, 1966, 1970b), little effort was expended in catching mullet. In their feeding, which is conducted primarily on the sediment surface, they select fine particles including benthic diatoms, filamentous algae, vascular plant detritus, and inorganic sediment particles. In the previous study from another south Florida mangrove system (W. E. Odum, 1970b), their cardiac stomach contents included 46 per cent inorganic sediments, 40 per cent fine detritus (primarily of mangrove origin), and 14 per cent living microalgae.

Family Atherinidae
Menidia beryllina (Cope)
Tidewater Silverside

Menidia beryllina is the most ubiquitous and probably the most abundant fish in the North River system. Although Tabb's (1966) catch data for 1965-66 shows this species as only the third most numerous fish taken, the gear used in that survey did not sample the fish in numbers representative of its abundance. We made six rotenone collections, two each: (1) in the marsh pools, (2) in the small streams in the headwaters region, and (3) along the shore of the North River. In all samples the most common species by a factor of at least 2 to 1 was *M. beryllina*.

The food of the tidewater silversides has been analyzed from a number of different environments. In Chesapeake Bay the principal foods were listed as small crustaceans and molluscs, insects, and worms, along with a few strands of algae (Hildebrand & Schroeder, 1928). Springer & Woodburn (1960) found *M. beryllina* in Tampa Bay, Florida, feeding on small insects, crustaceans, and tiny molluscs. Reid (1954) regarded planktonic organisms such as copepods as the primary food at Cedar Key, Florida. He mentioned that *M. beryllina* fed actively upon insects that had been attracted by night lights. From his experience with *M. beryllina* from Lake Pontchartrain, Louisiana, Darnell (1958) suggested that two feeding stages exist: the young fish feed upon zooplankton, while larger individuals prey upon anthropods (ants, beetles, spiders) that fall into the water, and isopods, amphipods, and other small invertebrates. His theory concerning the food of the small fish was speculation, since no specimens of this size were examined. Harrington & Harrington (1961) presented data from a Florida salt marsh, which indicated that *M. beryllina* of the size 5 to 15 mm feed on both cyclopoid and benthic harpacticoid copepods. In the same paper, Darnell presented data to support his contention that feeding activity in the larger fish is greatest during the morning hours. Our interpretation of his data (his fig. 6) indicates intensive night and early morning feeding with a slackening later in the morning.

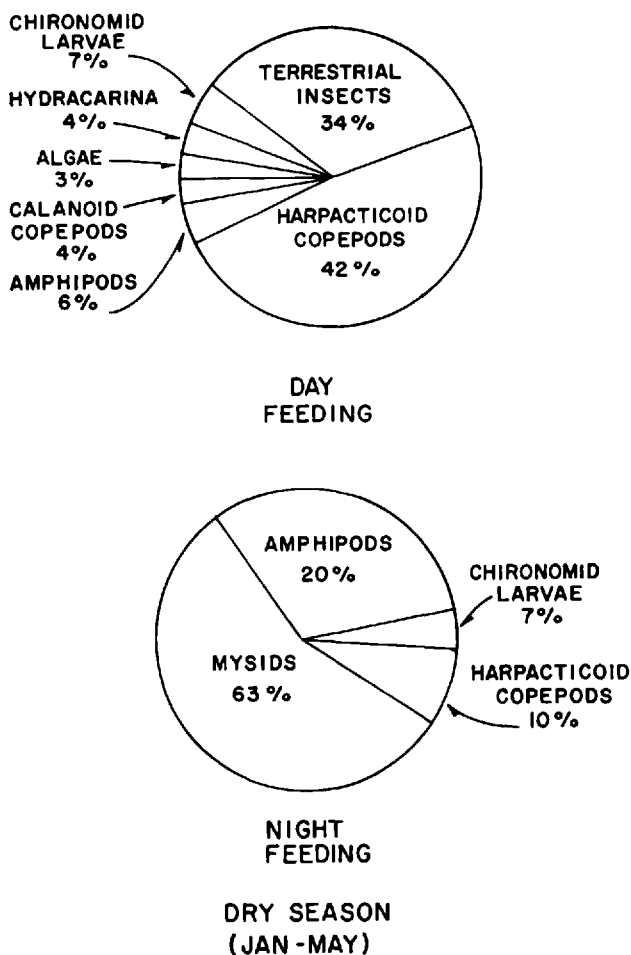


FIGURE 27. The volumetric composition (per cent) of the stomach contents of tidewater silversides, *Menidia beryllina*, 35-65 mm long, collected during the dry season. Of 122 fish examined from daylight samples, 34 contained food. All 28 fish examined from night samples contained food.

