# UNIVERSITY OF MIAMI

# Sea Grant Program (Living Resources)

## A Study of the Food of Juvenile Migrating Pink Shrimp, Penaeus duorarum Burkenroad

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# PREFACE

The Sea Grant Colleges Program was created in 1966 to stimulate research, instruction, and extension of knowledge of marine resources of the United States. In 1969 the Sea Grant Program was established at the University of Miami.

The outstanding success of the Land Grant Colleges Program, which in 100 years has brought the United States to its current superior position in agricultural production, was the basis for the Sea Grant concept. This concept has three objectives: to promote excellence in education and training research, and information services in the University's disciplines that relate to the sea. The successful accomplishment of these objectives will result in material contributions to marine oriented industries and will, in addition, protect and preserve the environment for the enjoyment of all people.

With these objectives, this series of Sea Grant Technical Bulletins is intended to convey useful research information to the marine communities interested in resource development quickly, without the delay involved in formal publication.

While the responsibility for administration of the Sea Grant Program rests with the Department of Commerce, the responsibility for financing the program is shared equally by federal, industrial, and University of Miami contributions. This report, A Study of the Food of Juvenile Migrating Pink Shrimp, Penaeus duorarum Burkenroad, is published as a part of the Sea Grant Program. Graduate research support was provided by the AID Program of the U.S. State Department.

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# INTRODUCTION

Shrimp are the most valuable fishery product in the United States. In Florida, the Tortugas shrimp fishery is supported by the pink shrimp, Penaeus duorarum Burkenroad. For rational management of this fishery it is necessary to have a comprehensive understanding of the biology of the animal. Considerable progress has been made in research on the adult phase of this species and on its larval and postlarval stages. The juvenile phase of its life history, however, is less well known. This juvenile stage is passed mostly in estuaries, where cover and food are available. After some months there is a migration to offshore grounds where the shrimp spend the adult phase. This work concerns the food and feeding habits of juvenile pink shrimp during its migration out of an estuary.

Food is one of the factors which determines the distribution of a species. As a component of the environment, it may influence an animal's survival, its capacity to reproduce and its speed of development (Andrewartha and Birch, 1954). Since the availability of food is one of the factors controlling the

abundance of the species that feeds on it, knowledge of food and feeding habits contributes to the evaluation of an exploited population.

The main aim of this investigation was to investigate the food and the feeding activity of pink shrimp during its migration from the estuary. Observations were made throughout the year.

It is hoped that these results will contribute to the understanding of fluctuations of abundance, rates of growth and other aspects of the biology of this species.

# LITERATURE SURVEYED

Food studies, when related to feeding habits and accompanied by ecological observations, constitute important information for resource management. This aspect of life history has been investigated for many species of fish but there have been few such investigations for shrimp and prawns.

Investigating the food habits of decapods is made difficult because these animals have either a very efficient gastric mill for trituration of the material, or an external masticatory system which grinds the food (Patwardan, 1935) until it becomes difficult to identify. As Marshall and Orr (1960) point out, the food of crustaceans is imperfectly known quantitatively and almost unknown.

Blegvad (1914), in his work on the food of invertebrate animals in the seabottom of Danish waters, found that the decapods Crangon vulgaris and Palaemon fabricii do not concentrate on one kind of food, but live on animal food, plant detritus and fresh plants. When shedding their exoskeletons, these decapods are always found with empty stomachs. In the spawning period crustaceans often appear to be fasting. Hunt (1925)

found the following organisms in the stomachs of decapoda natantia: polychaetes, amphipods, mysids and other crustacea, very young bivalves, remains of hydroids, small fishes, and detritus. Foster (1951), working with Leander serratus in the English Channel, found that algae and small crustaceans formed a large portion of the diet but that the stomach contents varied from place to place and throughout the year. Ikematsu (1955), working on the life history of Metapeneus joyneri of Ariake Bay, found that the main items in the diet of this prawn were Crustacea, bivalves, Gastropoda and Polychaeta. The high incidence of occurrence of diatoms (71.7 per cent) was very noticeable. In India, Kunju (1956), working on Leander styliferus, found no differences in the food ingested by individuals from 3 different sampling areas, nor among different classes from the same area. About 25 per cent of the prawns examined had empty stomachs; those that had material in the stomachs contained mostly sand grains, debris, crustacean and fish larvae, and, to a much smaller extent, algae, macrovegetation and "miscellaneous" material.

