AGE AND GROWTH OF THE NORTHERN SEAROBIN

PRIONOTUS CAROLINUS (LINNAEUS)

A Thesis

Presented to

The School of Marine Science

The College of William and Mary in Virginia

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

By

Robert S. P. Wong

1968

APPROVAL SHEET

This thesis is submitted in partial fulfillment

of the requirements for the degree of

Master of Arts

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ACKNOWLEDGMENTS

I am grateful to Dr. W. Jackson Davis who suggested the problem and made valuable comments and critical evaluation of the thesis. I also thank Dr. Edwin B. Joseph and Mr. John J. Norcross for their guidance and comments. Mr. Frank J. Wojcik supervised my use of the computers, for which I am indebted. Acknowledgments must also be given to the following persons who have rendered assistance: Mrs. Jane Davis, Miss Phyllis Edwards, Miss Evelyn C. Wells, Messrs. Robert S. Bailey, Peter J. Eldridge, John D. McEachran, Wilton E. Mansfield and James S. Sterling.

This study is a part of project 3-5-D of the U. S. Bureau of Commercial Fisheries and the Virginia Institute of Marine Science under provision of the Commercial Fisheries Research and Development Act of 1965 (PL 88-309).

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ABSTRACT

The purpose of this study was to determine the age and rate of growth of the northern searobin, Prionotus carolinus (Linnaeus) from Chesapeake Bight and its vicinity.

The first five age-groups could be determined on the basis of growth zones observed in transverse sections of scorched otoliths. From an analysis of length frequency histograms, the first three age-groups could be inferred despite an unusually large number of larger fish. The northern searobin has a slow growth rate and a long life span.

The length-weight relationship varied with seasons. Relative conditions reflected the sexual maturation period and the reproductive cycle. Prionotus carolinus spawned in July, August, and part of September in the Chesapeake Bight. They matured sexually at age II or III.

AGE AND GROWTH OF THE NORTHERN SEAROBIN

PRIONOTUS CAROLINUS (LINNAEUS)

INTRODUCTION

The present study was made to determine the age and rate of growth of the northern searobin, Prionotus carolinus (Linnaeus).

The northern searobin is abundant in the coastal waters of eastern North America from southern New England to North Carolina and its range extends from the Bay of Fundy to South Carolina (Bigelow and Schroeder, 1953). These fish move inshore during the summer and offshore during the winter; they have been caught in both shallow brackish waters and in waters 186 m deep (Bigelow and Schroeder 1953). According to the above authors, northern searobins prefer sandy bottoms and when disturbed, they bury themselves in the sand, leaving the top of their head and eyes protruding. They also emit a grunting noise when alarmed as opposed to a staccato call believed to be related to breeding behavior (Moulton, 1956). They feed primarily on copepods, mysids, amphipods and decapods (Marshall, 1946; Richards, 1963). The spawning season occurs in the summer and eggs develop in a manner typical of pelagic teleostean eggs (Kuntz and Radcliffe, 1918). Incubation period is about 60 hours at 22°C, and newly hatched larvae are approximately 2.8 mm long. When the fish attain a length of 25 to 30 mm, most of the adult features have been acquired. Characteristics and taxonomic features of this triglid fish were reviewed by Jordan and Hughes (1887) and Ginsburg (1950). The life history has been investigated by Marshall (1946).

METHODS AND MATERIALS

This study was based on data obtained from 3634 fish, most of which were caught on the continental shelf of Chesapeake Bight between November 1965 and May 1967 (Fig. 1). Samples of small fish were obtained from the Chesapeake Bay and the York River. The data in Table 1 are arranged in chronological order showing the date, locality, number of fish, depth and bottom temperature for each sample.

Chesapeake Bight was sampled from the trawler, Sea Breeze, chartered by the Virginia Institute of Marine Science. A 45-foot semi-balloon otter trawl having a small mesh liner ($^1/4$ inch) in the cod end was used in catching the fish. The small mesh was intended to reduce escapement of small fish. At each station the trawl was towed for 30 minutes at a speed of approximately 3 knots. Fish were preserved in ice and brought back to the laboratory for examination and analysis. The Chesapeake Bay and York River collections were made from the R/V Pathfinder using a 30-foot semi-balloon otter trawl with a $^1/2$ inch mesh in the cod end. Fish were preserved in formalin. Samples collected in 1955 and 1956 were preserved in alcohol.

Fork length of fish was measured in mm from the tip of the snout to the center of the fork of the caudal fin. All lengths in this paper are fork lengths unless otherwise stated. Weights were

Figure 1. Area (shaded) in which Prionotus carolinus were caught.

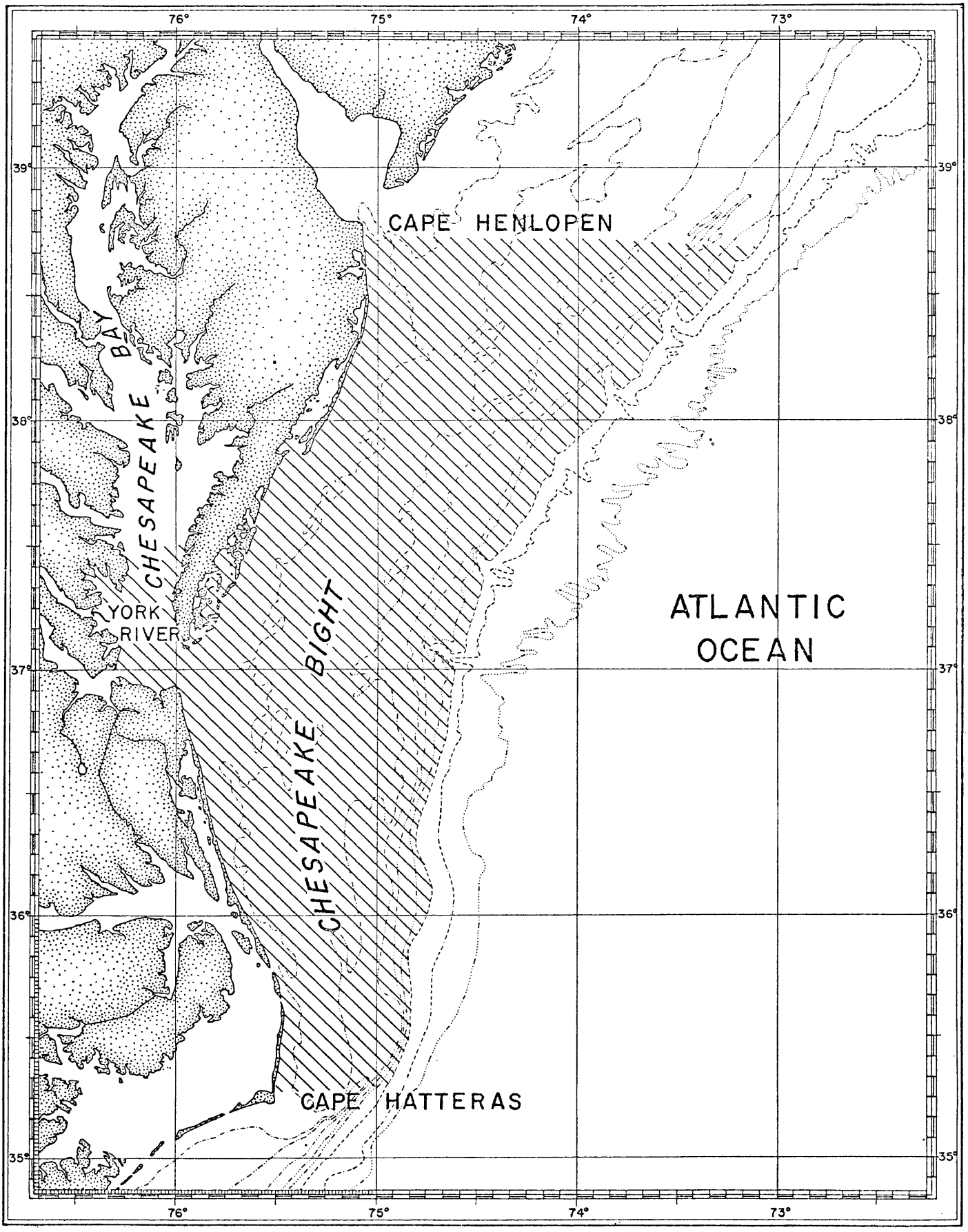

76°
75°
74°
73°
39°
38°
37°
36°
35°
CAPE HENLOPEN
CHESAPEAKE BAY
YORK RIVER
CHESAPEAKE BIGHT
ATLANTIC OCEAN
CAPE HATTERAS

TABLE 1

Data for each sample of *Prionotus carolinus*: date, locality, sample size, bottom temperature and depth.

