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Age and Growth of the Striped Searobin

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AGE AND GROWTH OF THE STRIPED SEAROBIN

A Thesis
Presented to
The Faculty of 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
John D. McEachran
1968

APPROVAL SHEET

This thesis is submitted in partial fulfillment of
the requirements for the degree of
Master of Arts

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ABSTRACT

Age, growth, relative condition, and distribution of the striped searobin were studied. The fish were collected from Chesapeake Bight and Chesapeake Bay during 1966 and 1967. The age of 803 fish was determined from otoliths. The otoliths were cross-sectioned and the exposed surface was then polished and heated. Age groups 0 to VII were represented in the sample. Males and females had the same growth rate and weight/length relationship. Growth in length was rapid until the fish reached maturity at age II. Age group II averaged 221 mm fork length. The fish accomplished most annual growth between May and September. Spawning occurred from May through July. Relative condition was plotted against fork length. The high values of relative condition corresponded to the mean lengths of age groups II, III, and V prior to the spawning season. Relative condition was thus an indicator of the length at sexual maturity and length at each succeeding year. The fish annually moved offshore in autumn and onshore in spring.

AGE AND GROWTH OF THE STRIPED SEAROBIN

INTRODUCTION

The purpose of this study was to develop a method for determining the age of the striped searobin Prionotus evolans (Linnaeus, 1766) and to reveal certain aspects of its biology such as: the rate of growth, age at sexual maturity, weight/length relationship, and seasonal distribution. Specimens were taken from Chesapeake Bight and Chesapeake Bay during 1966 and 1967.

Formerly Prionotus evolans was split into two species (Jordan and Hughes, 1887). Fish from the northern part of the range, the continental shelf from Cape Cod to Virginia, were classified as Prionotus strigatus (Cuvier and Valenciennes, 1829); those from the southern part of the range, off North and South Carolina, were designated as Prionotus evolans. The distinction was based on slight morphological and color differences. The southern species had relatively longer pectoral fins, which were plain rather than checkered as in the northern species. Jordan and Evermann (1898) preserved the specific distinction although they recognized that the two species might be geographical races. A comparative study was not undertaken until Ginsburg (1950) reviewed the systematics of the Triglidae of the Western Atlantic. Concluding that the differences cited by Jordan and Hughes (1887) were not sufficient to separate the populations at the subspecific level, he placed both forms in the same species, Prionotus evolans.

The striped searobin is a benthic fish which occurs on the continental shelf from Cape Cod to South Carolina (Bigelow and Schroeder, 1953) with a few strays reported outside of this range. In 1957 three fish were captured in the lower Bay of Fundy (Leim and Day, 1959) and between 1957 and 1960 specimens were taken from the northeastern coast of Florida (Bullis and Thompson, 1965).

Sumner, et al., (1913) stated that this species is parasitized by the acanthocephalan, *Echinorhyncus acus*, the cestodes *Rhynchobothrium imparespini* and *Tetrarhynchus bisulcatus*; and the trematodes, *Distomum* spp.

According to Nichols and Breder (1927), striped searobins feed primarily on crustaceans and mollusks. Hildebrand and Schroeder (1928) examined the stomachs from five fish and found the contents to consist entirely of small crustaceans, mostly mysids. Marshall (1946) stated that the majority of the food items are crustaceans found within a foot of the bottom. He discovered *Neomysis americana*, *Gammarus locusta*, and *Crangon septemspinosus* to be the most abundant food items.

Fish (1954) reported that striped searobins make sounds by contracting the striated muscles embedded in the outer surface of each lobe of the swim bladder. The muscular contraction sets up audible vibrations within the swim bladder. Fish described the sound as a series of grunts or clucks. Moulton (1958) stimulated sound production of this fish by transmitting sounds of the same frequency to it during spawning season.

MATERIAL

From 1966 through 1967, 1600 striped searobins were obtained from the continental shelf, inlets and estuaries in 9 sampling periods (Table 1). The bulk of the specimens came from the continental shelf between Cape May, New Jersey, and Cape Hatteras, North Carolina, at depths of 5 to 100 fathoms. All but the April, 1966 sample were collected from the trawler SEA BREEZE, under charter by the Virginia Institute of Marine Science. The SEA BREEZE was equipped with a semi-balloon trawl possessing an inner liner of 1/2 inch stretch mesh in 1966 and in July, 1967, and an Atlantic western trawl with a two inch stretch mesh cod end in the remainder of 1967. The April, 1966 sample was captured by a trawler of the Hampton, Virginia, fleet using a Yankee trawl with a 4 inch stretch mesh cod end.

The estuarine samples, taken from Chesapeake Bay, comprised only 4% of the collection. They were obtained in spring and summer and included single pound net samples obtained from the James River in April, 1966 and May, 1967 from the York River and samples from a trawl with a cod end of 3/4 inch stretch mesh.

The inlet samples, representing less than 0.4% of the collection, were taken in the seaside inlets of Eastern Shore, Virginia, during the spring and summer sampling periods. The samples were collected with a trawl possessing a 3/4 inch stretch mesh codend.

