SOME ASPECTS OF THE LIFE HISTORY OF CYPRINODON VARIEGATUS LACEPEDE 1803, IN SOUTHERN DELAWARE

Ву

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SUMMARY

During the period, May 12, 1962 to December 20, 1962, 5740 specimens of Cyprinodon variegatus were collected in the shore zones of Rehoboth and Indian River Bays of southern Delaware. The findings from a study of these collections serve as a basis for this paper in terms of the distribution of the species in the study area, age and growth patterns, reproduction and spawning, and food and feeding habits.

C. variegatus seems to be a permanent resident of the shallow brackish waters (0-5.0 ft.) of southern Delaware occurring in salinities which varied from 14.25 to 31.27 o/oo and water temperatures of 2-33°C.

Length-frequency distributions were used for the age and growth study since the use of fish scales did not prove feasible. The growth rate was rapid after hatching in May, being 2.4 mm per week but decreased to 0.5 mm per week in September. Fish hatched in May may have reached a standard length of 27-30 mm by September of the same year. Maximum standard length for females was 49 mm with a weight of 7.9 grams and for males 51 mm with a weight of 7.3 grams. Maximum age was probably three years.

The spawning season in \underline{C} . $\underline{\text{variegatus}}$ was quite extended, lasting from May to August as evidenced by an

examination of ovaries of the sheepshead minnow. Sexual maturity was attained in males at a standard length of 24-25 mm and in females at 27-28 mm. Females outnumbered males in all but two collections with an average sex ratio of 1.32 females to 1.00 males. Spawning was not observed but it was noticed that males did exhibit territorialism.

Analysis of intestinal contents showed that C. variegatus had a varied diet and that plant material, such as diatoms, algae, and possibly portions of Spartina, was the most important food. The only seasonal change in diet was the presence of copepods in the intestines during May and their absence thereafter. Fish of all sizes fed generally upon the same items.

INTRODUCTION

Although the sheepshead minnow, <u>Cyprinodon variegatus</u> Lacepede, 1803 is a well known brackish water species which is widely distributed, occurring in coastal waters from Cape Cod to Mexico, relatively little seems to have been recorded concerning its life history. What has been recorded is chiefly descriptive and there is a scarcity of information on the ecology of <u>C. variegatus</u>.

Hildebrand and Schroeder (1928) give a general description and a brief account of some of the habits of C. variegatus in the Chesapeake Bay area. Bigelow and Schroeder (1953) give similar information on the general habits, and a description of the species with its general range. Spawning, egg structure, and larval development of C. variegatus were observed by Kuntz (1914).

Newman (1907) was the first to describe the spawning habits of captive <u>C. variegatus</u>. Later, in 1919, Hildebrand was able to observe the sheepshead minnow spawning in laboratory aquaria and also gave information on other behavior and on the distribution of this species. More recently, Raney <u>et al</u>. (1953) studied the spawning habits of <u>C. variegatus</u> which occurred in shallow brackish water pools near Everglades, Florida. deSylva <u>et al</u>. (1962) present data on the environmental conditions in which this minnow occurs in the Delaware

Bay shore zone.

Due to the general lack of life history information, especially in the Delaware Bay region, the present study was undertaken to supply some of the needed information on: 1) the distribution of the species in the study area, 2) age and growth patterns, 3) reproduction and spawning habits, and 4) food and feeding habits. The findings on these four aspects of the biology of \underline{C} . variegatus serve as the basis of this paper.

MATERIALS AND METHODS

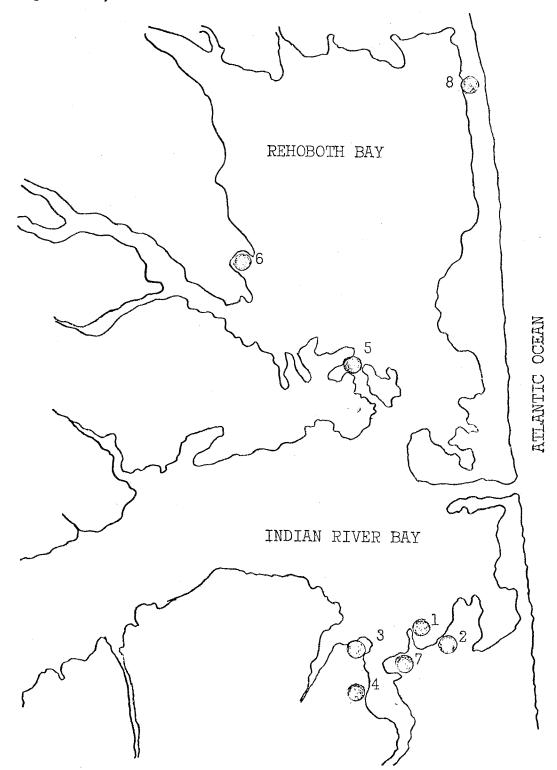
Distribution

During the eight-month period from May to December, 1962, 5740 specimens of Cyprinodon variegatus were collected in the shore zones of Rehoboth and Indian River Bays in southern Delaware. A total of 13 collections were made at eight sites from tidal pools, drainage ditches, marshes, and the shallow water near shore. The collecting sites as numbered on Fig. 1 were: 1) Pasture Point, 2) Pasture Point cove, 3) Big Marsh Point-drainage ditch, 4) Big Marsh Point-pool, 5) Roman-T Pond, 6) Sally Cove, 7) Derrickson's Point, and 8) Towers south of Dewey Beach.