Flint (1956) pointed out that the food intake of larval shrimp consisted almost entirely of

filamentous blue-green algae and diatoms. Investigations of Mistakidis (1957), Kesteven and Job (1958) and Allen (1963) show that penaeid and caridean shrimp are omnivorous animals which ingest a variety of plant and animal material. Allen (1960) made comparisons between the stomach contents of the inshore and the offshore population of Crangon allmani and concluded that more polychaetes were eaten offshore while more molluscs were eaten inshore. He found no significant differences between the diets of the males and the females. Analysis with respect to size and month of capture showed little variation in food in either case.

Studies on the food of Penaeus duorarum are scarce. Williams (1955), in his work on the life histories of commercial shrimp in North Carolina, said that these shrimp are bottom feeders. He examined the stomachs of 184 shrimp specimens from estuaries, finding that the stomachs were usually full or half filled during the fall and nearly always empty in the winter; those caught in summer usually had full stomachs. The most abundant materials, in order of decreasing frequency of occurrence, were: 1) a mass of

unrecognizable debris, 2) chitin fragments, 3) setae, apparently from annelids, 4) annelid jaws, 5) plant fragments, 6) sand. He suggested in a later paper that food undoubtedly plays a major role in the distribution of shrimp and that these omnivorous animals might be attracted to areas rich in food (Williams, 1958).

Eldred et al.(1961) reported that the types of plants and animal organisms utilized as food by Penaeus duorarum in Florida are associated with the grassy bottoms in this area. Their investigations indicated that P. duorarum feeds largely at night but under turbid water conditions they will feed during the day. They found particles of Thalassia leaves, algae, diatoms, flagellates, polychaetes, nematodes, shrimps, mysids, copepods, isopods, amphipods, ostracods, molluscs, and foraminiferans in the stomachs collected in October and November. Unidentified body structures, eggs, fish scales, sand and debris were common. Earlier Eldred (1958) made examinations of the stomach contents of the pink shrimp from the Tampa Bay area and found that a mollusc, Meioceras lermondi occurred frequently.

No published work was found on shrimp food habits on a year round basis.

# MATERIALS AND METHODS

The shrimp examined in this study were taken from the samples collected for the study of juveniles leaving the Everglades National Park estuary at the foot of the Florida peninsula. That research has been supported by the U. S. Bureau of Commercial Fisheries.

The samples were taken at night from Buttonwood Canal which connects Florida and Coot bays near Flamingo, Everglades National Park. Sampling was conducted only near the times of new and full moon. A channel net was placed under the bridge which crosses Buttonwood Canal approximately 0.5 mile from Florida Bay. The mouth of the channel net occupied the full cross-section of the canal and therefore the net filtered nearly all the canal water passing the bridge. Each sampling period was 30 minutes. The number of samples taken per night varied from two to ten. In some months shrimp were not available for certain sampling periods and all samples for December were missing. In this last case, a sample was taken from shrimp obtained by another kind of gear called "wingnets". These had a three by six foot rectangular mouth. They were hung one from each side

of a skiff, in the center of the canal, about seventy five feet north of the bridge. The nets fished only about 1/5 of the surface and to a depth of about two and one half feet, so that only a small portion of the shrimps were caught. The data obtained from these wingnet samples might not be strictly comparable with those from the channel net since the shrimp caught were only those moving at the surface.

The shrimp were put in formalin preservation about ten minutes after capture.

In the food study eight individuals were examined from each half-hour sample per month from ebb tides and another eight from flood tide samples. Unfortunately, some months samples are not available from each catch since the specimens were combined in one jar. In those cases 50 individuals, randomly picked, were examined.

Before examination the shrimp were rinsed in running water. Notes were made concerning the degree to which the stomach was filled. Sex and size were recorded. The stomach was dissected out between the esophagus and caudal end of the pyloric part. The extent of filling of the intestine was also recorded.

The dissected stomach was opened and the contents placed on a glass slide with a pipette. This material was first examined with a low-power binocular microscope, and the larger fragments were identified. The remainder was examined under higher magnification. Since the shrimp triturates its food it is so pulverized that identification is very difficult or impossible. Nevertheless, much of the food can be classified to phylum and sometimes to genus and species. The organisms found are tabulated under large groups; cases in which further identification was possible are mentioned in the discussion. Unidentifiable, finely divided material is included under the term "debris", following Forster (1951). This term is used in place of the more usual "detritus", since it was not known whether most of the material was organic or inorganic.