Date	Location		Sample	Bottom	Depth
	Lat.	Long.	Size (N)	Temp. (C)	(m)
April 1955	Chesapeake Bay		96	--	--
April 1956	York River Mouth		99	--	--
7 XII 1964	Chesapeake Bight		51	--	60
30 VI 1965	Chesapeake Bight		50	--	--
15 XI 1965	36°52'N	75°30'W	99	--	26
18 II 1966	38°18'N	73°51'W	65	7	86
24 II 1966	37°06'N	74°46'W	70	6	88
24 II 1966	36°50'N	74°48'W	50	6	53
24 II 1966	36°38'N	74°47'W	50	6	62
24 II 1966	36°29'N	74°49'W	175	6	73
24 II 1966	36°25'N	74°50'W	99	6	92
24 II 1966	36°31'N	75°00'W	50	5	37
3 III 1966	35°59'N	75°07'W	99	7	37
3 III 1966	36°18'N	74°55'W	99	7	55
11 III 1966	37°38'N	74°24'W	99	6	70
11 III 1966	37°47'N	74°15'W	99	7	92
13 IV 1966	35°42'N	75°02'W	99	--	48
6 V 1966	36°41'N	75°42'W	30	13	16

TABLE 1 (Continued)

Date	Location		Sample	Bottom	Depth
	Lat.	Long.	Size (N)	Temp. (C)	(m)
6 V 1966	36°28'N	75°44'W	50	13	18
9 V 1966	37°02'N	75°08'W	99	9	40
13 V 1966	38°01'N	75°07'W	70	13	18
13 V 1966	38°28'N	74°54'W	60	14	13
13 V 1966	38°38'N	74°37'W	99	12	29
13 V 1966	38°28'N	74°37'W	80	11	27
14 V 1966	38°12'N	74°44'W	99	11	22
19 V 1966	37°03'N	75°35'W	75	--	18
23 V 1966	37°01'N	75°38'W	99	14	13
26 VII 1966	37°04'N	76°05'W	95	--	26
4 VIII 1966	Chesapeake Bay		30	--	--
25 VIII 1966	37°08'N	75°41'W	150	17	15
25 VIII 1966	37°14'N	75°29'W	99	16	24
26 VIII 1966	37°46'N	74°55'W	99	11	29
27 VIII 1966	38°51'N	74°35'W	99	12	20
28 VIII 1966	38°36'N	74°53'W	40	11	22
28 VIII 1966	37°40'N	75°22'W	99	16	15
29 VIII 1966	37°03'N	75°47'W	40	16	9
1 XI 1966	37°04'N	75°26'W	30	16	27
16 XI 1966	37°47'N	74°47'W	60	12	38
25 XI 1966	36°51'N	75°19'W	33	13	26

TABLE 1 (Continued)

Date	Location		Sample	Bottom	Depth
	Lat.	Long.	Size (N)	Temp. (C)	(m)
25 XI 1966	36°36'N	75°19'W	30	12	31
26 XI 1966	36°49'N	74°45'W	250	11	73
30 III 1967	36°22'N	74°49'W	140	9	109
1 V 1967	36°54'N	75°33'W	50	8	20

accurate to ± 3 g; fish preserved in alcohol and formalin were not weighed.

Sex and gonadal condition were determined by gross examination.

Data were entered on IBM cards and computations were done with calculator and computer (IBM 360 Model 50).

CONVERSION FACTORS FOR LENGTHS OF FISH

The conversion factors for standard, fork and total lengths were derived from 175 fish having a range in length from 160 to 289 mm (Table 2). The standard and fork lengths were 76.9 and 94.2 per cent of the total length, respectively. Fish were measured according to the method of Hile (1945).

TABLE 2

Conversion factors for standard (S. L.), fork (F. L.) and total (T. L.) lengths of northern searobin.

F. L. = 0.942 x T. L.
S. L. = 0.769 x T. L.
S. L. = 0.816 x F. L.

DETERMINATION OF AGE

Cleithra, opercles, otoliths, scales and vertebrae were examined in a preliminary study to determine the skeletal structure most suitable for determining age and growth of Prionotus carolinus. All of these structures showed growth marks, but I could not determine the nature of the annulus. Scales and otoliths stored in corn syrup could be used for determining age of fish from age-groups 0 and I but were inadequate for older fish.

The technique of burning or scorching otoliths (Christensen 1964)was used to reveal zones for estimating age and growth. This method is based on the seasonally varying chemical composition of the otolith. The hyaline zone is primarily organic material (conchiolin) formed during the cold months; the opaque zone is primarily inorganic material (calcium carbonate) formed during the warm months (Dannevig, 1956; Irie, 1958). Normally, the opaque zone appears dark in transmitted light and whitish in reflected light, but the hyaline zone appears white in transmitted light and dark in reflected light. However, when the otolith is scorched the hyaline zone is carbonized and turns black, whereas the opaque zone remains white. When examined under low magnification, a transverse section of a scorched otolith exhibits alternating broad white zones (the opaque zones) and narrow black zones (the hyaline zones).

Techniques

The otolith was removed from the left sacculus by cutting with a stout scalpel through the bony layer forming the floor of the skull. Adhering tissues were removed from the extracted otolith. The length and width of the otolith were measured and the cleaned and dried otolith was weighed. The otolith was broken in two by applying gentle pressure with a scalpel at the middle of and perpendicular to the longer axis. The broken surfaces of the otolith were scorched in a low flame from a Bunsen burner for 5 to 20 seconds; the time of scorching depended on the size of the otolith and the temperature of the flame. During the process of scorching, the color of the hyaline zone changed from white to brown and then to black and the opaque zone changed from white to light-brown and then to white again. Some experience was necessary in order to avoid charring the surface.

After being cooled the brittle otoliths were imbedded in plasticine in slots of a wooden tray. In two to three days the plasticine hardened, affording a permanent mount. A few drops of glycerine on the surface of the otolith increased the contrast between the opaque and hyaline zones.

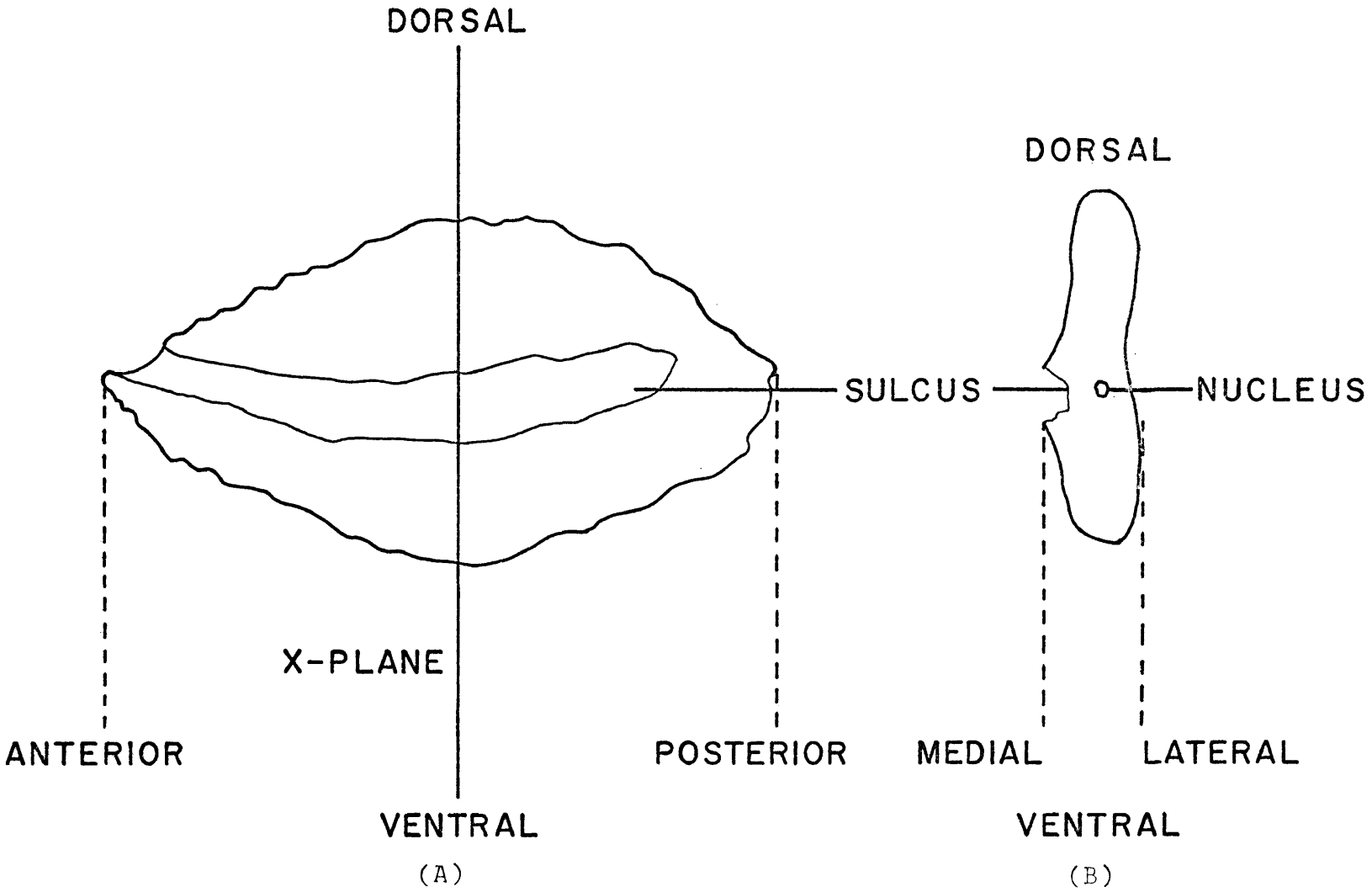
Topography and Growth of the Otolith

The otolith of the northern searobin is oval with a mildly crenated margin (Fig. 2). There is a slight concavity on the outer side and a broad but shallow sulcus on the inner side. The ventral

Figure 2. Otolith of Prionotus carolinus

(A) Side view showing the sulcus; x-plane is perpendicular to the anterior-posterior axis.

(B) Cross section of otolith (along the x-plane).


DORSAL
ANTERIOR
X-PLANE
POSTERIOR
VENTRAL
(A)
DORSAL
SULCUS
NUCLEUS
MEDIAL
LATERAL
VENTRAL
(B)

half is slightly thicker than the dorsal half and the anterior end tapers to a sharper point than the posterior end. The dorsal and ventral portions of the cross section of the otolith are not symmetrical; the nucleus is located toward the ventral portion. The maximum length and width of the otolith were approximately 9 and 5 mm, respectively, and the heaviest otolith weighed 753 mg.

Increase in length and width of the otolith was proportional to increase in length of the fish. A linear relationship was established for fish longer than 100 mm (Fig. 3). The length of fish showed a better correlation with the width of the otolith than with its length; the coefficients of correlation were 0.78 and 0.71, respectively. The weight of otolith increased logarithmically with the length of fish (Fig. 3).

Interpretation of Zones in the Otolith

In determining age, the most important features of the otolith are the alternating opaque and hyaline zones, one of each being formed at the margin of the otolith each year. The formation of these two zones has been considered by several investigators to be in response to an inherent annual rhythm (Trout, 1954; Molander, 1947; and Irie, 1960). However, such environmental variables as temperature and availability of food can determine how much organic or inorganic material is added to the otolith during each season. Generally, the opaque zones are formed in the summer and the hyaline zones in the winter.