Specimens were taken with two-man 0.50 inch stretched mesh push seines varying in length from four to eighteen feet, except on June 29 when Pro-nox fish poison (rotenone) was also used. These seines were useful only in sampling fish from water less than 5 feet deep. Fish were immediately preserved in 10% formalin for examination at a later date.

Water temperature data was recorded and water samples were taken for salinity determinations by the modified Knudsen method of ion titration. Other hydrographic information such as water depth, type of substrate, and stage of tide was noted along with the major plant types and fish associates. Identification of the fish associates was based on Breder (1948).

Fig. 1.—Map of the collecting area showing the eight collecting sites. From U.S. Coast and Geodetic Survey map #1219, 1961.



Age and Growth

Much of the information on age and growth was obtained from the length-frequency data. The standard length of 5740 fish was taken to the nearest millimeter with a fish measuring board and length-frequencies were obtained for both sexes in all collections. The length-frequency distribution for each collection was plotted and comparisons made between successive collections in an attempt to find characteristic modes which might serve to denote age-groups. Any gradual shift of these modes to higher values with the eventual loss of some groups due to mortality of old fish and also the addition of new groups due to natality and recruitment might indicate a growth pattern. The rate of modal change was examined to discern if it might give some indication of the growth rate.

Constants for the length-weight, relationship were calculated using Lagler (1956). By means of the formula (p.14) weights may be estimated from known lengths of fish.

Scale samples were taken from the area of the body between the origin of the dorsal fin and the lateral line on 300 randomly selected fish collected throughout the study period. The scales were cleaned, then mounted between two glass slides and marked for identification with a catalog number, size, and weight of fish.

Reproduction and Spawning

The sex ratio was obtained at the same time the

length-frequency data was taken on the 5740 fish.

A total of 300 fish (those from which scales were taken) of both sexes were opened and the gonads were removed, their condition noted (green, ripe, or spent), and weighed (except on immature fish) to the nearest 0.05 gram. The volume of the ovaries of each of 156 fish was taken by water displacement in a 5 milliliter graduated cylinder. The large ripe eggs were counted and measured and the data recorded. These large translucent eggs were over 1 mm in diameter, yellowish in color, and with minute oil globules and one large oil globule.

The size at sexual maturity was determined by examining the condition of the gonads for certain size groups of fish. Sexual dimorphic characters were observed and noted.

The condition of ovaries was also useful in determining the growth of <u>C</u>. <u>variegatus</u> by indicating the commencement and duration of the spawning period. By knowing the approximate time of hatching of a group of fish the growth rate could be calculated from the increase in length for a particular unit of time. Age could be approximated by figuring the time lapse from the time of hatching to the time of capture.

An attempt was made to observe spawning in laboratory aguaria and in the field.

Food and Feeding

The contents of the anterior portion of each intestine

of 122 fish was examined. At first, difficulty was experienced in determining which portion of the digestive tract should be examined since C. variegatus is stomachless, as are other members of the family Cyprinodontidae (Barrington, 1957). After a careful examination, the anterior portion of the digestive tract was arbitrarily selected for study. This part of the tract extends from behind the esophagus in the anterior part of the body cavity posteriorly around the first curve to a point where the intestine narrowed markedly. This most posterior point was sometimes hard to determine especially if the anterior gut was full.

The intestine samples were dissected out, placed in a petri dish, and the contents examined under the binocular dissecting microscope. Samples were also examined under the light microscope. Because of the nature of the food material ingested and its condition after entrance into the gut specific identifications were not attempted. Since the amount of the intestine studied was so small, the entire intestine of every fifth fish was examined to see if any items were being overlooked. The occurrence and number of food items was recorded whenever possible, along with estimated percent composition per gut and degree of fullness. Frequency of occurrence was calculated from this data.

Intestine-length to body-length ratios were obtained on 93 fish.

RESULTS

Distribution

<u>C. variegatus</u> was seined from shallow brackish water pools, drainage ditches, and on the shores of Rehoboth and Indian River Bays at various stages of tide. Fish seemed more abundant in the pools and drainage ditches during the flood-tide than during low waters and were always on or near the bottom. Many small fish less than 30 mm remained in the pools during the ebbing tide while the larger fish moved into the Bay proper. In the collections of August 30 and July 13 only relatively small fish were collected (about 25 mm average). These collections were made at low tide. On June 29 Pro-nox (rotenone) fish poison was applied at mid-ebb tide to kill fish in the pool at collection site #4. As a result all <u>C. variegatus</u> were killed. The pool was fully repopulated on August 2.

The type of substrate was nearly always sand in the Bay and the adjoining parts of the ditches and ponds. Silt covered the bottom of areas where water velocity was reduced. Some areas were covered with dense mats of <u>Ulva</u> and other large algal masses which provided excellent cover for the fish. There was much rooted-vegetation up to and growing in many of the pools and drainage ditches.