Owing to the effects of digestion and the small particle size of the ingesta, estimation of the weight or volume of particular stomach contents was not performed.

# RESULTS

## Feeding activity.

The results of the examination of 680 stomachs taken from the monthly samples during 1963 are condensed in Table 1.

One measure of feeding activity of an animal population is the percentage of sampled individuals having some food in their stomachs. This is assumed to reflect the percentage of actively feeding individuals in the population at the time of sampling.

Based on this measure the proportion of pink shrimp feeding fluctuated considerably throughout the year (Figure 1). In the colder months, January and February, most of the stomachs were empty; with increasing temperature in March and April the number of stomachs with food increased. In May it decreased again but stayed about as high as in March. With the coming of the warmer summer months, an interesting decrease in feeding activity occurred. This has not been reported by previous investigators, who have found that feeding activity was more intense during the warmer season.

In September almost all stomachs were partly filled, and 23 per cent were completely filled. It

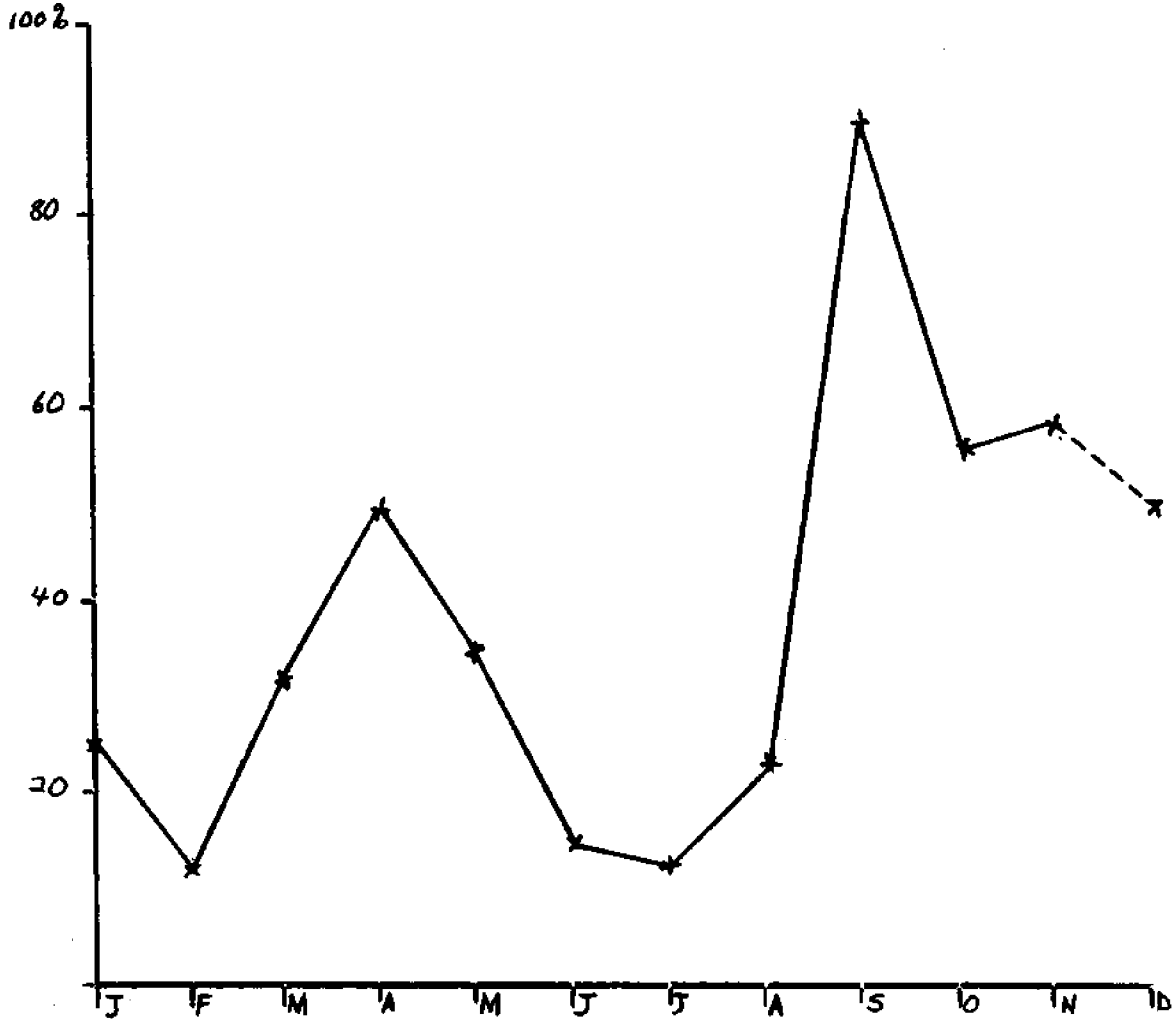


FIG. 1 PERCENTAGE OF STOMACHS CONTAINING FOOD FROM MONTHLY EBB SAMPLES. 1963.