TABLE 1

DATES OF COLLECTION OF STRIPED SEAROBINS

Sampling Period	Date	Number Analyzed	Total
Winter	Feb.-March 1966	61	66
Spring	April 1966	62	84
Spring	May 1966	198	224
Summer	Aug.-Sept. 1966	146	215
Autumn	Nov.-Dec. 1966	144	144
Winter	March 1967	56	445
Spring	May 1967	84	275
Summer	June 1967	15	41
Summer	July 1967	37	106
Total		803	1,600

Hydrographic data were collected from the SEA BREEZE during all of her sampling trips. Prior to setting the trawl, bottom temperature and a salinity sample were obtained with a bathythermograph and a Kemmerer bottle. Water depths were recorded with a Kelvin-Hughes white line fathometer.

Fish were weighed in grams and measured to the nearest millimeter of fork length. The gonads were inspected macroscopically to determine sex and stage of development. The fish were classified as: immature, gravid, running ripe, or spent, depending on the state of the gonads. A subsample of 803 fish representing all of the sampling periods was used for age determination by analysis of hard parts (Table 1). In 1966, scales, opercula, and otoliths were removed from the selected fish. In 1967 only otoliths were collected.

AGE DETERMINATION

Hard Part Analysis, Critique of the Method

Age determination by analysis of hard parts (scales, opercula, or otoliths) is based on the premise that growth slows or stops during part of the year and that the change in growth rate is marked on the hard parts. For a hard part to be reliable for determining age, it must not only have annual rings, but the rings must be formed at approximately the same time every year (Van Oosten, 1929). Also, growth of the hard part should be proportional to the growth of the fish. Fulfillment of these requirements insures that the annuli will be regularly spaced and thus aids in distinguishing annual rings from false annuli which may form during the growing season.

Annual rings could be determined with confidence on the otoliths but not on the opercula or scales.

Scale Method

About 20 scales were removed from the left side of the body below the second dorsal fin and between the lateral line and the lower lateral stripe. These scales were symmetrical and of uniform size. The scales were soaked in water for 12 hours, dried with xylene, and mounted in a vertical row on a glass slide. Each slide contained five vertical rows of scales, each row having four scales and representing a separate fish. The mounting medium was prepared by mixing equal portions of euparol and euparol essence. A second slide was placed over the scales and the two slides were bound together at each end with tape.

The scales were examined with both a dissecting microscope and an Eberbach micro-projector. Several features of sculpturing on the scales made identification of annuli uncertain: the circuli were set close together, the "cutting over" of internal circuli by adjacent external circuli occurred randomly in the lateral fields of the scale, circuli anastomosed randomly, and secondary radii were not formed according to any fixed pattern. Previous authors have used approximation of circuli, "cutting over" of circuli, anastomosing of circuli, and origins of secondary radii to indicate annuli on ctenoid scales (Tester, 1932; Creaser, 1926; Marshall, 1946; and Taylor, 1914). The disorderly arrangement of these features on the scales used in this study precluded the use of scales for age determination.

Opercular Method

The left opercular bone was removed with a scalpel and stored in an envelope. The operculum was cleaned by placing it in boiling water and removing the adherent tissue with a tooth brush. However, the opercula were of little value in age determination because they became opaque with increase in size. Although rings could be discerned near the nucleus on opercula of small fish, rings were evident only near the margin on opercula of large fish. The opercula thickened as they grew and thickening apparently obscured annuli on opercula of large fish.

Otolith Method

The left, or both, saccular otoliths were exposed with a scalpel and removed with forceps. The otoliths were stored in vials containing corn syrup and several drops of phenol. The corn syrup prevented desiccation, a requisite for age determination because dried otoliths were uniformly opaque. Phenol prevented fungal growth.

The saccular otolith, in lateral profile, is an oblong rugose concretion (Fig. 1). The anterior end is rounded. The posterior end is rounded ventrally but the dorsal section is slightly indented. The ventral edge is smooth and moderately curved while the dorsal edge is irregular and more strongly curved. Viewed dorsally, the otolith appears laterally compressed and slightly crescent shaped. The medial surface is convex and the lateral surface is concave. A groove, the sulcus acousticus, runs anteroposteriorly along the medial surface.