The species of fish most frequently found in association with <u>C. variegatus</u> were 1) <u>Fundulus</u> <u>heteroclitus</u> found

in 100% of the collections, 2) Menidia menidia 78.2%, 3) Fundulus majalis 73.9%, 4) Lucania parva 43.4%, and 5) Mugil curema 13.0%. Temperature, salinity, and depth readings for each site are shown in Table 1.

Age and Growth

The scale method for determining age did not prove useful and no data was obtainable. This method was discarded due to the difficulty in discerning annuli and the large number of discrepancies in reading those concentric markings which appeared to be annuli. In some larger fish, 39-43 mm, collected in June, no annuli on scales were seen while smaller fish had what appeared to be 2 annuli.

Scale formation in <u>C. variegatus</u> is probably complete at 11-12 mm S.L., however, only 5 specimens below 12 mm were available for measurement. One 9 mm fish had no scales and all fish over 12 mm possessed scales. Other bony parts such as otoliths and vertebral centra were not examined for annuli.

The length-frequency distributions for the collections from May to December are shown in Fig. 2.

Fish less than 21 mm long were collected for the first time on June 16. The modal length for this group was 16 mm which indicates an increase of 12 mm in length if these fish were hatched this spawning season (1962). The newly hatched larvae are approximately 4 mm long (Kuntz, 1914). All of the

Table 1.—Temperature, salinity, and water depth readings for collections from May 12 to December 20, 1962.

Date	Collecting site	Temp°C	Salinity-o/oo	Depth-ft.
5-12-6	2 1	26.0	no sample	.5-3,5
	2	21.0	no sample	1-2
5-26-6	2 3	29.5	27.02	2-4
	4	31.0	26,98	.5.5
6-16-6	2 5	23.0	21.01	.5-2
	6	25.0	21.46	1-2
	4	25.0	17,75	l l
6-29-6	2 1	22.0	18,29	.5-1
	2	24.0	28,99	.5-3
	4	27.0	28,15	. 5 . 2
7-13-6	2 5	28.5	30.06	0~1
	6	28.0	28,52	1
	4	33.0	28,69	0- , 5
	4	31.0	29,48	0-2
8-2-62	7	24.5	29,35	0-1
	3	25.0	29.12	0-2.5
	4	29.5	29.45	0-1.5
	2	27.5	no sample	0-2
8-17-6	2 7	28.0	27.53	0-2
	4	28.0	28.59	0-3
8-30-6	52 5	24.0	31.02	1-2.5
	7	28.5	31.27	0-1

Table 1.—Con't.

Date	Collecting site	Temp°C	Salinity-o/oo	Depth-ft.
9-22-6	52 7	15.0	18.64	0-1
	3	17.0	29.54	1-2.5
10-13-	62 8	19.5	25.91	0-3
	8	19.5	24.24	0-3
11-2-6	8	16.0	14.25	0-2
12-8-6	8	2.0	17.00	0-5
12-20-	62 7	3.0	27.99	0-3

females examined in the May 12 collection were gravid indicating that spawning may have commenced or was about to begin. The 12 mm increase from May 12 to June 16 gives a growth rate of 2.4 mm per week for the young fish.

The modal length for the young fish in July was 20 mm and in August it was 24 mm, growth of 4 mm each of these months or 0.89 mm per week. Modal point for the young fish in September was 26 mm which was an increase of 2 mm or 0.5 mm per week. The modal length for this group in October was 25 mm.

The length-weight relationship follows a characteristic J-shaped curve which may be calculated for this species by using the following formula (W=cLn) expressed logarithmically, log W=log c + n(log L), where log W=log of the weight, log L=log of the length, log c=constant (-4.03611), and n=constant (2.88618). The constants weré calculated from lengthweight data on 118 C. variegatus. Maximum recorded length for males was 51 mm and 49 mm for females. The maximum weight of 7.9 grams was recorded for a 49 mm gravid female.

Table 2 and Fig. 2 attempt to show growth of young fish by showing the increase in length of fish during the summer of 1962. In Table 2, all of the specimens were collected at Big Marsh Point except those for August 30, which were collected at Derrickson's Point.

A number of tumors were noticed which resembled those

Fig. 2.—Length-frequency distributions of <u>C. variegatus</u> collected May-December, 1962 in Rehoboth and Indian River Bays.