appears that the feeding activity of shrimp increases considerably as the water cools. In the winter months the number of stomachs with food decreased again to about 50 per cent. In December there was some feeding activity despite lower water temperature.

Besides the seasonal rhythm of feeding activity, which may be related to climatological changes, a nightly rhythm was exhibited, presumably associated with light. Data from several months showed that most shrimp with food in their stomachs were caught between 19:00 hours and 21:30 hours (Table 2). This may be the result of energetic feeding following daylight hours of deprivation of food, the pink shrimp being nocturnal (Fuss, 1964).

Within the size range of shrimp studied, little difference in feeding activity was observed (Table 3). Differences in the food of male and female individuals were not found. This observation agrees with studies on Crangon allmani by Allen (1960).

Five flood tide samples were examined. The ones taken in January, February, March and November had considerably more individuals with food in their stomachs than did those taken from corresponding ebb

tide samples. Shrimp taken in July flood tides all had empty stomachs. It would be interesting to investigate this further, and to analyze monthly flood samples for a whole year, to discover if the differences in feeding activity are brought about by differences in availability of food or from other causes.

Food material.

The most frequently occurring food items in the stomachs of the emigrating juvenile pink shrimp were crustaceans and polychaetes (Table 1). Crustaceans occurred in 65 per cent and polychaetes in 24 per cent of the stomachs containing food. Plant material and "debris" formed most of the remaining diet. Fish, shrimp, squids, mollusc shells, insects, and foraminifera were found occasionally.

Crustacea:

Crustaceans were the most frequently occurring type of identifiable stomach contents in all months. Whole specimens were rare: in two stomachs a whole small amphipod was found, and in one case an almost whole isopod. In other cases the organisms were broken and identification only to order was possible.

TABLE 1. Proportion of Stomachs Containing Food and Contents of Stomachs of the Pink Shrimp During 1963.

| MONTH | STOMACHS INSPECTED | STOMACHS CONTAINING FOOD | | CRUSTACEANS | | POLYCHAETES | | HIGHER PLANTS | | ALGAE AND DIATOMS | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. | % | No. | % | No. | % | No. | % | No. | % |
| EBB: | | | | | | | | | | | |
| January | 24 | 6 | 25 | 4 | 66 | - | | - | | - | |
| February | 42 | 5 | 12 | 3 | 60 | 1 | 20 | 1 | 20 | 1 | 20 |
| March | 44 | 14 | 32 | 8 | 57 | 4 | 29 | - | | 1 | 7 |
| April | 24 | 12 | 50 | 9 | 75 | 4 | 33 | 2 | 17 | 1 | 8 |
| May | 48 | 17 | 35 | 16 | 94 | 2 | 12 | 2 | 12 | - | |
| June | 48 | 7 | 15 | 4 | 57 | 1 | 14 | - | | - | |
| July | 32 | 4 | 13 | 4 | 100 | 2 | 50 | - | | - | |
| August | 48 | 11 | 23 | 6 | 54 | 1 | 9 | 1 | 9 | - | |
| September | 50 | 45 | 90 | 28 | 62 | 7 | 15 | 8 | 18 | 13 | 29 |