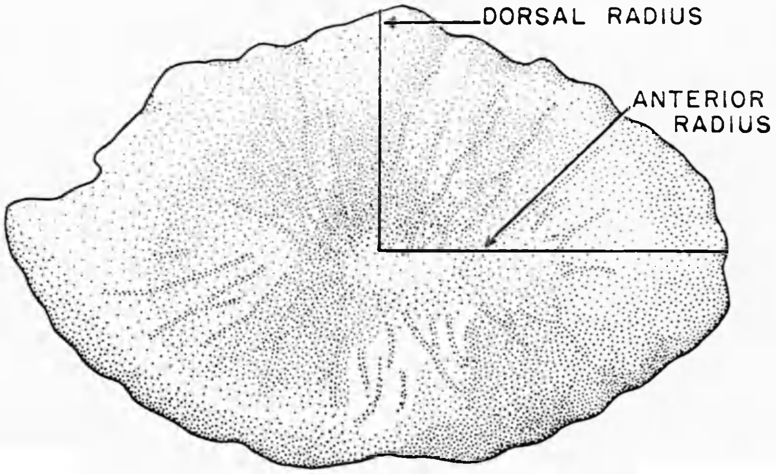
The dorsal and anterior radii were measured before the otoliths were prepared for age determination. The otoliths were placed in a watch glass, concave surface up, covered with water, and examined with a dissecting microscope at 14X. Measurements, to the nearest ocular unit (0.07 mm), were made from the focus, a small opaque central area, to the dorsal and anterior margins (Fig. 1).

It was necessary to imbed the otoliths in plaster and then grind, polish, and heat them to distinguish the annuli. A heat resistant plaster called Vel Mix Stone was poured into cylindrical paper molds and slightly over one-half of the otolith was imbedded on a plane perpendicular to the long axis of the otolith. The station and specimen numbers were scratched on the base of the hardened plaster cylinder. A whetstone was used to grind the protruding section of the otolith flush with the

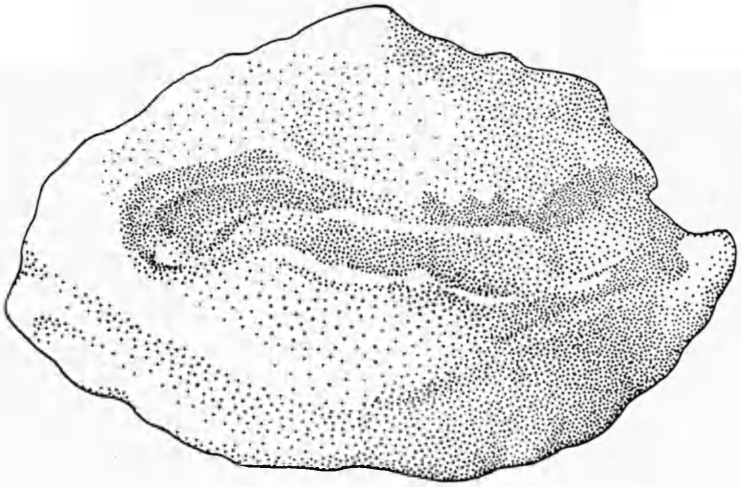
Fig. 1

Saccular otolith of the striped searobin.

Magnification 11X.



LATERAL SURFACE



MEDIAL SURFACE

plaster. The otolith was further ground with #320 alundum until the nucleus was exposed. This surface was then polished with finer abrasives, #400 and #600 alundum. The polished otoliths were heated in an electric furnace for 20 minutes, the time required for the furnace to reach 530 C. It has been demonstrated by Lawler and McRae (1961); Chugunova (1963); Christensen (1964); and Poinsard and Troadec (1966) that the visibility of annuli is enhanced by heating otoliths.

The heated otoliths had alternating dark and light bands. According to Hickling (1931), Irie (1955), and E. Dannevig (1956) the banding is due to a disproportion of organic and inorganic constituents. When growth is most pronounced, a greater percentage of inorganic salts is added; when growth is reduced, a greater percentage of protein is deposited (Irie, 1957). Annual growth consists of a wide crystalline band and a narrow protein band. The protein band customarily considered to be the annulus can be differentiated from the remainder of the otolith with heat. Heating oxidizes the protein and darkens it without affecting the crystalline ring.