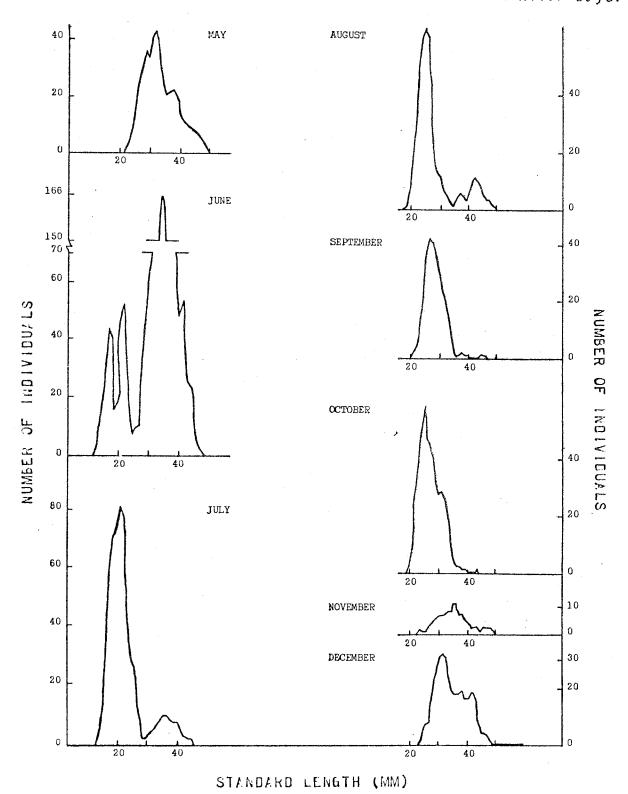


Table 2.—Changes in length-frequency distribution for young C. variegatus collected during the summer 1962.

S.L. (mm)	Freq	uency f	for each	colle	cting d	ate	
	6-16	6-29	7-13	8-2	8-17	8-30	A MADE TO THE
11			1				
12		1	0				
13	1	3	0				
14	7	2	2	1			
15	9	2	15	7	2	1	
16	4 5	7	29	11	0	0	
17	69	18	58	13	1	0	
18	124	15	90	7	6	1	
19	87	12	58	13	7	4	
20	51	16	69	25	14	5	
21	19	21	51	30	, 15	9	,
22	3	29	22	35	40	22	
23		11	11	19	43	13	
24		7	5	27	51	18	
2 5		2	4	25	48	19	
26				17	21	17	
27				10	8	5	
28				1	9	6	
29					3	8	
30					2	7	
Total	415	146	415	241	270	137	
Median length	18	20	19	22	23	24	

reported for <u>C. variegatus</u> by Nigrelli and Smith (1938).

These tumors usually occurred on the dorsal half of fish 2845 mm S.L. and were only observed on fish collected during May through August.

Reproduction and Spawning

An average sex ratio of 1 male: 1.32 females was obtained from examination of 5470 fish. In only 2 collections were males in the majority. It was not possible to determine the sex of 270 of the smaller fish by means of external observation. These fish ranged in size from 11-21 mm S.L. and resembled the larger females.

Table 3 shows the change in ovary weights, the ratio of ovary-weight to body-weight, ovary volume, and the number of matured eggs during the probable spawning season. This data shows a decline in average egg production after a spring peak in early May. There appears to be another peak in mid-July followed by a sharp decline until the end of the spawning season in mid-August. These preserved ripe eggs were demersal and averaged 1.18 mm in diameter. Examination of ovaries of fish collected from August 17 to December 20 showed no matured eggs and the ovaries were greatly reduced in weight and volume to less than 0.10 gram and 0.10 milliliter respectively. (See Figs. 3 and 4.)

Ovaries contained eggs of different sizes especially in fish collected in May and June, however, these eggs were not

Table 3.—Changes in ovary-weight and volume, ovary-weight to body-weight ratio, and the number of matured eggs during the probable spawning season. Weight in grams and volume in milliliters.

Coll. date	A	В	С	D	E	F	G	Н	
5-12	15	32.9	2.4	.54	.225	.3].	193.3	0	-
5-26	16	35.6	3.0	.27	.088	.26	90.6	4	
6-16	14	35.5	2.8	.22	.077	. 23	56.6	5	
6-29	12	37.1	3.1	.17	.055	.1.5	35.3	6	
7-13	8	36.2	3.1	.34	.110	.23	97,5	0	
8-2	10	37.7	3.4	.22	.064	.20	19.4	4	
8-17	11	38.7	3.9	.12	.031	.13	0.2	10	
Total	86								