In the North River, nocturnal feeding predominates. We found 74 per cent of 315 specimens of *M. beryllina* (35 to 65 mm) taken during the daylight hours to have empty stomachs, while all but one of 37 fish taken at night had full stomachs. Not only is there a difference in intensity of feeding between day and night, but the items eaten during the two periods were different. The food of *M. beryllina* (35 to 65 mm) from the North

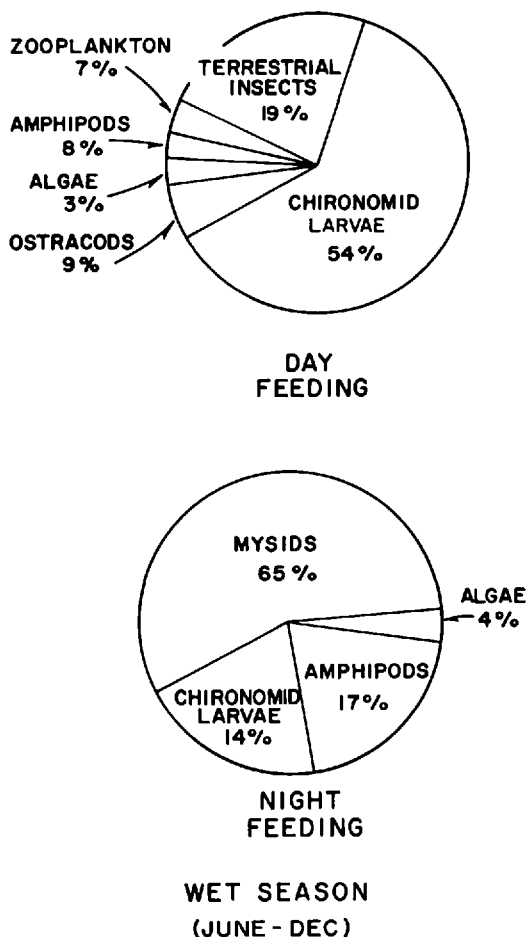


FIGURE 28. The volumetric composition (per cent) of the stomach contents of tidewater silversides, *Menidia beryllina*, 31-58 mm long, collected during the wet season. Of 156 fish examined from day samples, 38 contained food; eight of nine from night samples contained food.

River system is shown in Figures 27 and 28. During the day, insects that fall into the water predominate, along with copepods and chironomid midge larvae; at night, mysids are of primary importance. This switch in diet can be correlated with the fish's position in the water column. During the day, *M. beryllina* is most often found either near the surface or in midwater; it does not appear to feed actively, except when a spider or an insect such as an ant or a beetle falls into the water. Examination of the water at night

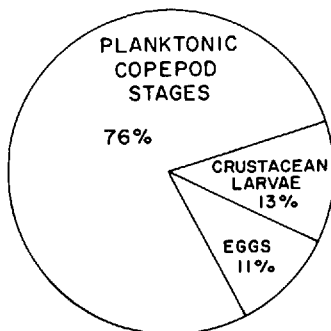


FIGURE 29. The volumetric composition (per cent) of the stomach contents of 36 tidewater silversides, *Menidia beryllina*, 12-16 mm long, collected during May and June 1968.

with an underwater flashlight reveals the fish close to the bottom, evidently in search of mysids and small amphipods.

The food of very small individuals of *M. beryllina*, as shown in Figure 29, is similar to that theorized by Darnell (1958). All fish of this size had full stomachs during the day and empty stomachs at night.

Family Soleidae

Trinectes maculatus (Bloch & Schneider)

Hogchoker

Achirus lineatus (Linnaeus)

Lined Sole

Both *Trinectes maculatus* and *Achirus lineatus* are common in the muddier areas of the river and mangrove ponds. Tabb (1966) listed each species as forming 0.1 per cent of the catch from the North River.