TABLE 1 (Continued)

| MONTH | STOMACHS INSPECTED | STOMACHS CONTAINING FOOD | | CRUSTACEANS | | POLYCHAETES | | HIGHER PLANTS | | ALGAE AND DIATOMS | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. | % | No. | % | No. | % | No. | % | No. | % |
| October | 50 | 28 | 56 | 14 | 50 | 6 | 21 | 1 | 4 | 6 | 21 |
| November | 50 | 29 | 58 | 20 | 69 | 4 | 14 | 3 | 10 | 1 | 3 |
| December | 50 | 25 | 50 | 9 | 36 | 3 | 12 | 2 | 8 | - | |
| FLOOD: | | | | | | | | | | | |
| January | 2 | 2 | 100 | 2 | 100 | - | | - | | - | |
| February | 60 | 37 | 62 | 33 | 89 | 18 | 49 | 11 | 30 | 6 | 16 |
| March | 40 | 18 | 45 | 13 | 72 | 8 | 44 | 5 | 28 | 5 | 28 |
| July | 16 | 0 | | - | | - | | - | | - | |
| November | 50 | 43 | 86 | 23 | 53 | 12 | 26 | 5 | 12 | 8 | 18 |
| TOTAL | 680 | 330 | | 196 | 65 | 73 | 24 | 41 | 13 | 42 | |

TABLE 2. Numbers of Pink Shrimp Stomachs Containing Food Before and After 21:30 Hours.

A : Number of stomachs examined
B : Number of filled stomachs
C : Percentage of filled stomachs

| MONTH | | TIME OF SAMPLING: FROM 19:00 HOURS TO 21:30 HOURS | TIME OF SAMPLING: FROM 21:30 HOURS TO 24:00 HOURS |
|---|---|---|---|
| Jan. | A | 21 | 3 |
| | B | 4 | 2 |
| | C | 19 | 66 |
| Febr. | A | 16 | 17 |
| | B | 2 | 3 |
| | C | 13 | 18 |
| Mar. | A | 22 | 22 |
| | B | 11 | 3 |
| | C | 50 | 14 |
| Apr. | A | 24 | - |
| | B | 12 | - |
| | C | 50 | - |
| May | A | 16 | 32 |
| | B | 10 | 7 |
| | C | 63 | 22 |
| June | A | 24 | 24 |
| | B | 6 | 1 |
| | C | 25 | 4 |
| July | A | 24 | 8 |
| | B | 4 | 0 |
| | C | 17 | 0 |
| Aug. | A | 16 | 32 |
| | B | 4 | 7 |
| | C | 25 | 22 |

TABLE 3. Number of Pink Shrimp Stomachs Containing Food for 4 Size Classes of Shrimp and both Sexes

| MONTH | JANUARY | | FEBRUARY | | MARCH | |
|---|---|---|---|---|---|---|
| | NUMBER EXAMINED | NUMBER CONTAINING FOOD | NUMBER EXAMINED | NUMBER CONTAINING FOOD | NUMBER EXAMINED | NUMBER CONTAINING FOOD |
| MALE | 12 | 4 | 16 | 3 | 27 | 7 |
| FEMALE | 12 | 2 | 21 | 2 | 17 | 7 |
| CARAPACE LENGTH CLASS | | | | | | |
| 50 - 99 | -- | - | -- | - | -- | - |
| 100 - 149 | 16 | 5 | 15 | 2 | 24 | 8 |
| 150 - 199 | 7 | 1 | 21 | 2 | 20 | 6 |
| 200 - 249 | 1 | 0 | 1 | 1 | -- | - |

| MONTH | APRIL | | MAY | | JUNE | |
|---|---|---|---|---|---|---|
| | NUMBER EXAMINED | NUMBER CONTAINING FOOD | NUMBER EXAMINED | NUMBER CONTAINING FOOD | NUMBER EXAMINED | NUMBER CONTAINING FOOD |
| MALE | 17 | 7 | 25 | 8 | 28 | 2 |
| FEMALE | 7 | 5 | 23 | 9 | 20 | 5 |
| CARAPACE LENGTH CLASS | | | | | | |
| 50 - 99 | -- | - | -- | - | -- | - |
| 100 - 149 | 15 | 10 | 13 | 4 | 14 | 1 |
| 150 - 199 | 9 | 2 | 31 | 12 | 24 | 4 |
| 200 - 249 | -- | - | 4 | 1 | 10 | 2 |