A= Number of fish

B= Mean length of fish

C= Mean weight of fish

D= Mean weight of ovary

E= Ovary-weight to body-weight ratio

F= Mean volume of ovary

G= Mean number of matured eggs

H= Number of ovaries without large eggs

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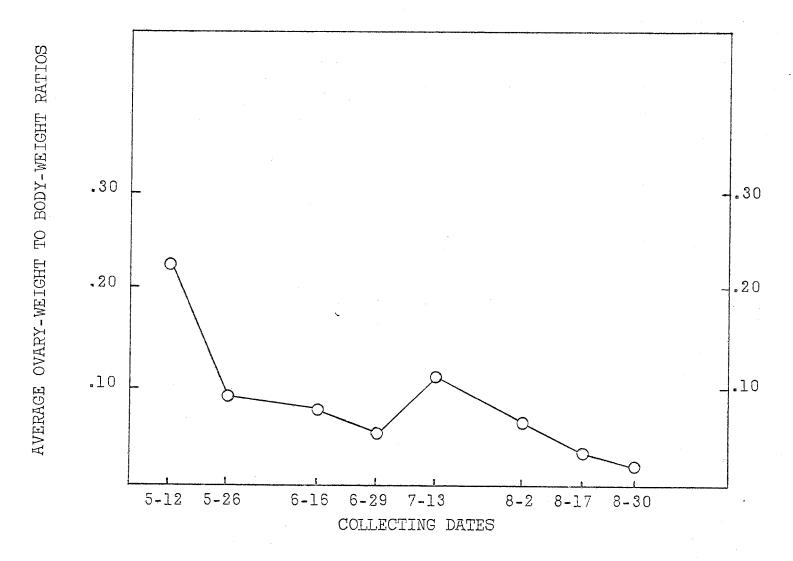
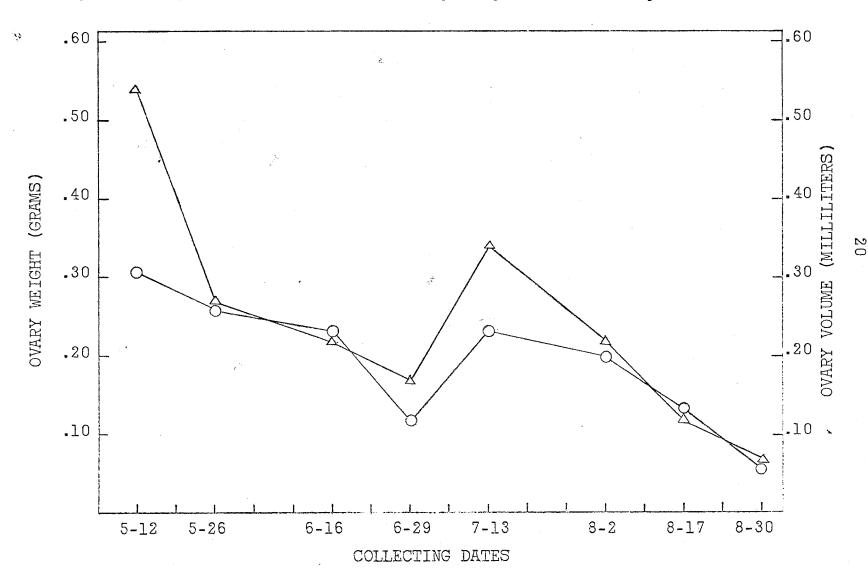


Fig. 4.—Mean weight and volume of ovaries of 94 fish collected during the probable spawning season. Δ =mean ovary-weight. σ =mean ovary-volume.



counted. Nearly mature eggs measured 0.70 mm.

Four male <u>C. variegatus</u> kept in laboratory aquaria acquired spawning colors after the first week in April 1963. No other data is available as to the advent of the spawning season due to the fact that collections were not begun until after spawning was in progress.

No females below 27 mm S.L. were found to contain ripe eggs. Males were mature at 24-25 mm S.L.

Spawning was not observed in captive fish or in the natural habitat. Males kept in aguaria exhibited territorialism. These males drove away other males and even the females in most cases without making contact. These males were in bright spawning coloration (greenish-blue on the dorsal surface anterior to the dorsal fin, dark black margin of caudal fin, ventral and portion of lateral side orange) and when other fish approached would extend the dorsal and pelvic fins and begin pursuit of the invader.

Food and Feeding

The anterior portion of the intestine of 122 C.

variegatus of various sizes was examined; of these 17 were
empty of food. The entire intestine of 16 of the latter,
which were all collected in December 1962, were empty.

Table 4 shows an analysis of the contents of the portion of intestine examined for 105 C. variegatus including

the number of intestines which contained the various items and the percentage of intestines containing each item. Percentage of total volume refers to the relative amount that each item contributes to the total amount in the examined portion of the gut. Contents referred to as unidentified organic debris were well-crushed. This is probably due to the fact that C. variegatus possess maxillary and pharyngeal teeth which can be used for scraping and grinding food material respectively. Diatoms were included in this category and were found in the guts of most fish.

The almost total absence of any recognizable animal parts and the general appearance of the material in the intestine suggest a plant composition of the diet. Animal tissue made up only 4.6% of the organic contents of the gut while plant material and unidentified organic, remains accounted for 95.4%. Filamentous algae was quite abundant in some intestines. Most of this algae was probably Oscillatoria sp. while the remainder was probably green or red algae. Higher plant remains consisted mainly of portions of roots or stems recognized by their fibrous nature and gross appearance.

The most common animals in the diet of <u>C</u>. <u>variegatus</u> were copepods and nematodes. Copepods were observed only in the intestines of fish from the spring collections of May 12 and 26 with the greater number per intestine sample in the May 12 collection. This was the only qualitative change in diet

from May to December.

Fish kept in laboratory aquaria fed at all times of the day on a number of food items, such as <u>Ulva</u>, plant roots, commercial aquarium fish food, parts of crabs, clam, squid, and even showed cannibalistic habits. Fish in the aquaria fed actively at both the surface and on the bottom.

No qualitative differences in diet were apparent between size groups of the sheepshead minnow.

An average ratio of 3.1:1.0, intestine-length to body-length, was obtained from measurements on 93 fish. Intestine-length was as much as 1.46 to 4.80 times the length of the body. The average ratio of intestine-length to body-length did not change with an increase in length of the fish.

Table 4.—Contents of the anterior portion of the intestine of 122 Cyprinodon variegatus collected from May to December 1962.