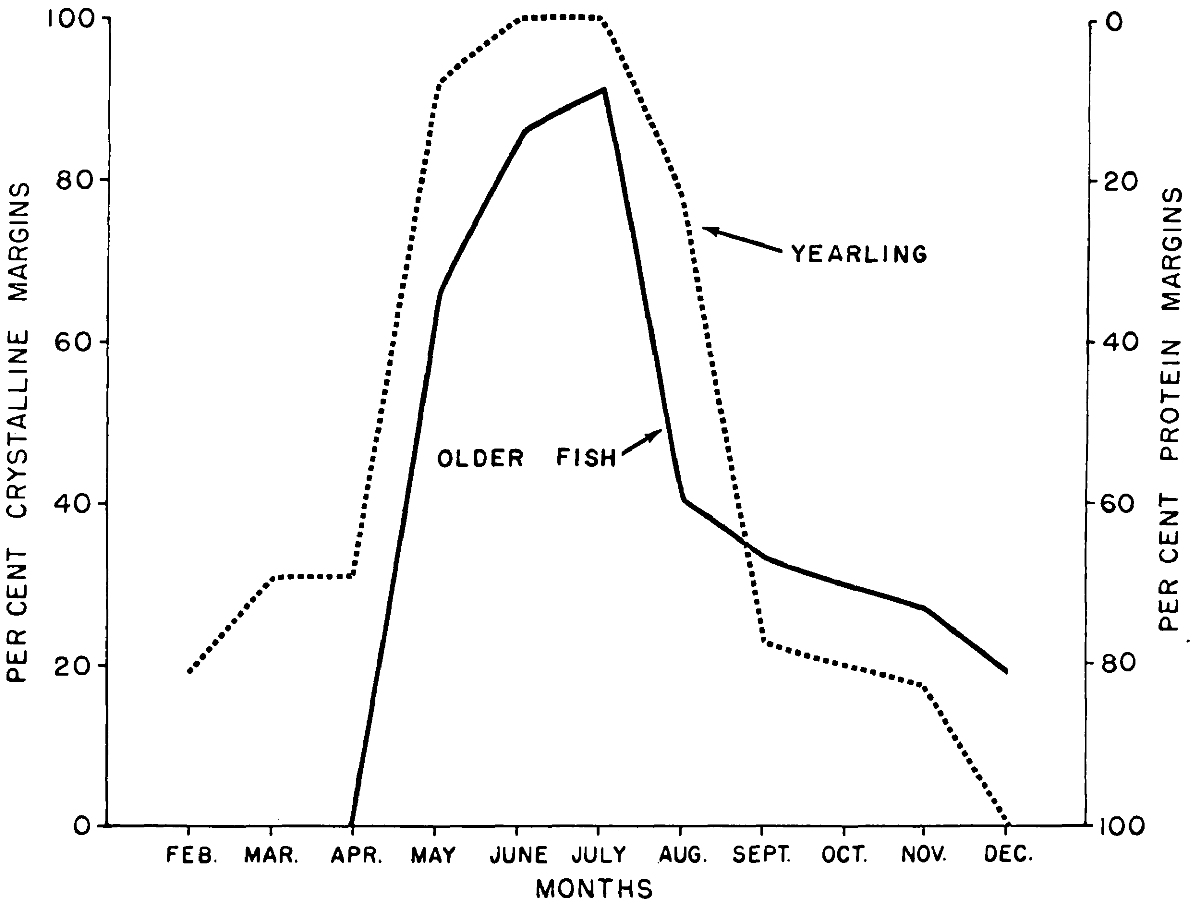
The annulus formed in autumn remained on the margin of the otolith until the following spring (Fig. 2). This is the same phenomenon described for other species by A. Dannevig (1956), Bratberg (1956), Irie (1960), and Gambell and Messtorff (1964). About one-fourth of the yearlings captured in February and March had narrow crystalline bands outside the annulus (Plate I, Fig. A). The otoliths of older fish did not have crystalline edges until May (Plate I, Fig. B). The percentage of crystalline margins increased through July. Annulus formation began in August and the percentage of otoliths with protein bands increased through December. The otolith margins indicated that growth for most fish occurred between May and August.

The otolith margins showed growth commencing earlier for yearlings than for older fish. According to Nikolsky (1963) the reduced period of growth of older fish is due to the fact that metabolities in mature fish are used primarily for gonadal development and accumulation of fat for overwintering. The older striped searobins did not begin yearly growth until gonadal maturation was nearly complete. However, the two groups did not differ in time of termination of growth (Plate I, Figs. C and D). Thus the accumulation of fat did not affect the linear growth of the older fish more than that of the yearlings.

A majority of the fish began a new year's growth after commencement of vernal warming of the waters of the continental shelf. Table 2 lists the bottom water temperatures at sites where striped searobins were captured. Vernal warming began prior to May, the time at which crystalline material first appeared on the margins of most of the otoliths. However, growth terminated before there was a decline in water temperature. This phenomenon was also reported to occur in _Coregonus_ _clupeaformis_ (Van Oosten, 1923). A. Dannevig (1956) found that _Gadus_ _morhua_ formed an annulus even when held at a constant temperature. These observations suggest that, although temperature affects growth, other factors are involved.

Fig. 2

Seasonal change in the margin of the otolith of the striped searobin.



PER CENT CRYSTALLINE MARGINS
100
80
60
40
20
0
PER CENT PROTEIN MARGINS
0
20
40
60
80
100
YEARLING
OLDER FISH
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
MONTHS

Plate I

Seasonal change in the margin of the otolith of the striped searobin.

Fig. A. A thin crystalline band on margin of an otolith from a yearling captured in March.

Fig. B. A thin crystalline band on margin of an otolith from a three year old fish captured in May.

Fig. C. A wide crystalline band on the margin of an otolith from a yearling captured in November.

Fig. D. A relatively wide crystalline band on the margin of an otolith from a four year old captured in November.