The most common method for determining that the opaque and hyaline zones together constitute a year's growth is to examine

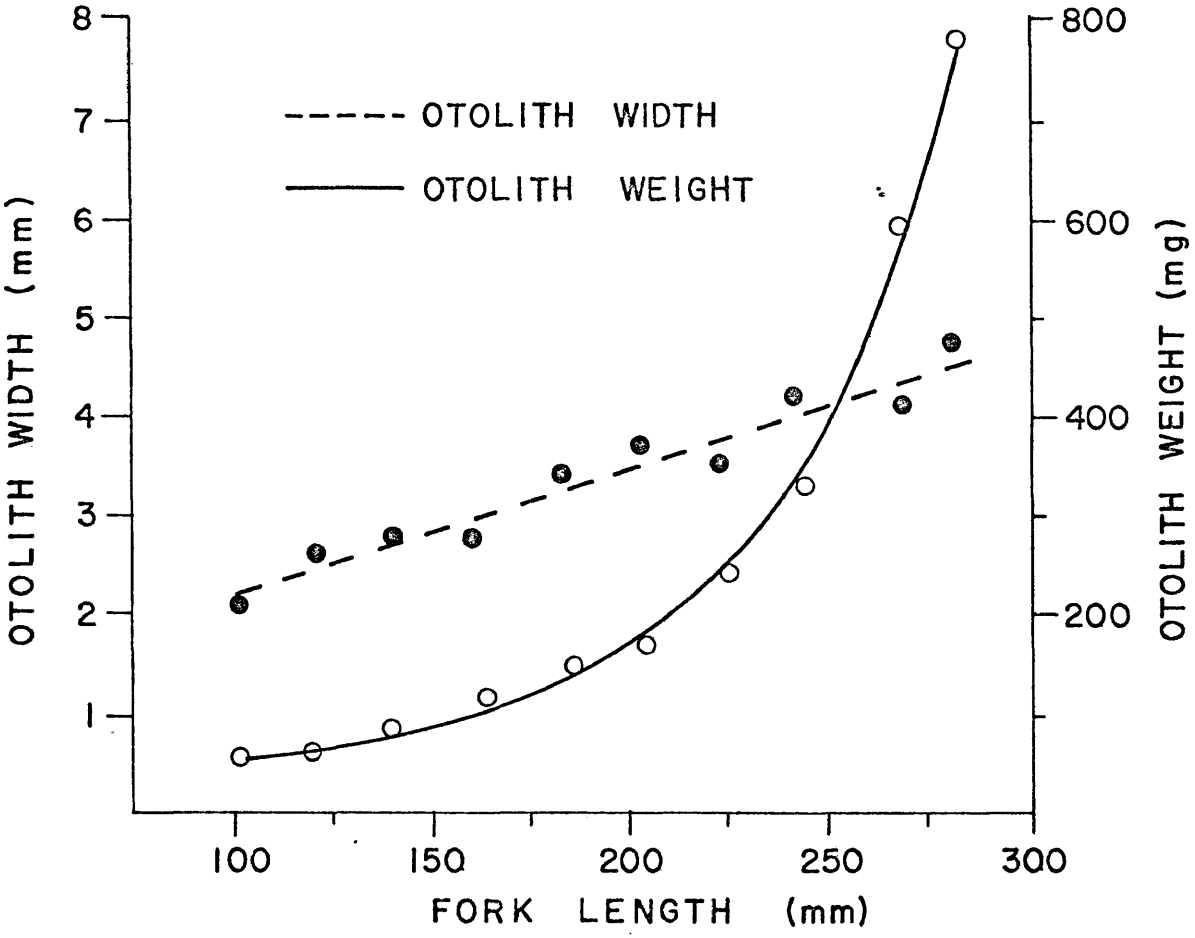


Figure 3. Regressions of otolith width and weight on length of Prionotus carolinus.

the marginal changes during each month of a year. In Prionotus carolinus, the percentage of opaque zones (with respect to both types of margins) increased from May to June, reached a maximum during August and declined thereafter. Conversely, the percentage of otoliths having hyaline margins increased during January and reached a maximum in March (Fig. 4). This definite trend of alternating opaque and hyaline zones confirmed that only one of each was formed within a year and that together they constituted a year's growth. Since no samples of otoliths were taken in October, values for October, as shown in the histogram, were taken from samples collected in early November. No fish were collected in January. The sample in June was taken in 1965. In no month was the margin restricted to one type, and the opaque zone was more prevalent than the hyaline zone in nine months of the year. I was unable to determine the nature of the margins of 10% of the otoliths for two reasons: (1) the hyaline zones were usually narrow; (2) any organic substance that was not removed from the surface of the otolith before scorching could be mistaken for a hyaline margin.

The greatest proportion of hyaline margins was observed during the coldest month, March, and the greatest percentage of opaque margins occurred in one of the warmest months, August. The bottom temperatures shown in Fig. 4 were taken in 1959 and 1960 (Joseph, Massmann and Norcross, 1961). Temperatures for 1965 and 1966 were not used because they were not measured in some months. However, a comparison of the temperatures of the Chesapeake Bight from 1959 to 1967 (personal communication from J. J. Norcross) showed that the average monthly temperatures in 1959 and 1960 were representative of an average year.

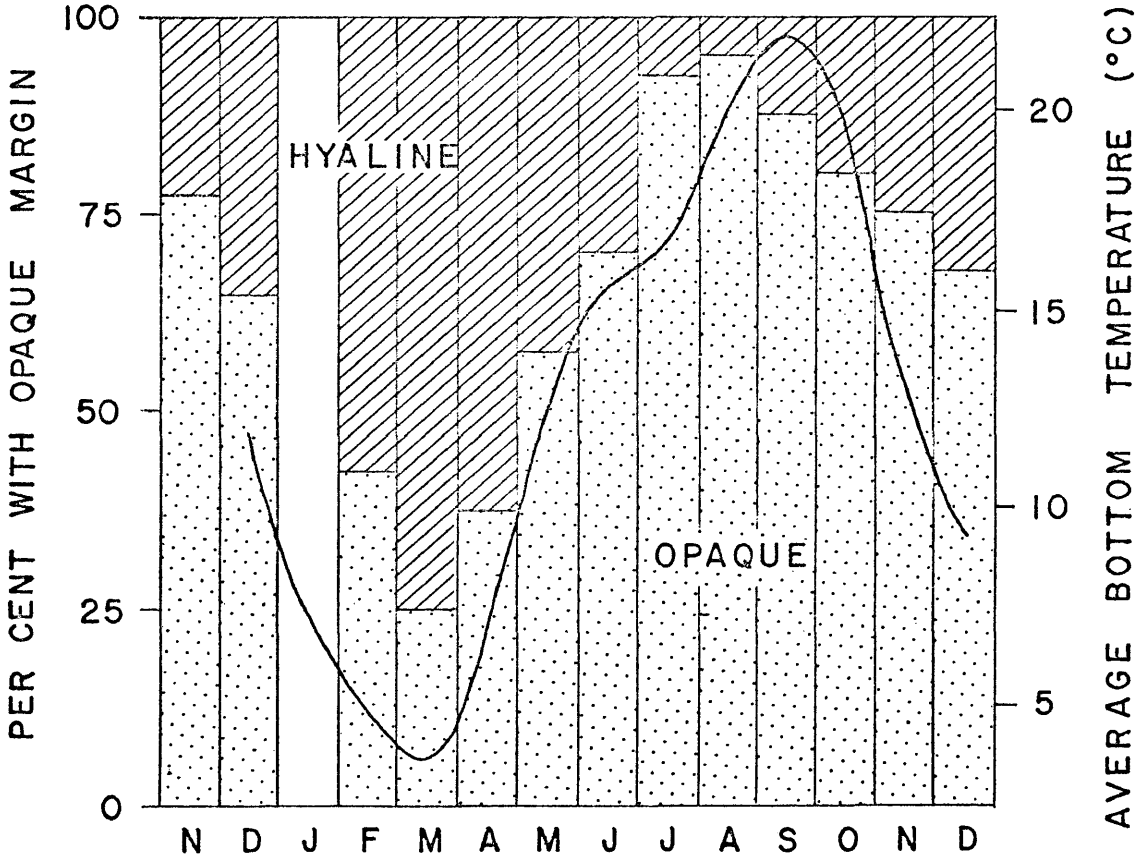


Figure 4. Percentage of opaque margins in otoliths during 1966; the curve represents average monthly temperatures of 1959 to 1960.

The nucleus of the otolith consisted of hyaline material (Fig. 5A). Outside of this was a broad opaque zone in which were several narrow and incomplete hyaline zones. The opaque zone was bounded by a clearly marked hyaline zone interpreted as the first annulus (Fig. 5B). The first annulus was surrounded by a broad opaque zone which in turn was surrounded by a hyaline zone (second annulus). The opaque zone between the first and second annuli was greater than that between any other two adjacent annuli. From the second annulus outward, the spacing was regular, with the alternating opaque zones becoming narrower toward the periphery (Fig. 5E). The transverse section of the dorsal portion of the otolith was the most desirable field for age determination because the zones were regularly spaced and could be followed around the dorsal edge.

In some otoliths, faint and incomplete hyaline zones similar to those in the first opaque zone were present between the more definite hyaline zones or annuli. These incomplete zones were considered adventitious marks. Frequently the zones appeared as double structures (Fig. 6A). These double zones differed from two separate annuli; the opaque zone between them was comparatively narrow and one of the hyaline zones united with the other after curving around the dorsal edge of the otolith. These double zones were interpreted as one annulus. Gambell and Messotorff (1964) found similar double zones in Merlangius merlangus and Walford and Mosher (1943) described adventitious marks as lines that meet an annulus at some point. Such accessory marks were perhaps similar to the "checks" found often in fish scales. Therefore, an annulus may be described as a distinct hyaline zone that can usually be

Figure 5. Cross-sections of otoliths of Prionotus carolinus. Roman numerals designate annuli. Pictures taken at different magnifications.

(A) Young-of-the-year fish 98 mm long.

(B) Age-group II fish 205 mm long, opaque margin.

(C) Age-group III fish 215 mm long.