Few data exist concerning their feeding habits. *T. maculatus* is reported to feed upon annelids, small crustaceans, and strands of algae (Hildebrand & Schroeder, 1928). Darnell (1958) examined three specimens of *T. maculatus* from Lake Pontchartrain, Louisiana, and found 50 per cent amphipods, and an equal amount of unrecognizable material and detritus in their stomachs; intestinal contents included chironomid larvae, microcrustaceans, Foraminifera, and plant seeds. Springer & Woodburn (1960) found polychaetes and amphipods in *A. lineatus* from Tampa Bay, Florida, while Reid (1954) considered this species' food to be copepods, amphipods, and polychaetes.

Eight specimens of *T. maculatus* (14-110 mm) and six specimens of *A. lineatus* (32-74 mm) were examined from the North River; only two specimens of each species contained food. These food items included

amphipods, mysids, chironomid larvae, *Nereis pelagica*, and Foraminifera. No difference in diet between the two could be distinguished from these small samples.

Family Gobiesocidae
Gobiesox strumosus Cope
Skilletfish

Gobiesox strumosus was collected under mangrove logs and dead oyster shells in December and May. Since salinities at these times were 3‰ and 21‰, the fish is probably present in the river at all times of the year. Hildebrand & Schroeder (1928) examined specimens of *G. strumosus* from Chesapeake Bay and found isopods, amphipods, and annelids in their stomachs. Runyan (1961) found only amphipods in 20 specimens from the same area, but observed fish in captivity feeding upon young sticklebacks and attempting unsuccessfully to devour *Palaemonetes*.

All 18 fish (10 to 32 mm) that we analyzed from the North River contained food. Stomach contents in order of greatest occurrence were amphipods, isopods, and chironomid larvae.

Family Batrachoididae
Opsanus beta (Goode & Bean)
Gulf Toadfish

Examination of 26 stomachs of *Opsanus beta* at Cedar Key, Florida, by Reid (1954) revealed crabs to be the most important food, followed by penaeid and crangonid shrimp, hermit crabs, molluscs, amphipods, and fish. Springer & Woodburn (1960) found decapod crustaceans and gastropods to comprise the major portion of the diet of 191 gulf toadfish from Tampa Bay, Florida. The closely related *O. tau* is considered omnivorous, with small crabs and other crustaceans as the principal food (Hildebrand & Schroeder, 1928); smaller individuals were reported to feed upon amphipods and isopods.

Small gulf toadfish ranging from 18 to 135 mm were taken at all stations in the North River except for the *Juncus* marsh pools. They appeared in the catches between February and June, a period when salinities were above 10‰. Whether they are present during times of lower salinity is not known. The food in the stomachs of 12 specimens of *O. beta* varied according to the fish's size. Those in the range 18 to 60 mm had eaten amphipods, chironomid larvae, mysids, isopods, and a few fishes. Larger toadfish contained *Palaemonetes* sp., *Rhithropanopeus harrisi*, *Alpheus heterochaelis*, mussels, fish remains, and bits of mangrove bark.

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SUMMARY

This is the first of three papers describing an investigation of the trophic relationships in a Florida mangrove ecosystem. Summaries are presented of food habits based on digestive-tract analyses and information from the literature for most of the resident fish and aquatic invertebrate species. This information provides the basis for a subsequent paper which delineates the pathways of energy flow by which the primary production of mangroves is utilized by consumer organisms.

SUMARIO

ANÁLISIS TRÓFICOS DE UNA COMUNIDAD DE MANGLES EN UN ESTUARIO

Bordeando la costa sudoeste de la Florida hay un cinturón de manglares que mantiene a grandes poblaciones de pájaros, peces para pesca deportiva y especies de invertebrados de importancia comercial. Entre 1967 y 1969 se realizó un estudio de esta región de manglares en la cuenca del North River para determinar las bases de la energía para esta gran población de animales y delinear las rutas por las cuales esta energía es transferida en la cadena alimenticia.

Esta es la primera de tres publicaciones que resumen los resultados de este estudio. Consiste en sumarios de hábitos alimenticios de la mayoría de los peces y especies de invertebrados acuáticos que se encuentran en el ecosistema de manglares del North River. En adición a nuestros datos, que incluyen más de 10,000 análisis de contenidos estomacales, se ha sumariado, cuando ha sido pertinente, información de otras publicaciones. Finalmente para la mayoría de las especies se da un estimado de su importancia relativa en el sistema del North River, en términos de abundancia.

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