Item	A	В	C	D
Unidentified organic debris	102	97.1	69.5	1
Higher plant remains	87	82.9	8.4	3
Filamentous algae	27	25.7	3.8	4
Copepods	12	11.4	1.4	5
Nematodes	10	9.5	0.2	7 .
Sand	86	81.9	15.3	2
Insect larvae or remains	3	2.9	0.1	8
Polychaete worm remains	3	2.9	1.1	6
Crustacean remains	2	1.9	0.2	7

A= Number of intestines containing item

B= Percent occurrence

C= Percent of total volume

D= Rank by volume

17 of the 122 intestine samples were empty of food and are not included in the above table.

DISCUSSION

Distribution

- C. variegatus has a broad general range on the Atlantic coast of the United States from Cape Cod to Mexico (Jordan and Evermann, 1900). According to Hubbs (1936) there may be four subspecies in the United States and Central American area; C. v. cvinus from Cape Cod to Virginia, C. v. variegatus from North Carolina to Texas, C. v. artifrons in the Yucatan peninsula, and C. v. riverendi of Cuba and Jamaica.
- C. variegatus is an abundant species found in shallow brackish water coves, bays, ponds, and creeks, but less common along the open beaches (Hildebrand and Schroeder, 1928). All fish in the present study were collected in less than 5 feet of water; depths over 5 feet could not be sampled with the gear available. Further sampling is needed to determine if these fish inhabit waters deeper than 5 feet. Most fish, however, were collected in water less than 2.5 feet deep in the shallow drainage ditches and ponds which connected to Indian River and Rehoboth Bays. Water depth may be one factor limiting the distribution of C. variegatus in the study area, but it is difficult to state the importance of this factor due to the lack of sampling of deeper water.

Salinity seemed to be irrelevant in affecting the

distribution of <u>C</u>. <u>variegatus</u>. The salinity range was 14.25—31.27 o/oo. Massman (1954) found many <u>C</u>. <u>variegatus</u> in a tidal creek of the Rappahannock River, Virginia where the salinity was only 5 o/oo. At the other extreme, Pearse and Gunter (1957) state that <u>C</u>. <u>variegatus</u> has been found alive and active in shore ponds of Texas which contained water at specific gravities equivalent to sea water of 144 o/oo. deSylva <u>et al</u>. (1962) collected this minnow in salinities of 4-35 o/oo from the Delaware River estuary. It is concluded that <u>C</u>. <u>variegatus</u> is definitely a euryhaline species with considerable powers of osmoregulation.

The temperature range of 2-33°C indicates an ability to tolerate a wide seasonal variation in temperature. deSylva et al. (1962) recorded temperatures of 4-24°C for this minnow. High water temperatures (29-33°C) were probably the result of high air temperatures and dark substrate in shallow pools. Harrington and Harrington (1961) found young C. variegatus in one shallow water pond in which the water temperature had risen to 43°C, which according to Brett (1956) is above the lethal limit of fishes tested experimentally. Barlow (1958a) states that species of Cyprinodon tend to avoid temperatures above 36-37°C. In the present study only small fish were found in pools with temperatures above 29°C. This might indicate that small sheepshead minnows possess a higher incipient lethal temperature than larger ones, however this hypothesis was not tested. Pearcy (1962) does suggest this as a possible

mechanism in the distribution of the winter flounder,
Pseudopleuronectes americanus.

Temperature may be important in affecting the distribution of <u>C. variegatus</u> by indirectly influencing the amount of dissolved oxygen. Larger fish require more oxygen for their higher metabolism and thus might not be found in water with little dissolved oxygen, whereas small fish may be able to survive in the same waters. deSylva <u>et al</u>. (1962) collected <u>C. variegatus</u> in waters with dissolved oxygen values of 1-6 ml/liter and oxygen saturation from 20-90%.

Since relatively little is known of the habits of Fundulus heteroclitus, it is difficult to say how much if any competition exists between this species and C. variegatus. Perhaps there is some competition for space since the two species were always collected together.

Age and Growth

Very little information is available in the literature pertaining to age and growth of <u>C. variegatus</u>. According to Kuntz (1914) newly hatched larvae are 4 mm long and 5 days after hatching the yolk sac is completely absorbed and the fish are 5 mm long. At 12 mm virtually all of the diagnostic characters of the full grown fish are developed (Hildebrand and Schroeder, 1928). These authors give no data on the time required to reach a total length of 12 mm. In the present study the modal length for the group of smallest fish caught

in June is 16 mm S.L. It seems unlikely that fish of this size in June had lived through the previous winter. So it is assumed that these fish were from the May 1962 spawning. This would give an increase of 12 mm for a 5 week period and an average growth rate of 2.4 mm per week. The growth rate decreases considerably during July and August to an average of 0.89 mm per week and 0.5 mm per week in September. modal standard length of 24 mm for the August collections approximates the 32 mm total length of fish in August as reported by Hildebrand (1919). Many factors may account for such discrepancies such as mean temperatures during the time since spawning, difference in spawning time, differences in diet and climate during the two studies, etc. It is concluded that for fish hatched at the advent of the spawning season, the growth rate up to 16 mm is rather rapid and decreases until October and that throughout the winter very little growth takes place.

Fig. 3 suggests a period of late spawning decreasing from mid-July to no spawning after mid-August. The fish from these spawnings are represented in Fig. 2 on the curves for October, November, and notably for December. If fish were spawned as late as mid-August they would have grown to only 16-20 mm by mid-December. This represents a maximum growth of 12-16 mm in 4 months compared to a similar increase in the first 2 months of life of those fish spawned in early May. Fish spawned as late as mid-August might reach a length of

22-24 mm by the next May which could be represented by individuals such as those in a similar range in the May 1962 collection.