(D) Age-group IV fish 223 mm long.

(E) Age-group V fish 248 mm long, with fifth annulus at the margin.

(F) Age-group VI fish 268 mm long, with sixth annulus at the hyaline margin.

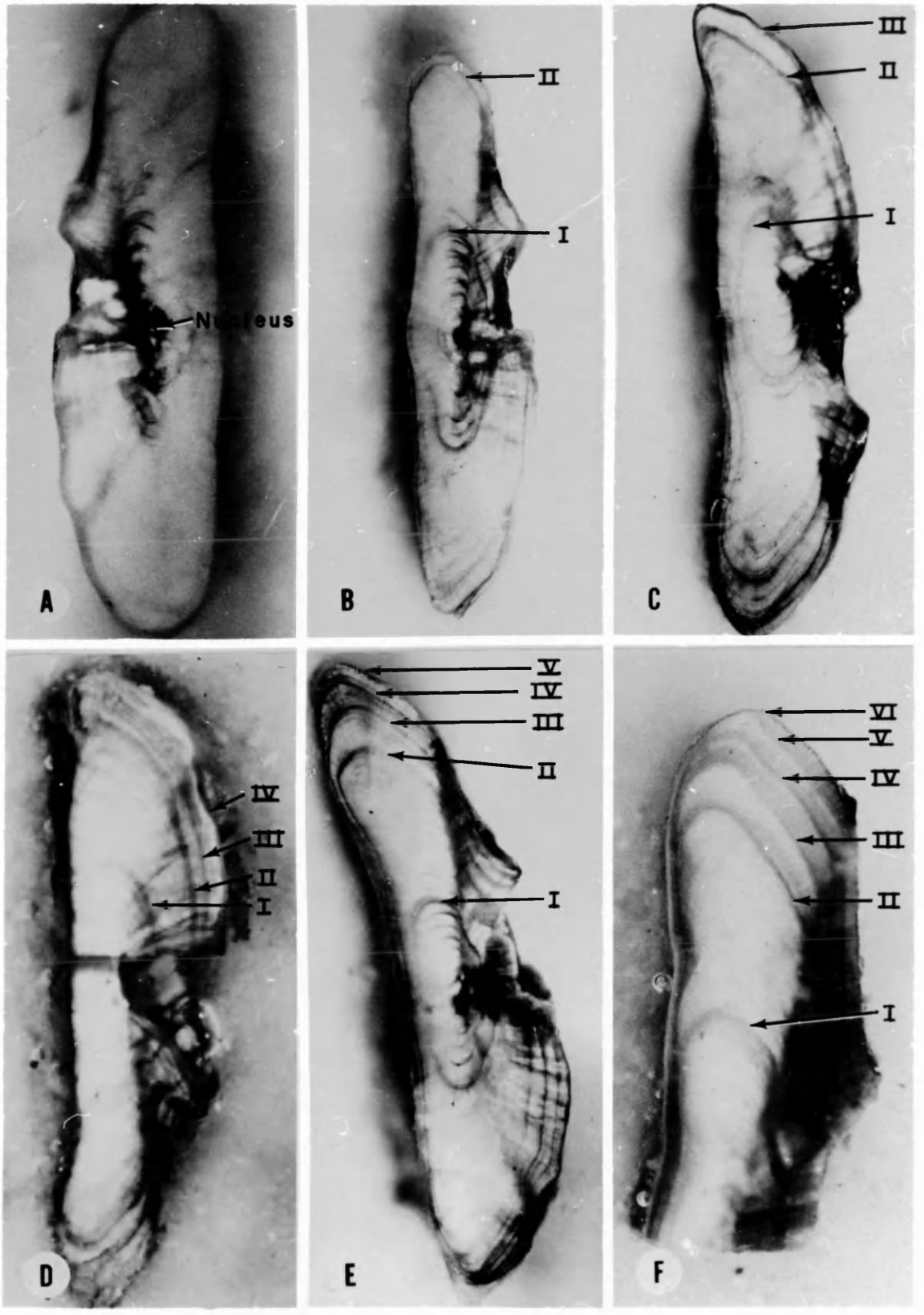
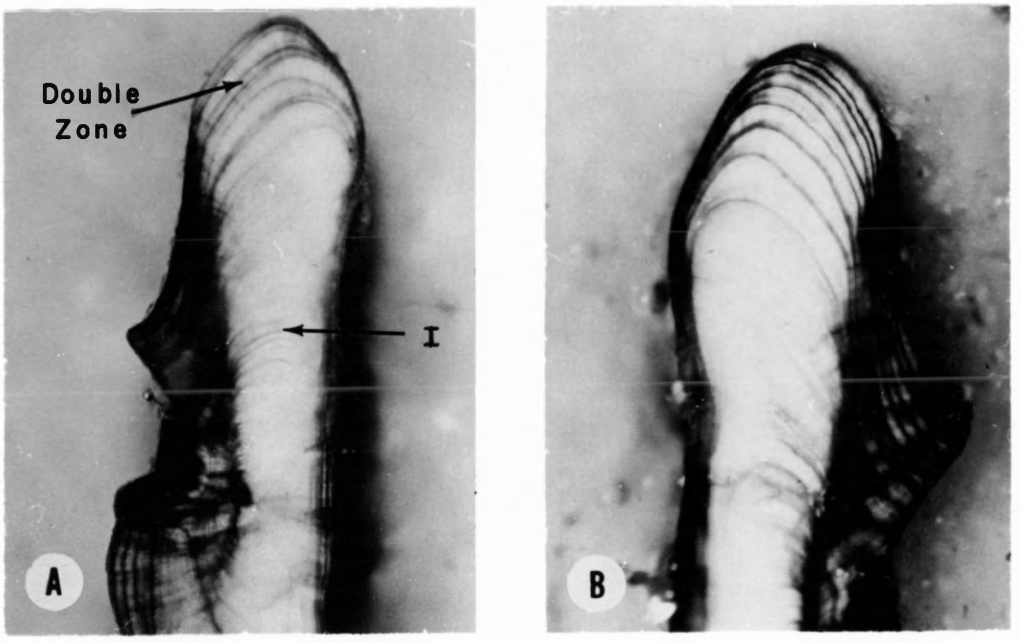

A
Nucleus
B
II
I
C
III
II
I
D
IV
III
II
I
E
V
IV
III
II
I
F
VI
V
IV
III
II
I

Figure 6. Otoliths of Prionotus carolinus

(A) Double zones after the first annulus.

(B) Crowding of zones near the periphery of an otolith from a fish 263 mm long.


Double
Zone
I
A
B

discerned around the dorsal portion of the transverse section of the otolith. The opaque zone between annuli is of regular width in relation to other opaque zones. In contrast false annuli are usually indistinct and incomplete and tend to merge into true annuli after curving around the dorsal edge. The opaque zones between the false and true annuli are narrower than the adjacent opaque zones. The zones in the otoliths of older fish were crowded at the periphery; Fig. 6B shows the otolith of a relatively old fish with numerous marks close to the periphery. To compound the picture double zones became prevalent in older fish. Thus, I could determine the age of fish up to age-group V with confidence.

Except for one sample of age-group I fish that was used to back-calculate the lengths of fish at the formation of the first annulus, lengths of fish were not back-calculated. There are several variables in the back-calculation of lengths of fish that render results inaccurate. In this study, a variable that should be mentioned was the manner in which the otolith was cut; in order for lengths to be back-calculated accurately, the otoliths must be cut in the center of the nucleus and perpendicular to the anterior-posterior axis. Such a procedure was not followed.

Validity of the Hyaline Zone as an Annulus

The use of otoliths to determine the age and growth of Prionotus carolinus is validated as follows:

(1) One hyaline zone is formed each year.

(2) A proportional relationship exists between the growth of the fish and its otolith.

(3) There is good correlation between the increase in size of fish and the increase in number of annuli in the otolith, indicating that occurrence of the zones is not random.

(4) Age determination from examination of otoliths agrees with the result obtained from the analysis of length frequency distribution.

Analysis of Age and Growth

The average length and weight of each age-group based on the examination of otoliths are given in Table 3 and illustrated in Figs. 7 and 8. The values for length and weight of each age-group are averages of monthly means. As mentioned earlier, age determination became increasingly confusing after age-group V. Therefore, results presented for the older fish should be interpreted with caution. The oldest fish was an 11-year-old female measuring 298 mm in length and 326 g in weight. The heaviest fish weighed 386 g and was 305 mm long. Few fish exceeded 300 mm in length.

For the first five age-groups, growth of females was not significantly different from that of males. Very few males exceeded 280 mm in length. The sex ratio was approximately 1 : 1.

The average length at the formation of the first annulus, 62 mm, was derived by back-calculation of a sample of 100 age-group I fish collected in August, 1966.

The annual growth in length was greatest during the second year of life when the fish attained a length of 155 mm (average of monthly means). Growth decreased to 45 mm during the third year (Fig. 9), 21 mm during the fourth year, 21 mm during the fifth year and 8 mm during the sixth year.

TABLE 3

Results of age and growth determinations based on examination of otoliths. Average length and weight, range, sample size, $S_{\bar{x}}t_{.05}$ and 1 standard deviation for each age-group.