TABLE 3 (Continued)

| MONTH | JULY | | AUGUST | | SEPTEMBER | |
|---|---|---|---|---|---|---|
| | NUMBER EXAMINED | NUMBER CONTAINING FOOD | NUMBER EXAMINED | NUMBER CONTAINING FOOD | NUMBER EXAMINED | NUMBER CONTAINING FOOD |
| MALE | 23 | 4 | 31 | 9 | 31 | 29 |
| FEMALE | 9 | - | 17 | 2 | 19 | 16 |
| CARAPACE LENGTH CLASS | | | | | | |
| 50 - 99 | -- | - | -- | - | -- | -- |
| 100 - 149 | 21 | 3 | 29 | 9 | 24 | 21 |
| 150 - 199 | 11 | 1 | 17 | 2 | 24 | 22 |
| 200 - 249 | -- | - | 2 | - | 2 | 2 |

| MONTH | OCTOBER | | NOVEMBER | | 11 MONTHS | |
|---|---|---|---|---|---|---|
| | NUMBER EXAMINED | NUMBER CONTAINING FOOD | NUMBER EXAMINED | NUMBER CONTAINING FOOD | NUMBER EXAMINED | NUMBER CONTAINING FOOD |
| MALE | 29 | 23 | 26 | 17 | 265 | 113 |
| FEMALE | 21 | 5 | 24 | 12 | 190 | 65 |
| CARAPACE LENGTH CLASS | | | | | | |
| 50 - 99 | -- | - | 3 | 1 | 4 | 1 |
| 100 - 149 | 21 | 9 | 39 | 24 | 231 | 96 |
| 150 - 199 | 27 | 18 | 8 | 4 | 199 | 74 |
| 200 - 249 | 2 | 1 | -- | -- | 22 | 7 |

TABLE 4. Food Found in Stomachs of the Pink Shrimp (excluding debris as a type)

| MONTH | CRUSTACEANS ONLY | POLYCHAETES ONLY | GRASS ONLY | ALGAE OR DIATOMS ONLY | NUMBER OF TYPES 1 | 2 | 3 OR MORE |
|---|---|---|---|---|---|---|---|
| EBB: | | | | | | | |
| January | 3 | - | - | - | 3 | 1 | - |
| February | 1 | 1 | - | - | 2 | 2 | - |
| March | 4 | 1 | - | - | 5 | 3 | 1 |
| April | 3 | - | - | 1 | 5 | 5 | 1 |
| May | 9 | 1 | 1 | - | 14 | 6 | - |
| June | 4 | 1 | - | - | 6 | - | - |
| July | 2 | - | - | - | 2 | 2 | - |
| August | 4 | - | 1 | - | 7 | - | - |
| September | 9 | 1 | 1 | - | 15 | 9 | 3 |

TABLE 4 (Continued)

| MONTH | CRUSTACEANS ONLY | POLYCHAETES ONLY | GRASS ONLY | ALGAE OR DIATOMS ONLY | NUMBER OF TYPES 1 | 2 | 3 OR MORE |
|---|---|---|---|---|---|---|---|
| October | 8 | 4 | - | - | 12 | 2 | - |
| November | 12 | - | - | - | 12 | 2 | 1 |
| December | 6 | - | - | - | 12 | 5 | 1 |
| FLOOD: | | | | | | | |
| January | 2 | - | - | - | 2 | - | - |
| February | 13 | 2 | 2 | - | 17 | 15 | 6 |
| March | 2 | - | - | - | 3 | 6 | 7 |
| July | - | - | - | - | - | - | - |
| November | 8 | - | 1 | - | 10 | 7 | 6 |
| TOTAL | 90 | 11 | 6 | 1 | 127 | 65 | 28 |

Most of the remains were of chitin plates of the segments, pereipods, pleopods, antennae and mouthparts. In several instances stomachs were found filled with broken antennae about the same size as those of the specimen being examined. This might have resulted from a shrimp eating his own molt, as is reported by Lloyd and Yonge (1947) for Crangon vulgaris and by Kunju (1956) for Leander styliferus.

Animals frequently found in the stomachs in identifiable form were amphipods, isopods, and copepods. If the remnants could not be further identified they were designated only as "crustaceans".

In many individuals the stomach was filled but the intestine was empty. In several cases the stomach contents were undigested body parts of an animal, for instance only three pleiopods, part of an antenna or several dactylids. This suggests that the whole prey was not eaten, or that the shrimp regurgitated part of the undigested matter.

Polychaetes:

These were found in 24 per cent of the stomachs containing food. Never was a body part or head found in condition good enough for precise identification.

The most frequently found parts were the setae and aciculae. Very often a pair of jaws was encountered. However, in many instances when no jaws were found, the stomachs did contain setae. This points again to the possibility that the whole animal was not eaten.

Higher plants:

In 13 per cent of the stomachs containing food, small pieces of leaves or roots of higher plants, mostly sea grasses, were found.