It is difficult to make any definite statements as to the growth rate other than during the first summer. A tentative age-size grouping might be as follows: hatching at 4 mm, one year 20-34 mm, two years 38-45 mm +, three years most fish which survive to their third year probably will die early during the same year. The wide variation in sizes for each group is probably due to differences in growth rate and time of hatching.

during part of the summer 1962 comparable to portions of the curves in Fig. 2. These are separate collections while the curves in Fig. 2 are combined totals for each month. Median lengths for the distributions are given. The median length of 19 mm for the 13 July 1962 collection may be influenced by measurement of a greater number of 14-16 mm fish which may have come from the June spawnings and not the May spawnings as are most of the fish. This would seem to throw this median length out of phase with the other median length values.

Reproduction and Spawning

The mean sex ratio of 1 male: 1.32 females for the May to December collections in Rehoboth and Indian River Bays indicate a general predominance of females. Only in the

collections of November 2 and December 8 did males predominate. Hildebrand (1919) states that the sexes appear to occur in equal proportion.

The spawning season in North Carolina continues from the middle of April until the middle of August (Kuntz, 1914). Hildebrand (1919) was able to obtain ripe females at nearly any time from April until October. In the present study it is concluded that the spawning season lasts from at least May 12 to the middle of August (Fig. 4). Further sampling is necessary to determine exactly when the spawning season begins. It seems reasonable to think, in view of the findings of other workers, that spawning of <u>C. variegatus</u> in southern Delaware begins in the month of April. Three males kept in a laboratory aquarium did exhibit bright spawning colors beginning the first week of April 1963. The temperature ranged from 20-23°C during the preceding several weeks and it is conceivable that water in shallow pools could warm to this temperature during the early part of April.

The ovary-weight to body-weight ratios in Table 3 tend to show a relatively high weight of ovaries when collecting began in May 1962. The ratio was then 0.225 but gradually decreased to 0.055 at the end of June. The mean number of matured eggs per ovary also decreases during the same period. These data seem to indicate that the heaviest spawning takes place in May with a gradual reduction in

spawning by the end of June. There is during the same time an increase in the number of female fish in which the ovaries are without mature eggs. An increase of ovary-weight to bodyweight ratio up to 0.110 is seen in the July 13 collection along with an increase in the mean number of matured eggs per ovary. All of the ovaries examined in mature fish had ripe eggs. Although the number of ovaries examined in this collection was small, the presence and large mean number of mature eggs in each of the ovaries suggests that there was a second peak of spawning in mid-July. This second peak is somewhat less in magnitude than the major spawhing in May (Fig. 4). The apparent second spawning peak might be due to the late spawned fish of 1961, which were not quite mature in May 1962, but became mature and spawned in July 1962. Late spawned fish would have grown to about 22 mm by the next May and would have easily reached a spawning size by July. The smallest fish which contained mature eggs were 27 mm S.L. Males in the June 16 collection were mature at 25 mm S.L. According to Hildebrand and Schroeder (1928) sexual differentiation in color takes place when the fish are about 30 mm long which is equivalent to 23-24 mm S.L.

Fish probably do not spawn during their first summer, since they do not attain spawning size (27 mm for females, 25 mm for males) until after the termination of the spawning season in mid-August. A number of fish in the 22-25 mm size range were maturing during August and September but it is

doubtful whether these fish would spawn during their first summer.

Kuntz (1914) found that the mature unfertilized ova are spherical in form, demersal, and 1.2-1.4 mm in diameter. Hildebrand (1919) indicates the diameter of mature eggs to be about 1.0 mm. In the present study the average size of mature ova was 1.18 mm with a range of 0.97-1.37 mm. These eggs are yellowish to cream colored and fairly translucent and contain many small oil globules and usually one obviously larger oil globule. They may also be situated on minute threads like beads on a string. These threads may aid in keeping the eggs together and for attachment to bottom materials.

Newman (1907) was the first to record observations on the spawning of <u>C</u>. <u>variegatus</u> in captivity. More recently, Raney <u>et al</u>. (1953) observed <u>C</u>. <u>variegatus</u> spawning in their natural habitat in Florida. They noted that spawning took place in shallow, quiet or slowly moving, brackish water during daylight hours. Males usually build nests and defend territories. Males in bright spawning colors maintained territories in laboratory aquaria for several days at a time during June and July 1962. No spawning was observed in the aquarium possibly due to the fact that conditions were crowded.

In the present study it was not determined if individual females spawn for any extended period of time. Hildebrand (1919) observed that one large female produced eggs intermittantly from April 28 to August 16. He also states that the species spawns throughout the summer. The presence of eggs of different sizes in the ovaries of <u>C</u>. <u>variegatus</u> seems to indicate that the spawning season for this species is fairly long. Hickling and Rutenberg (1937) have shown that by recording a size-frequency distribution of eggs in ovaries it is possible to ascertain whether a species spawns within a short or long period. In fish with long spawning periods such as the hake there is no sharp segregation between ripening eggs and the small eggs of the general egg-stock. This seems to be the condition in <u>C</u>. <u>variegatus</u>, however, no size-frequency distributions were made. Ovaries did contain ova of various sizes from less than 0.1 to 1.37 mm.