	LENGTH					WEIGHT				
	Range (mm)	Average (mm)	$S_{\bar{x}}t_{.05}$	Sample Size (N)	1 Standard Deviation	Range (g)	Average (g)	$S_{\bar{x}}t_{.05}$	Sample Size (N)	1 Standard Deviation
I	72-213	155	2.78	301	24.6	10-105	41	1.71	286	14.8
II	168-232	200	2.39	137	14.3	37-148	85	3.16	123	17.9
III	193-255	221	2.61	108	13.7	80-170	117	4.66	100	23.5
IV	222-274	242	2.79	83	12.8	115-260	157	6.79	64	27.2
V	204-305	250	2.81	110	14.9	125-265	181	8.81	88	41.6
VI	236-290	259	3.32	62	13.1	135-267	204	8.59	56	32.1
VII	240-287	265	3.14	54	11.5	172-297	221	10.83	43	35.2

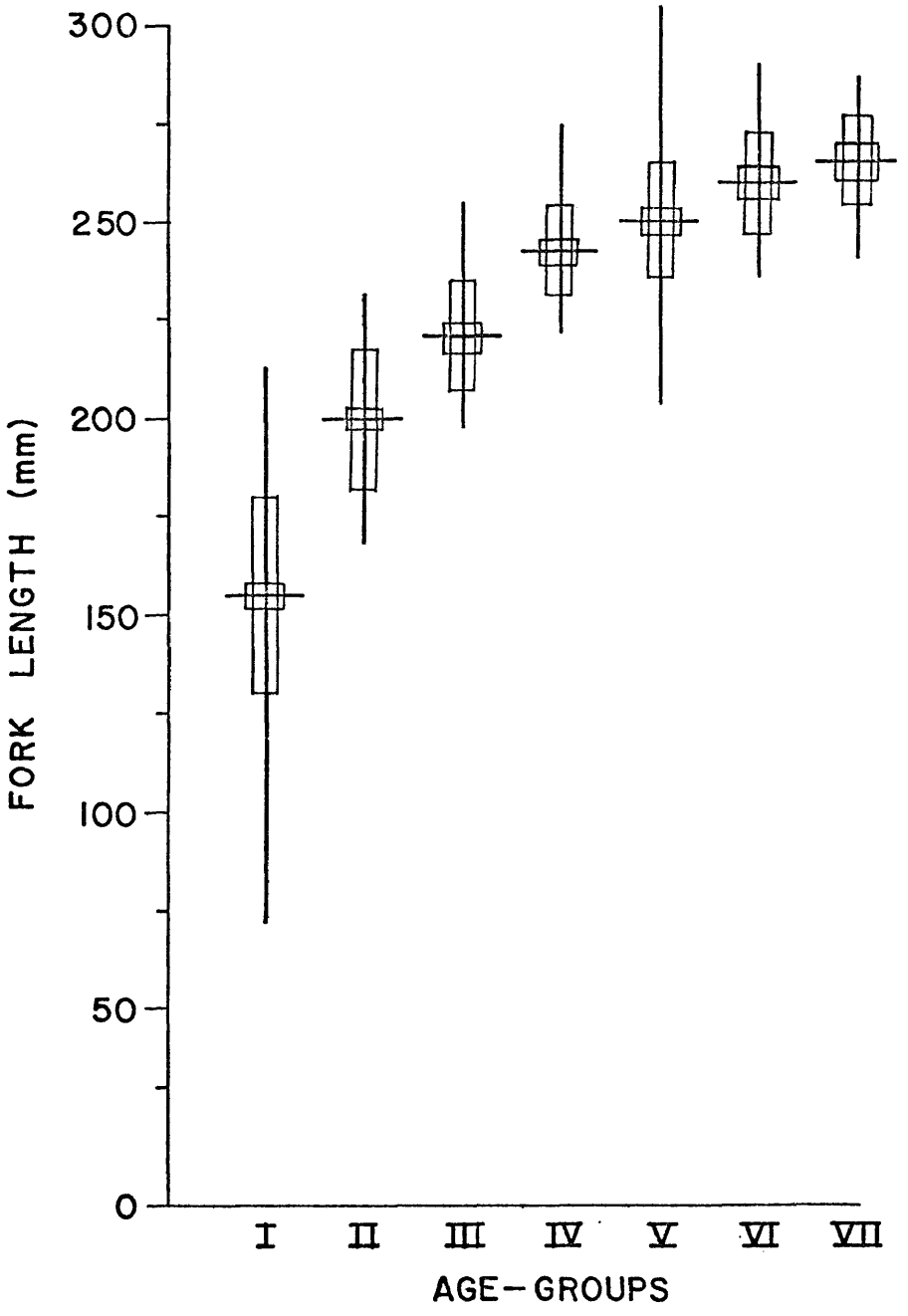


Figure 7. Average length, range and $S_{\bar{x}}t_{.05}$ of Prionotus carolinus at different ages.

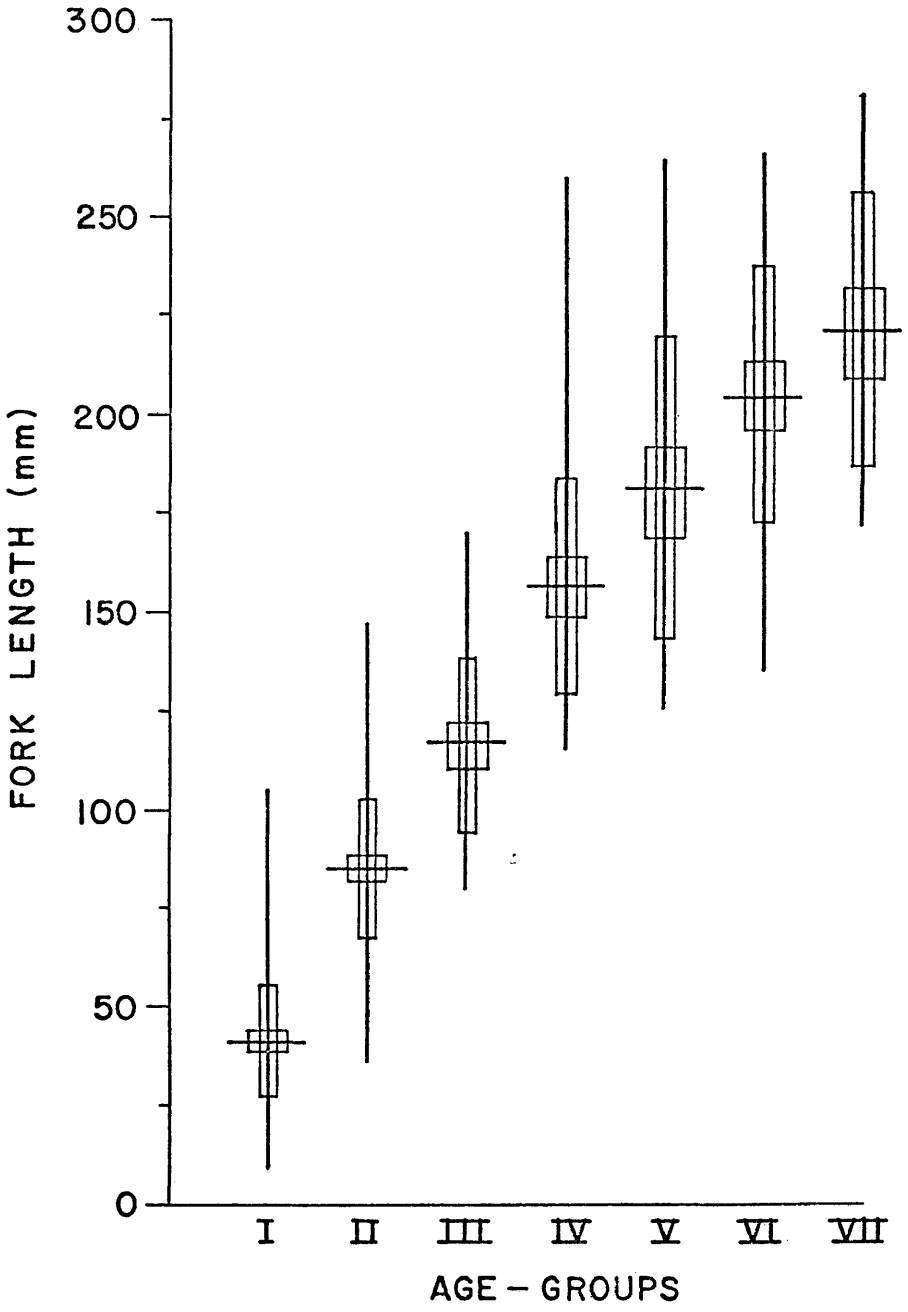


Figure 8. Average weight, range and $S_{\bar{x}}t_{.05}$ of Prionotus carolinus at different ages.