PLATE I

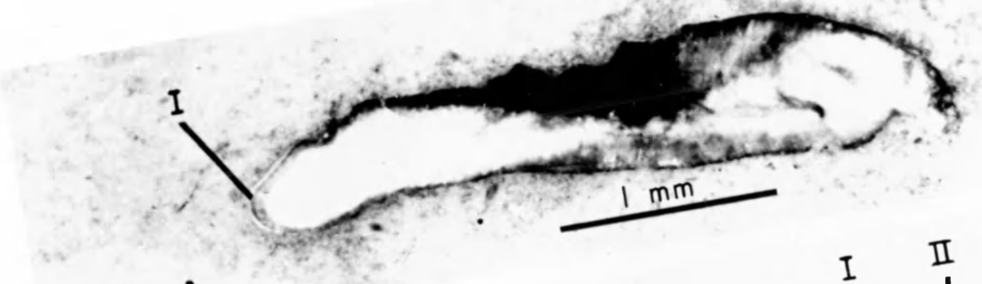


FIG. A

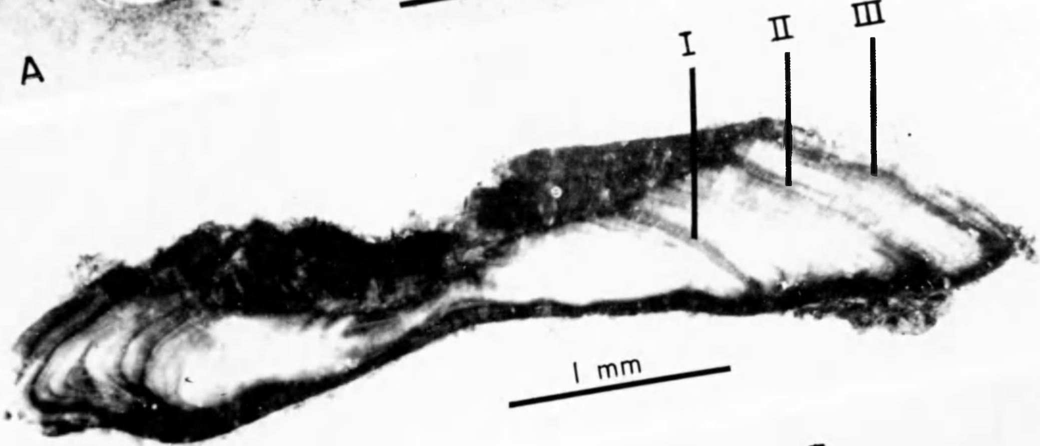


FIG. B

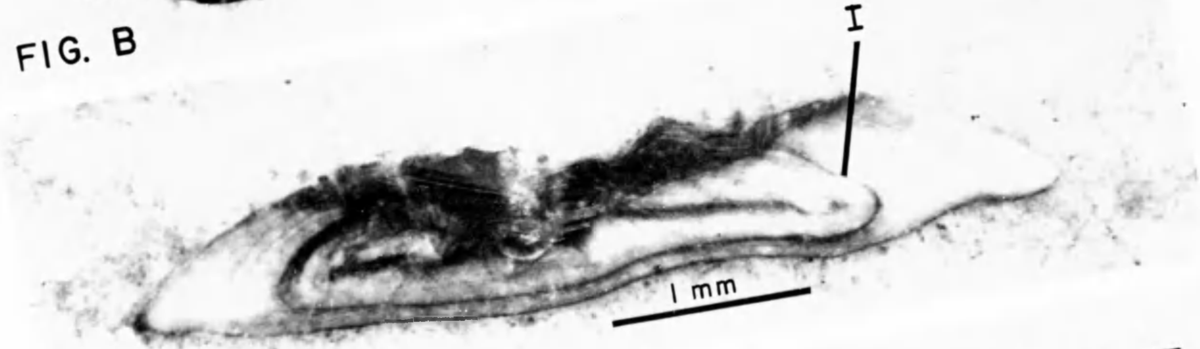


FIG. C

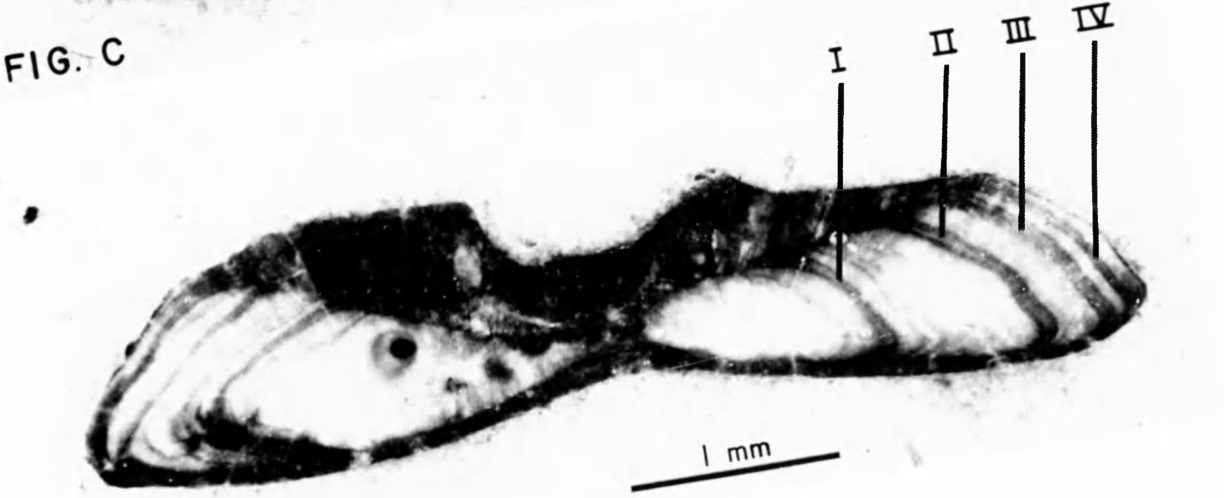


FIG. D

TABLE 2

BOTTOM WATER TEMPERATURES AT SAMPLE SITES

	1966	
	Temperature Range C	Average Temperature C
February	5.6 - 8.4	6.4
March	5.6 - 11.7	7.7
May	11.9 - 15.4	13.7
August	11.0 - 17.0	14.1
September	13.0 - 23.0	19.2
November	11.7 - 15.6	13.7
December	14.4	14.4

	1967	
	Temperature Range C	Average Temperature C
March	10.3	10.3
May	9.4 - 10.0	9.7
June	7.8 - 11.1	9.8
July	12.2 - 15.0	13.6

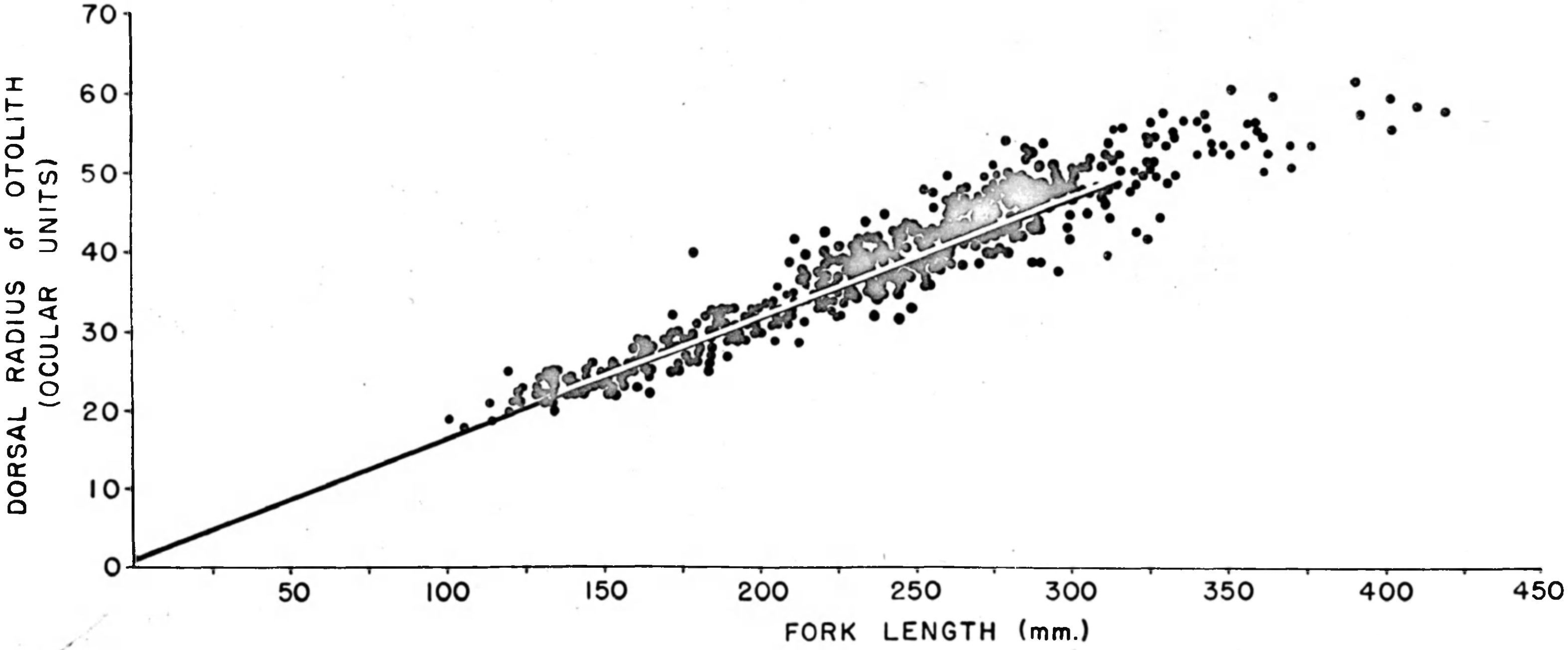
Although growth of the otolith, both dorsally and anteriorly, was proportional to linear growth of the fish, the former axis of growth showed a closer relationship to growth in length than the latter. The dorsal radius of the otolith increased in a linear manner with fork length until the fish reached 315 mm. After the fish attained about 315 mm fork length the growth of the otolith appeared to slacken in relation to linear growth (Fig. 3). For this reason, one linear regression was developed for fish $\leq$ 315 mm and a second was developed for fish > 315 mm. The regression of otolith radius (y) on fork length (x) for fish $\leq$ 315 mm was: $y = 1.1976 + 0.1547x$ with a correlation coefficient of 0.82711. The regression for fish > 315 mm was: $y = 24.3208 + 0.0855x$ with a correlation coefficient of 0.56123. The two correlation coefficients indicated that otolith growth was closely related to growth in length for fish $\leq$ 315 mm, but not for fish > 315 mm. The fact that growth of the otolith did not appear to be proportional to growth in length for fish > 315 mm did not greatly influence the age analysis because only 6.5% of the specimens exceeded 315 mm.