Algae and Diatoms:

Algae could be recognized in only a small number of stomachs, and the species could not be identified. It is probable that considerable additional quantities of algae were undetected, and reported as debris.

Diatoms were never found in large quantities, although their occurrence was not rare. They are pennate, very likely a benthic or epiphytic form. Only in one stomach were they found alone; in all the others they were found together with other organisms. This suggests they might have been consumed along with the bottom debris or as ingesta of the eaten animals.

Miscellaneous:

In several stomachs remains of fish were found in the form of scales, and on two occasions a number of vertebral bones. It is impossible to tell whether the fish were caught alive, or eaten after death. It would be of interest to know this since shrimp may be predators on larval fish.

Shells were occasionally found as small broken pieces, and it was hard to determine whether they came from gastropods, bivalves, or echinoderms. It is noticeable that the December sample had many shrimp containing shells.

In one instance a stomach was completely filled with fragments of a squid.

Corixid insects were found in several stomachs. Every stomach containing these insects was fully distended.

Foraminifera occurred occasionally, three to six at a time. Most were identified as Ammonia beccarii.

Tissues too big to be grouped as debris but too small to be identified occurred in many stomachs. These are termed "unidentified".

Debris:

This includes all unidentifiable, finely divided matter. It was not possible to decide whether the debris had been ingested as such or was formed in the stomach when the food items were gound up. Debris was found frequently, occurring in 28 per cent of the filled stomachs with no other constituent present.

Out of the 303 specimens containing ingesta of the five frequently occurring foods (crustaceans, polychaetes, higher plants, algae and diatoms, and miscellaneous types), 28 stomachs contained three or more types in combination, and 127 were restricted to a single type (excluding debris) (Table 4). Of these, most stomachs had crustaceans, 11 had polychaetes and 6 contained grass only. This confirms the fact that shrimp do not restrict themselves to one kind of food. Even so, the pink shrimp apparently showed some food preference. Despite the availability of grasses, for instance, only a few shrimp had this food in their foreguts, and even in these cases the grass was found in very small quantities. In no month were crustaceans absent from the ingesta, and polychaetes were lacking only in January.

Differences in food taken by shrimp caught during ebb tides and those obtained during flood tides might be expected, not only because the shrimp occupy a slightly different habitat prior to movement with the tide, but also because the tide may affect the physiology of the shrimp and change their activity, as is true of many littoral organisms (Cloudsely-Thompson, 1961). Only five flood samples were available for this work, one of which consisted only of two animals so that very little can be said about such differences.

The flood samples in January, February, March, and November had a higher proportion of stomachs containing food and the extent of filling of these stomachs was more than those of the corresponding ebb samples. In flood samples there were also more shrimp with stomachs with two or more food types found together, and appears that these shrimp were feeding more actively during flood tides than during ebb tides. Not much difference was found in composition of the food contents between tide stages except for higher proportions of polychaetes and plants during flood tides. More flood samples from other months are needed before generalizations could be made on these differences.

Seasonal rhythms are apparent in the lives of almost all animals. Many fish change their diet completely with a change in the season (Pliszka, 1954), and several reports on invertebrates have been published citing this (Cloudsley-Thompson, 1961). The present work showed no indication that the kind of food changed materially during the year. There were slight fluctuations in composition which might have been caused by the varying availability of the food. Crustacean occurrence was highest (100 per cent) in July and lowest in December (36 per cent). The latter might be a result of the different way of taking the sample of this month by wingnet instead of channel net.

The ratio of the number of stomachs containing crustaceans to those containing polychaetes was not constant for all the samples. The highest was in the May ebb sample (8:1) and lowest in the February flood sample (1.8:1). In most of the months with low feeding activity, most stomachs were filled with only one type of food, generally crustaceans (Table 4). In cases where the contents were only grass or only diatoms, the amounts were very small. This again indicates the non-preference of the shrimp for these foods.

It is conceivable that the size of the shrimp might affect the composition of its food. This might be caused, among other reasons by differences in the mechanics of securing food. Although no statistical analysis was done in this work to relate size and food composition, it can be seen from Table 3 that there is apparently no difference in diet between small shrimp (carapace length 5.0-9.9mm) and large ones,(carapace length 20.0-24.9mm). Kunju (1956) working on Leander styliferus, came to a similar conclusion.