Food and Feeding

C. variegatus seems to have a relatively varied diet (Table 4). Hildebrand and Schroeder (1928) state that the diet of this minnow in Chesapeake Bay consists largely of vegetable matter and in 20 "stomachs" examined, only sand, mud, debris, and filamentous algae were found. Hildebrand (1919) found plant stems, algae, and mud in their "stomachs".

C. variegatus collected from Florida salt marshes was found to subsist primarily on plant material and only during the development of a mosquito brood (Aedes) did they switch from the herbivorous diet to feed partially on the mosquito larvae (Harrington and Harrington, 1961). Only after the larvae had developed to the pupal stage did Cyprinodon revert entirely to

its plant diet.

Unidentified organic debris is the most important category occurring in 97.1% of all intestines. This category gave an average percent of total volume of 69.5 for 105 intestines examined. In many intestines this was the only category present. It is difficult to make any statements as to the precise composition of this category. As previously stated, diatoms were included in this category, and were quite abundant but made up a relatively small portion of the total organic contents of most intestines. Other than diatoms all other material in this category was unidentifiable. known whether this material was ingested as detritus or reached an unrecognizable state due to mastication and chemical diges-It seems likely that a large part of this material was of plant nature, perhaps non-fibrous portions of Spartina which was very common in and around the collecting sites. Portions of colonial or multicellular algae other than diatoms may have also contributed volume to this category.

The paucity of identifiable parts of crustaceans or annelids suggest that these made up only a minor part of the diet and that their soft tissues were not significant as unidentified organic debris. It is possible that the soft tissue of other animals, such as fish contributed some volume to this category. No fish scales were found, however, thus eliminating fish as a typical food item even though it is

reported that captive <u>C</u>. <u>variegatus</u> will feed on other fish (Hildebrand, 1919; Hildebrand and Schroeder, 1928). Harrington and Harrington (1961) found that <u>C</u>. <u>variegatus</u> was nonpiscivorous. Sheepshead minnows in aquaria were observed to feed on other small fish (<u>Fundulus</u>) and exhibited cannibalism.

This may have been due to the crowded conditions of the aquarium and the lack of natural food. It is presumed that plant material was the primary constituent of unidentified organic debris.

Higher plant remains were present in many intestines but made up only an average of 8.4% of the total volume. Filamentous algae had an average of 3.8% of the total volume. Identification of algal forms was difficult due to the loss of pigments and the crushed appearance of the cells.

All identifiable animal categories constituted an average of only 3.0% of the total volume. Copepods were fairly abundant in the intestine of \underline{C} . variegatus but only in the spring (May 12 and 26) and afterward were not present. This was presumeably due to the fact that there was then more plant material available for consumption. Further collections are necessary to determine what importance copepods have in the diet of \underline{C} . variegatus during early spring months (March-April). It is possible that the nematodes were not food items at all but rather parasites on the fish containing them.

Sand was present in 81.9% of the intestines and

contributed a considerable amount to the average percentage (15.3) of the total volume, ranking second. The prominence of this category may be influenced by the fact that sand is not digested and remains in the gut while organic materials are digested. Perhaps the sand is not moved through the intestine at the rate that food is and therefore may appear more important in the total volume. Possibly the sand in the intestine has some function as a mechanism for the mechanical breakdown of food along with the maxillary and pharyngeal teeth. These teeth and sand may take over the mechanical function that the stomach would usually have in other fish.

Ingestion of materials found on or near the bottom such as sand, nematodes, filamentous algae, and debris tend to indicate that the sheepshead minnow is a bottom feeder. However, fish in aquaria fed both on the surface, throughout the water column, and on the bottom. A distinction between benthic and surface feeding may not be important since fish probably feed in shallow water less than 3 feet.

The ratio of 3.1:1.0 intestine-length to body-length, and the highly convoluted nature of the intestine tend to support the idea that <u>C</u>. <u>variegatus</u> is chiefly herbivorous. Hildebrand (1919) found the intestine length to be about 2.3 times the length of the fish and suggests from this that plants form the principal natural food. Hildebrand and Schroeder (1928) suggest the same thing. The longer intestine

may have a great advantage over a shorter one under certain conditions, since it may be expected to retain food longer and this may serve as an adaptation to an herbivorous diet (Barrington, 1957). Apparently little is known of the enzymes, rate of passage of food through the gut, or the histology of the intestine of C. variegatus all of which could influence the kind and amount of certain materials that will be digested. The correlation between intestine length and the type of diet, however, is weakened by the omnivorous habits of many fish (Barrington, 1957). This is shown by the variety of items in the diet of the sheepshead minnow and by the data of Harrington and Harrington (1961). concluded that in the present study C. variegatus can by classified as a primary consumer (second trophic level) feeding directly on plant material which constitutes the first trophic level.

C. variegatus has no apparent economic value but is an important link in the food chain serving as food for larger fish. The sheepshead minnow may have some value as an eradicator of mosquitoes although not demonstrated as such in this study.

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