The processed otoliths thus satisfied the requirements for age determination. Annuli were laid down at about the same time every year and growth of the otolith was proportional to growth of the fish.

The processed otoliths showed the nucleus closer to the ventral margin than to the dorsal margin (Plate I, Figs. A-D). Since annuli were crowded on the ventral radius but well separated on the dorsal radius, age was determined by counting the annuli along the dorsal radius. The age of most fish could be determined

Fig. 3

Relationship of dorsal radius of the otolith to fork length.


70
60
50
40
30
20
10
0
DORSAL RADIUS of OTOLITH
(OCULAR UNITS)
50
100
150
200
250
300
350
400
450
FORK LENGTH (mm.)

by this method; however, certain irregularities did occur. Accessory rings were occasionally found between the first and second annuli (Plate II, Fig. A). These rings, often occurring in pairs, were judged to be accessory rings because they were thinner and less distinct than the two encompassing rings. Some of the otoliths formed double annuli (Plate II, Fig. B). Double rings could not be interpreted accurately when they occurred near the margins on otoliths of older fish because reduction of growth rate caused the rings to be set close together. Reorientation of growth on the dorsal margin was observed on some of the larger otoliths. Growth sometimes became more appreciable medial to the dorsal radius than along the dorsal radius after age IV or V causing the annuli to be closely spaced and making age determination uncertain (Plate II, Fig. C).

The change in axis of growth may have been the reason why the relationship of dorsal radius of the otolith on fork length was uncertain for fish longer than 315 mm. Reorientation of growth on the dorsal radius may have been due to mechanical pressure of the otic capsule. Presumably the otolith continued to grow dorsally until interference from the otic capsule caused a reorientation.

Because of the irregularities in growth of the otolith and reduction of growth with time, age could be determined only up to seven years.

Figure 4 shows mean lengths in 1966 and 1967 prior to the new year's growth. Mean lengths of age group I were obtained from the samples collected during February and March, 1966 and March, 1967. Mean lengths of older age groups were obtained from the samples taken in May, 1966 and May, 1967. In 1966 the one and

Plate II

Irregularities in growth of the otolith of the striped searobin.

Fig. A. Otolith from a seven year old fish.

1. False annuli.

Fig. B. Otolith from a seven or eight year old fish.

1. First double annulus.
2. Second double annulus.
3. Third double annulus.

Fig. C. Otolith from a seven year old fish.