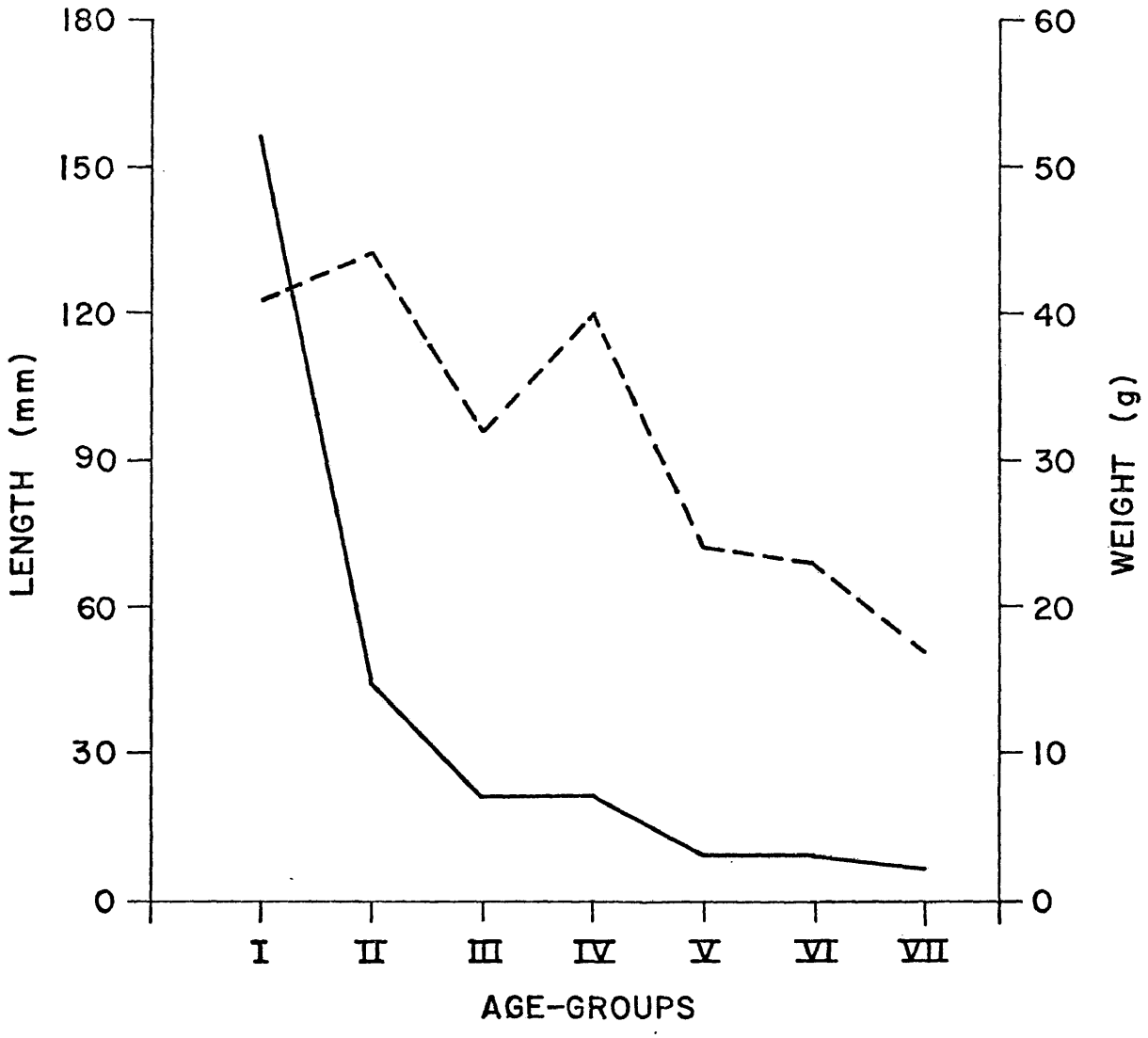


Figure 9. Annual increments of length and weight of the northern searobin.

Annual increment in weight (Fig. 9) was relatively constant from age-group I to IV and declined thereafter. Fish weighed 41 g as 1 year-olds. Increments were 44 g for the second year, 32 g for the third year, 40 g for the fourth year and 24 g for the fifth year.

From this study, it can be deduced that Prionotus carolinus is a slow growing species with a long life span.

Marshall (1946) found that marks on otoliths were too variable for age determination; however, he did not heat the otoliths. Using scales he was able to determine the first two age-groups. His results showed that fish attained a length of 153 to 214 mm (average 172 mm) and a weight of 42 to 57 g during the second summer (age-group I); and a length of 233 to 260 mm and a weight of 113 g or more during the third summer (age-group II). Scales from fish over 260 mm long were practically worthless for age determination because of illegibility and conflicting interpretations; over 30% of the readings were discarded. The heaviest fish recorded weighed 780 g and was 347 mm long.

Fish belonging to age-group I of this study measured 155 mm in length and 40 g in weight compared to 172 mm and 50 g from the study made by Marshall (1946). Further comparisons are impossible because he designated all fish over 233 mm long as age-group II or older. Some discrepancies between our results could be due to the fact that larger fish of a species are frequently distributed further north within the range of distribution. That fish from the Woods Hole area were larger

than those from Chesapeake Bight was indicated by the goodly number of fish over 300 mm long in Marshall's samples. His heaviest fish was nearly twice as heavy as the largest from Chesapeake Bight.

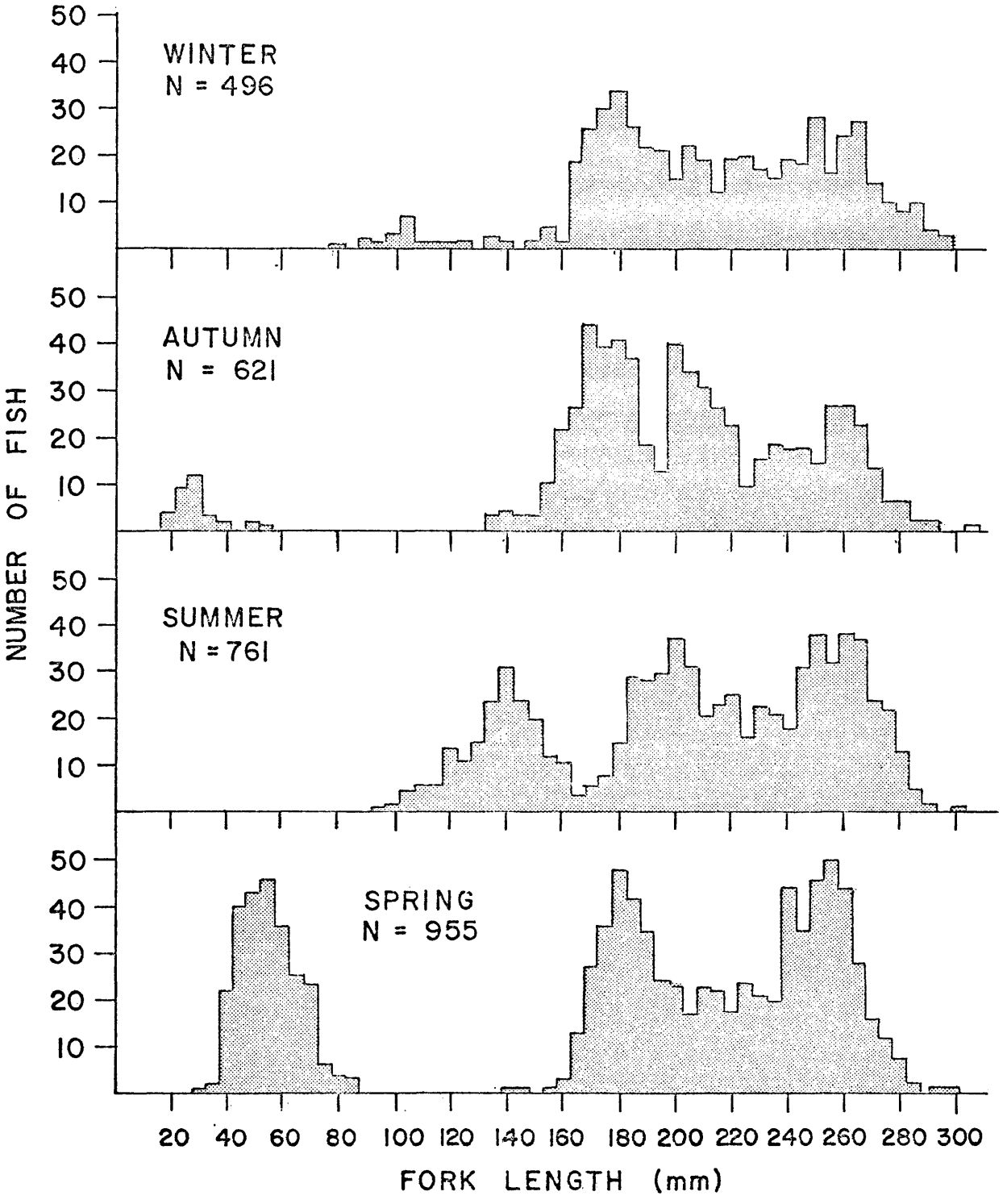
Length Frequency Distribution

A total of 2833 fish collected over a period of 12 months was included in the length frequency distribution study. Figure 10 shows the seasonal distribution of the length groups in 5 mm intervals. Three features may be noted in the length frequency histograms as follows: (1) fish below 100 mm long were poorly represented in the samples from the Chesapeake Bight (2) large fish were unusually abundant (3) there were three distinct modes in the histograms.

Most of the smaller fish were caught in the Chesapeake Bay and York River. The virtual absence of juvenile fish in the trawl samples from Chesapeake Bight could be partially attributed to escapement from the trawl between the foot rope and the cod end liner.

The length frequency distribution was unusual because of the great number of large fish. There are several possible explanations for the incongruity: (1) smaller fish were inadequately sampled (2) growth is especially slow in the older age-groups and therefore the large frequency may represent several age-groups of older fish reaching an asymptote of the growth curve (3) one or two dominant year-classes were present. Explanations (1) and (2) appeared evident from this study.

Figure 10. Length frequency histograms of Prionotus carolinus according to seasons.


WINTER
N = 496
AUTUMN
N = 621
SUMMER
N = 761
SPRING
N = 955
NUMBER OF FISH
50
40
30
20
10
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
FORK LENGTH (mm)

The tri-modal distribution appeared to represent the first three age-groups. However, a closer examination detected minor modes between the second and third modes. Age determination by examination of otoliths indicated that these modes represented distinct age-groups.

A sample (N=30) of small fish averaging 30 mm in length and collected in November 1966 was unmistakably the 0 age-group (Fig. 10c). In spring (April 1955 and 1956) samples of fish averaging 55 mm long were obtained; these fish had passed their first winter and therefore are designated as age-group I (Fig. 10a). Fish of that size were caught frequently but not abundantly in the James and York Rivers in Spring of 1965 and 1966. A large gap occurred between the mode at 55 mm and the following mode at 140 mm derived from the August samples (Fig. 10b). It was assumed that there were no other modes in between, and scarcity of fish between 55 and 140 mm reinforced this assumption. Thus, fish attained a modal length of 140 mm during the second summer. Through seasonal progression of modal lengths, age-groups 0 and I were established and adjacent modes in the length frequency histograms were designated as successively older age-groups.

The histogram of fish collected in spring (Fig. 10a) showed a mode at 55 mm which was designated as age-group I as explained previously. The next mode at 183 mm represented age-group I as explained previously. The next mode at 183 mm represented age-group II; age-group III was at 212 mm and age-group IV was probably at 227 mm.

In the summer collections (Fig. 10b) the distinct mode at 140 mm represented age-group I. Age-group II was at 195 mm, age-group III at 218 mm and the mode at 233 mm could be age-group IV.

The histogram of the autumn samples (Fig. 10c) showed a mode at 30 mm which represented age-group 0. The modes at 177, 208 and 235 mm represented age-groups I, II and III respectively.

In the histogram of fish caught in winter (Fig. 10d), the mode at 178 mm represented age-group I; age-group II was at 207 mm and age-group III at 225 mm. A minor mode at 105 mm was assumed to be age-group 0, although this length was large relative to age-group I in the histogram of spring.

The lengths of different age-groups during different seasons are presented in Table 4.