# GENERAL DISCUSSION

The measurement of feeding activity of shrimp from the proportion of stomachs containing food is not precise since empty stomachs do not necessarily mean a non-feeding situation. Rate of digestion in a poikilothermic animal such as shrimp may vary seasonally. Different kinds of food materials may be digested at unequal rates, and therefore may disappear from the digestive tract at unequal rates. Forster (1951) and Kunju (1956) mentioned the possibility of regurgitation as the cause of empty stomachs. It was difficult in the present case to decide whether the foreguts were empty due to not taking food or to regurgitation, but it is believed that regurgitation was minimal. This is based on inspection of stomachs from thirty shrimp randomly picked from a sample with high feeding activity. All thirty contained food. If regurgitation occurred frequently and caused the whole contents to be vomitted completely, some stomachs of this sample would probably have been empty.

In this study the main criterion for the relative importance of any organism as food is the frequency of its appearance in the shrimp stomach.

This method must be used with reservation since a small number of one form might occur in all the stomachs while large quantities of another organism might be found in somewhat fewer stomachs. In this work, however, crustaceans clearly were the most important food, since they occurred most frequently and the quantities of this food found in the shrimp stomachs were larger than those of any other organism. This was difficult to see in stomachs with mixed contents, but could be inferred from instances where only one type of ingesta was found. Polychaetes were second in importance. Stomachs containing only crustaceans were more completely filled than those containing only polychaetes.

The type of food eaten by the shrimp is restricted to that available in the habitat. Ecological investigations made in this area by Tabb, Dubrow and Manning (1962), have provided lists of the existing flora and fauna. It may be inferred that abundant organisms found in this habitat but not in the shrimp stomachs were avoided by the animal or somehow unavailable. The scarcity of plant material in the stomachs, when availability is high, indicates that the shrimp can

eat this food, but prefers other kinds.

The fact that diatoms were never found in large quantities, and that they were found only once with no other food present, suggests that these organisms do not constitute an important part of the diet. Since the shrimp's mouth is not equipped with a filtering device, diatoms found in the stomachs may have been ingested with other matter, like leaves and detritus, or as ingesta of the shrimp's prey.

The pink shrimp apparently does not seek out algae. Yet in India another shrimp, Penaeus indicus, consumes algae in large quantities (Panikkar and Menon, 1956).

It is of interest to note that in none of the stomachs were snails or clams encountered, unless some of the unidentified shells were molluscan in origin. These animals exist abundantly in the area of sampling. Most workers have found it as a constituent of the ingesta of pink shrimp (Eldred et al., 1961; Williams, 1955).

Debris was found frequently, by itself or combined with other food. With some elaborate technique it might be possible to differentiate which part of it came from the mud eaten by shrimp and which part was the result

of trituration and digestion, but this was not attempted in the present investigation. The mud contained in this debris might have some food value. It has been shown by Rae and Bader (1960) that "...it is almost certainly true that the natural sediments and detritus which are in temporary suspension in the sea scavenge out by sorption a proportion of the dissolved organic material .." They mention the possibility that benthic animals might be able to use this material as food.

In this work there was no indication of seasonal differences in the kind of food taken. Differences in the quantities of food consumed did occur, probably a consequence of the availability of the various items. The use of the same kinds of food the whole year round was reported by Kunju (1956) for Leander styliferus and by Allen (1960) for Crangon allmani in England.

The results of this study differed from most other studies on shrimp feeding habits because no previous investigators report a lower feeding activity during summer. The most similar conclusion, that of Mistakidis (1957) showed no significant differences between percentages of filled stomachs of Pandalus montagui between summer and in winter. Williams (1955) found that during

the fall pink shrimp stomachs were usually found to be full or half filled. This was confirmed in this work; but his further statement that gross examinations of shrimp in summer showed that stomachs and guts were usually filled could not be confirmed for this area. Eldred et al. (1961) found 8 per cent of their November specimens taken in the evening had empty stomachs. This was of the same magnitude as observed in this work for the flood sample of the same month.

# CONCLUSIONS

1. Stomachs of shrimp taken from monthly ebb tide samples from Buttonwood canal during the year 1963 showed low feeding activity in late winter and in summer. The highest feeding activity was in September.

2. Although the pink shrimp is omnivorous it has some preference for certain foods. Of the materials ingested, preferred food were crustaceans and polychaetes. Seagrasses, diatoms and foraminifera were apparently not preferred.

3. There were no differences in the kinds of food taken at different seasons of the year.

4. Among the sizes investigated, there were no differences in the diet or feeding activity among size classes of specimens.

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