Marshall (1946) found three distinct modes at 49, 172 and 282 mm from the length frequency distributions and assigned them as 0, I and II or older age-groups respectively. In two of his length frequency diagrams, the third mode was replaced by two or more modes; in one, there were distinct modes at 250 and 288 mm, in the other the modes were at 245 and 300 mm with minor modes between. He did not assign two separate age-groups to the modes at 245 or 250 mm and 288 or 300 mm. Instead, he designated all fish belonging to the mode at 282 mm as age-group II or older. I am puzzled by his failure to accept modes at 245 or 250 mm and 288 or 300 mm as age-group II and III, respectively, despite the fact that most age-group II fell within the range of 233 to 257 mm and age-group III within the

TABLE 4

Modal lengths (in mm) derived from length frequency distributions during different seasons.

Age-group	Spring	Summer	Autumn	Winter
0	---	---	30	55
I	105	140	177	178
II	182	195	208	207
III	213	218	235	223
IV	227	233	---	---

range of 282 to 300 mm according to the results of age determination based on his scale method. It should be mentioned that his analysis was based on relatively few fish obtained over a period of two or three months.

Marshall (1946) also found an unusually large number of bigger fish and he attributed this phenomenon, in part at least, to the "summation of several age-groups two years or above falling close together in the expected plateau phase of their growth curve".

LENGTH-WEIGHT RELATIONSHIP AND RELATIVE CONDITION

The analysis of length-weight data has two different purposes (Le Cren, 1951). First, it describes mathematically the relationship between length and weight, so that one can be predicted from the other. Second, it measures the variation from the expected weight for length of individual fish or relevant groups of individuals as an indication of fatness, general 'well being', gonadal development and so on. The first is discussed under the term 'length-weight relationship' and the second under the term 'condition'.

The length-weight relationship of most species of fish can be described by the formula:

$$W = aL^n$$

where W = weight, L = length, "a" is a constant and "n" an exponent lying between 2.5 and 4.0 (Hile, 1936). The equation, expressed logarithmically becomes a straight line where:

$$\text{Log } W = \text{Log } a + n \log L$$

and where n represents the slope of the line and Log "a" its origin.

Individual variations from the computed length-weight relationships have usually been considered more interesting than the length-weight relationship itself. The study of condition has come under the terms condition factor (Graham,

1929), coefficient of condition (Hile, 1936) and ponderal index (Kesteven, 1947) all of which measure the heaviness relative to the expected average weight at any given length. The condition factor K is based on an ideal fish whose length-weight formula follows the cubic relationship, $W = aL^3$, whereupon, $K = W/aL^3$. Martin (1949) and others have drawn attention to the fact that the cubic relationship is not obeyed generally. Le Cren (1951) proposed the relative condition factor K_n which is based on the relationship $K_n = W/aL^n$ to be determined empirically. Therefore, $K_n = W/\hat{W}$ where the observed weight is divided by the predicted weight for the observed length of fish. Values of K_n vary around 1.0; differences from 1.0 represent deviations from the regression or a measure of variability. These deviations describe all variations in weight not associated with length in a way that is not possible with the condition factor K, unless n equals 3.0, which is rarely the case (Blackburn 1960).

A scatter diagram of weights on lengths (Fig.11) indicates that the length-weight relationship of northern searobin conforms to the general exponential formula ($W = aL^n$) and that there is no significant difference between the sexes except that females predominate at lengths of 280 mm or more.

Since the weight of fish varies with feeding, spawning and other activities, the length-weight relationship was presumed to vary from season to season. Consequently, the latter relationships were calculated for each month by the least squares

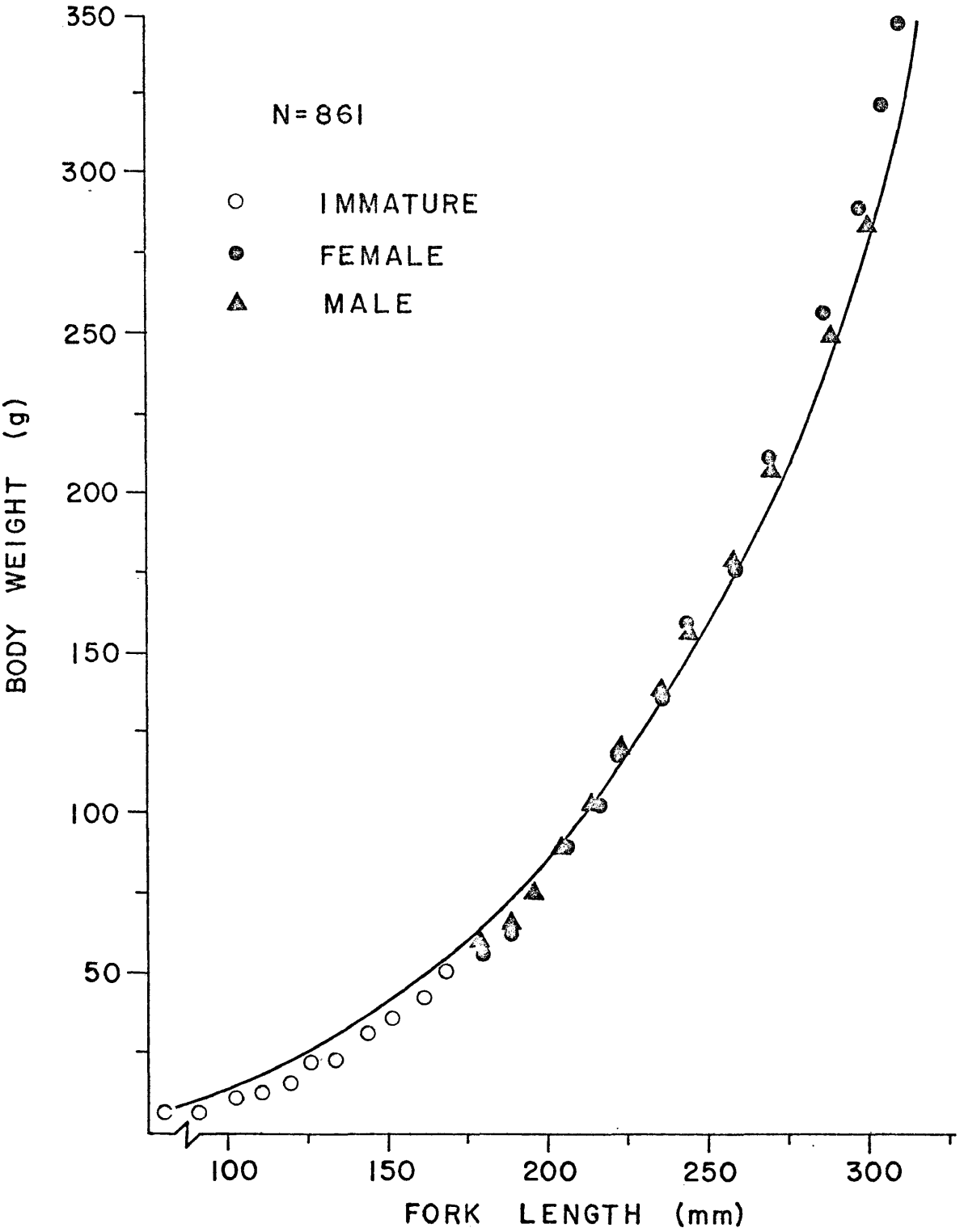


Figure 11. Annual average length-weight relationship of Prionotus carolinus. The curve is derived from the equation, $W = 0.000004627L^{3.1467}$.

method. The values for a and n were lowest in February and highest in June (Table 5). Analysis of covariance (Le Cren, 1951; Snedecor, 1956) demonstrated that the variance and the slope were homogeneous for March through July and in November and December. February and August were significantly different from all other months. This series of tests showed that length-weight relationships changed significantly within a year.

The average length-weight relationship of Prionotus carolinus was $W = 0.000004627L^{3.1467}$ or $\text{Log } W = -5.3347 + 3.1467 \text{ Log } L$ where W = weight in grams and L = length in mm.

The relative condition values were calculated for each fish and the mean values were obtained for each month's sample. No attempts were made to differentiate between the males and females or mature and immature fish. Mean relative condition, K_n, plotted against time showed a gradual increase from November 1965 to July 1966, followed by a decline from August to November 1966 (Fig. 12).

Accumulation of fat prior to gonadal maturation is observed in many fishes (Hoar, 1957). Such a trend could be inferred from the gradually increasing relative condition as indicated by the ascending curve in Fig. 12. During July and August fish were running ripe and this was indicated by the high values of K_n. Although there were no data for September and October, the low relative condition in November (in both 1965 and 1966) suggested that a decline occurred in September. This was not unexpected since most fish had completed their spawning and were spent. In his study on Perca fluviatilis Le Cren (1951) found

TABLE 5

Values of a and n from the length-weight formula $W = aL^n$ and mean relative condition (K_n) for each month.

Month	Sample Size (N.)	a	n	Mean K_n
December 1964	52	-5.1729	3.0806	1.012
June 1965	50	-5.9141	3.3557	0.836
November 1965	120	-5.1117	3.0401	0.956
February 1966	599	-4.8039	2.9231	1.014
March 1966	395	-5.4668	3.2085	1.034
April 1966	100	-5.6665	3.2924	1.048
May 1966	562	-5.3808	3.1593	0.968
July 1966	92	-5.4651	3.2315	1.125
August 1966	164	-5.0308	3.0298	1.107
November 1966	189	-3.1314	3.0723	0.907

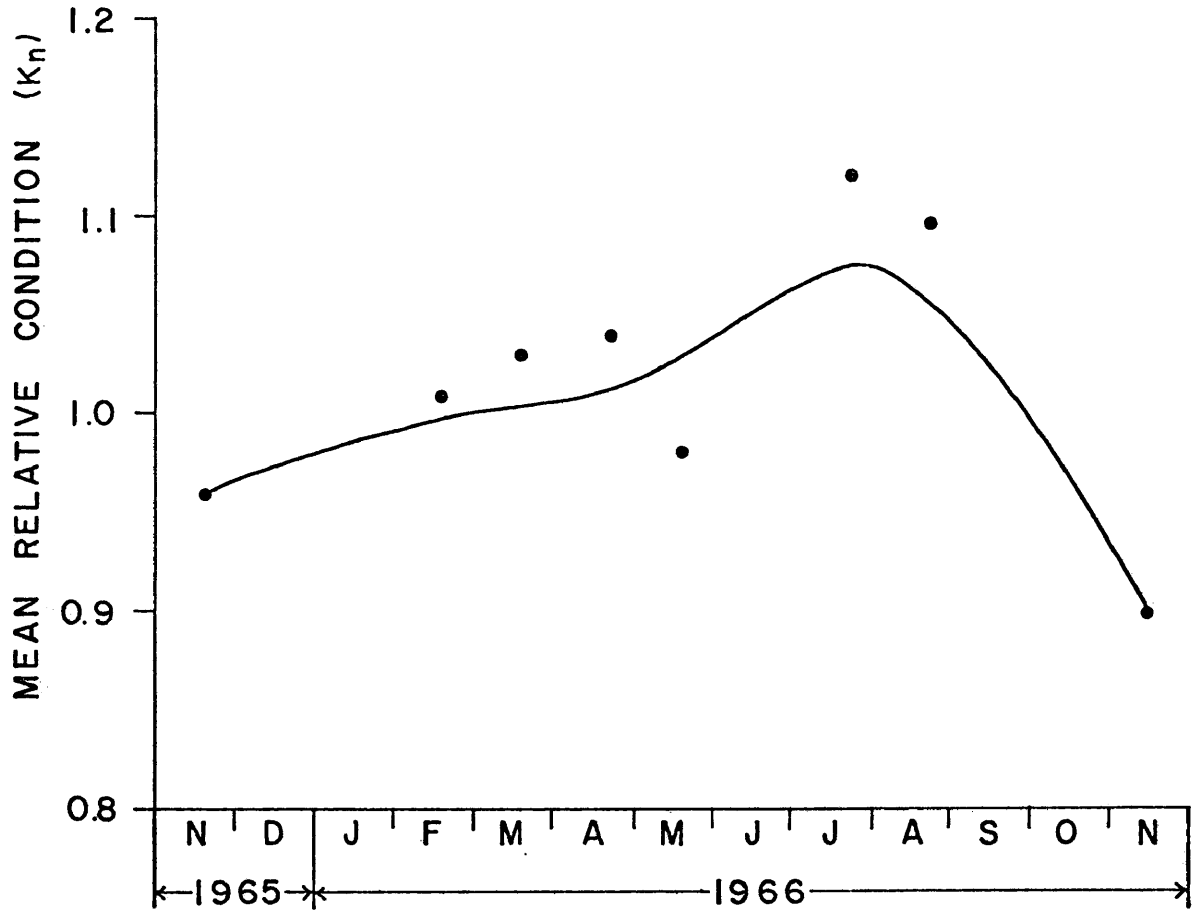
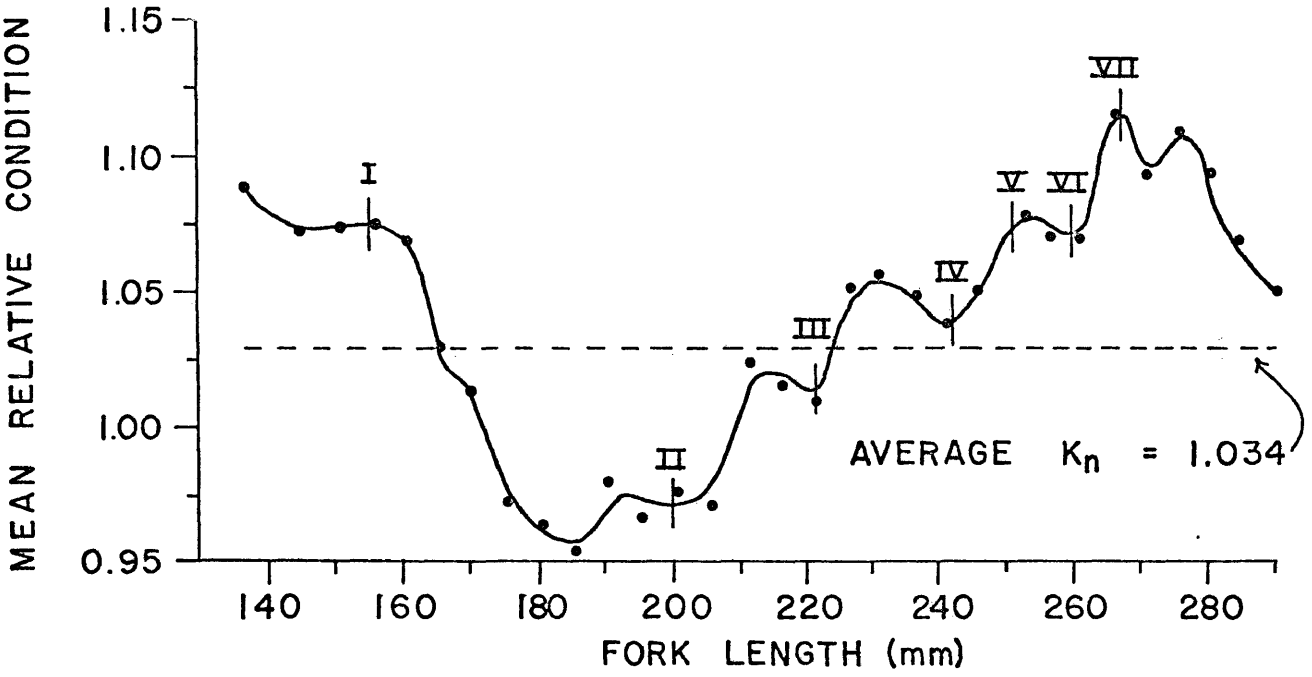


Figure 12. Mean relative conditions (K_n) of Prionotus carolinus for months of 1965 and 1966.

that seasonal changes in the weight of gonads, especially the ovaries, influenced the relative condition curve substantially. For example, when the ovaries of the perch were ripe, they averaged about 20% of the body weight and in the freshly spent fish ovaries were about 3% of the body weight. Therefore, the relative condition corresponded closely to the spawning cycle in spite of the fact that data were lacking in a few months.

Relative condition values were plotted against the length of fish for the month of March (Fig. 13). The K_n values were high for fish below 160 mm in length. Between 170 and 220 mm, relative condition was at its lowest, being less than the average for the month. Relative condition began to rise after 185 mm, reached a peak at 265 mm, and declined after 275 mm. There were several depressions between 210 and 275 mm. In other months the pattern was similar.

Relative condition was high in both the small and large fish; the former could be due to the high rate of growth before the onset of sexual maturation and the latter due to the fact that as fish increased in age, weight increased much faster than length. The decline after 275 mm was probably caused by senility. The most plausible explanation for the low relative condition between 170 and 220 mm was attributed to the demands on metabolic processes during sexual maturation (Pantulu, 1963). Fish within this length range were undergoing sexual maturation.


MEAN RELATIVE CONDITION
1.15
1.10
1.05
1.00
0.95
I
II
III
IV
V
VI
VII
AVERAGE K_n = 1.034
140
160
180
200
220
240
260
280
FORK LENGTH (mm)

SPAWNING PERIOD AND AGE AT SEXUAL MATURITY

Gonads of sexually mature fish began to increase in size in March. By May, some fish were gravid, and in July the running ripe condition was observed. Running ripe fish were prevalent in August and early September. Most fish were spent by November, except for a few males. The gonads of fish caught in February appeared little different from those found in November. The incomplete data (there were no samples in January, April, June, October and December 1966) indicated that spawning season in 1966 in the Chesapeake Bight was July, August and at least part of September.

Table 6 shows the spawning periods of Prionotus carolinus in various regions according to several authors. Except for Smith (1907) the other investigators reported that northern searobin spawned in the summer. However, there is doubt that P. carolinus spawns earlier than July in areas north of Chesapeake Bight. Wheatland (1956) differentiated the eggs of P. carolinus and P. evolans by the distribution of oil globules in the eggs --- dispersed in the former and clumped in the latter. Recent studies at the Virginia Institute of Marine Science (personal communication from E. B. Joseph) showed that the distribution of oil globules in the eggs of both species changed ontogenetically. The oil globules in the eggs were clumped in early stages and dispersed in later stages in both species. Therefore, the early

TABLE 6

The spawning periods of Prionotus carolinus in various regions as reported in the literature.

Spawning Period	Locality	Reference
Spring	Beaufort, N.C.	Smith, 1907
June, July and perhaps later	Woods Hole	Sumner, Osburn and Cole, 1913
June, July and early August	Woods Hole	Kuntz and Radcliffe, 1918
June, July and August	Southern New England; N. Y.	Nichols and Breder, 1927
August 19 to 25	Atlantic City, N. J.	Hildebrand and Schroeder, 1928
May through August	Long Island	Perlmutter, 1939
Mid-June to early August	Southern New England	Marshall, 1946
June to September	Woods Hole	Bigelow and Schroeder, 1953
June through August	Long Island Sound	Wheatland, 1956

spawning reported in the northern range could be due to errors in the study of embryology of P. carolinus and P. evolans. The latter species was found to spawn earlier in Chesapeake Bight.

Fish around 200 mm long were ready to spawn even though the gonads were small. Therefore, P. carolinus attained sexual maturity at age II or III.

SUMMARY

1. The first five age-groups of the northern searobin could be determined on the basis of growth zones observed in transverse sections of scorched otoliths.
2. The first three age-groups could be inferred from length frequency histograms despite unusually large numbers of bigger fish.
3. The northern searobin has a slow growth rate and a long life span.
4. Statistical tests showed significant seasonal differences in the length-weight relationship. The annual average length-weight formula was $W = 0.000004627\ L^{3.1467}$.
5. The lowest values of relative condition occurred during the period of sexual maturation.
6. Prionotus carolinus spawned in July, August and part of September in the Chesapeake Bight.
7. Prionotus carolinus mature sexually when 2 or 3 years old and at a length of about 200 mm.

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