1. Reorientation of growth after fourth year.

PLATE II

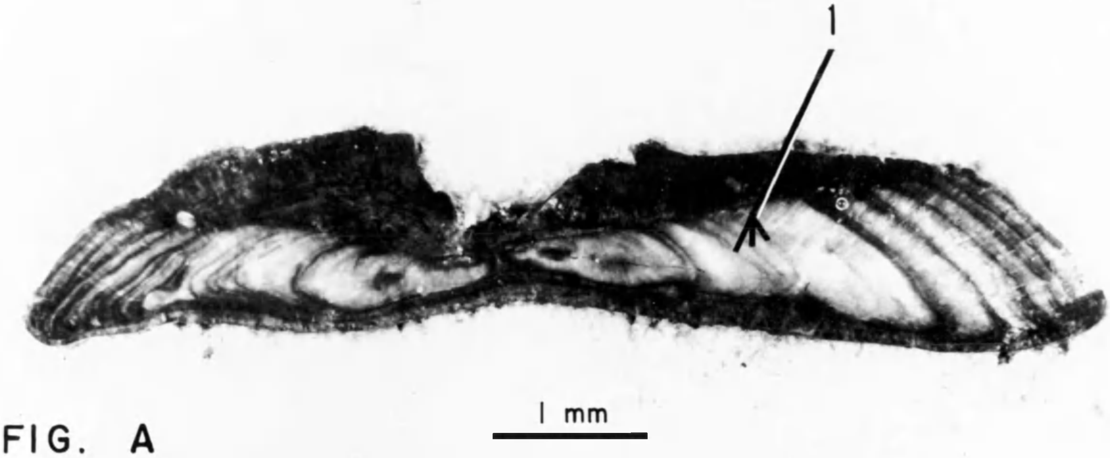


FIG. A

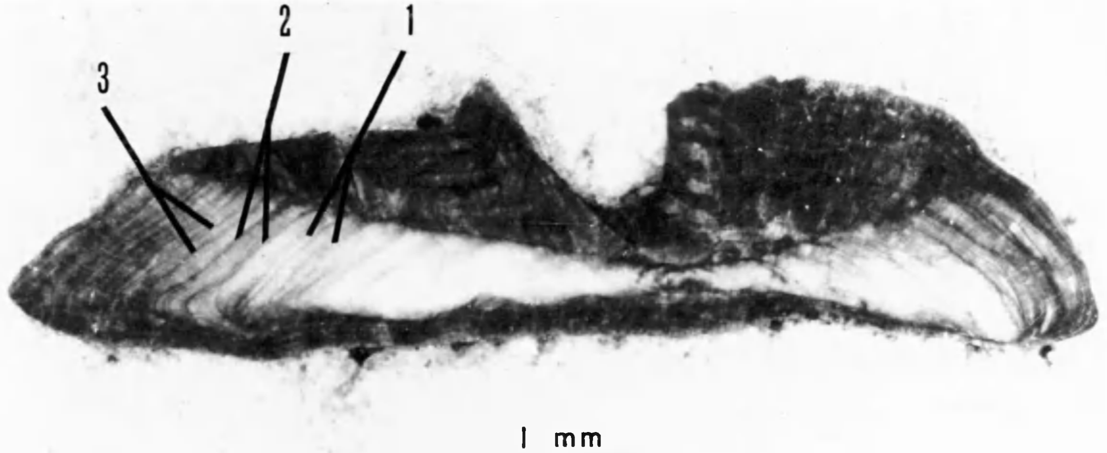


FIG. B

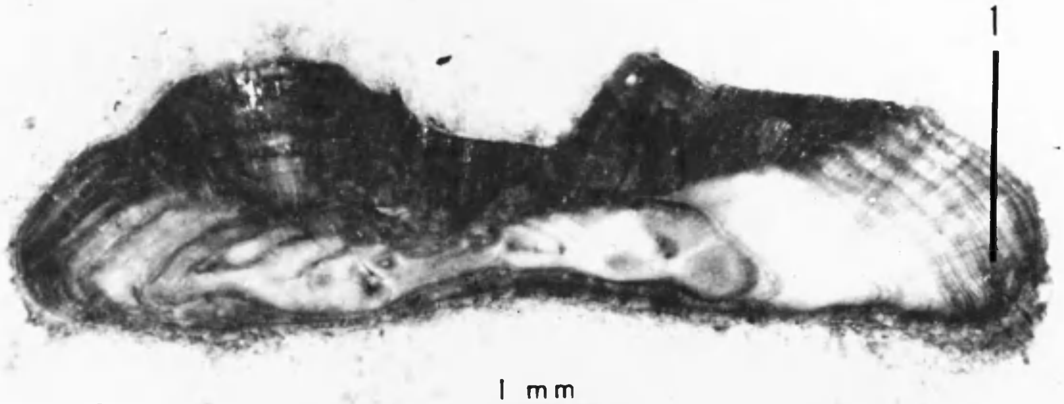


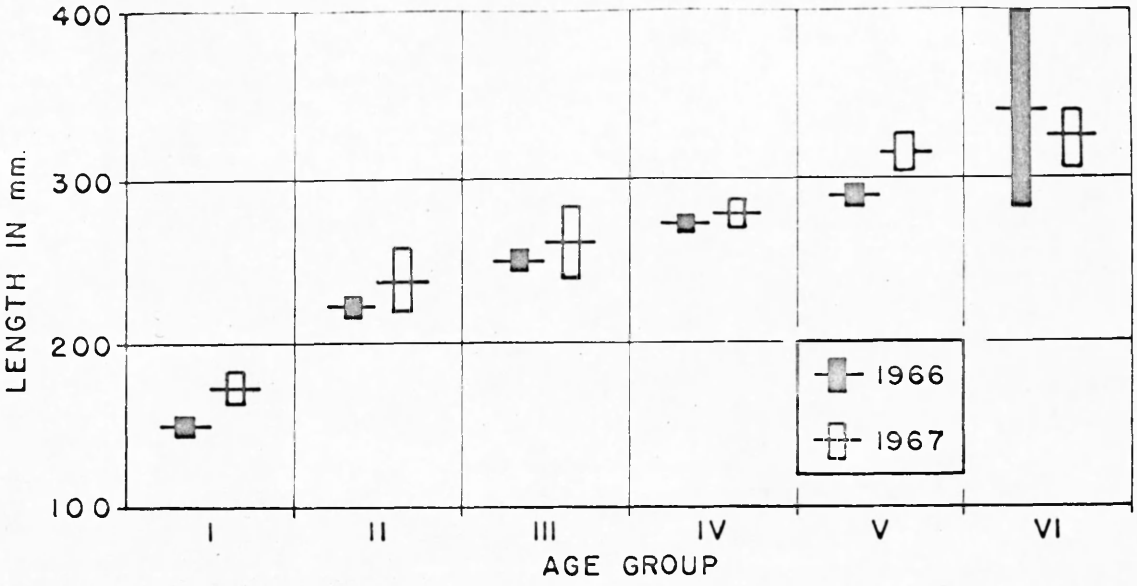
FIG. C

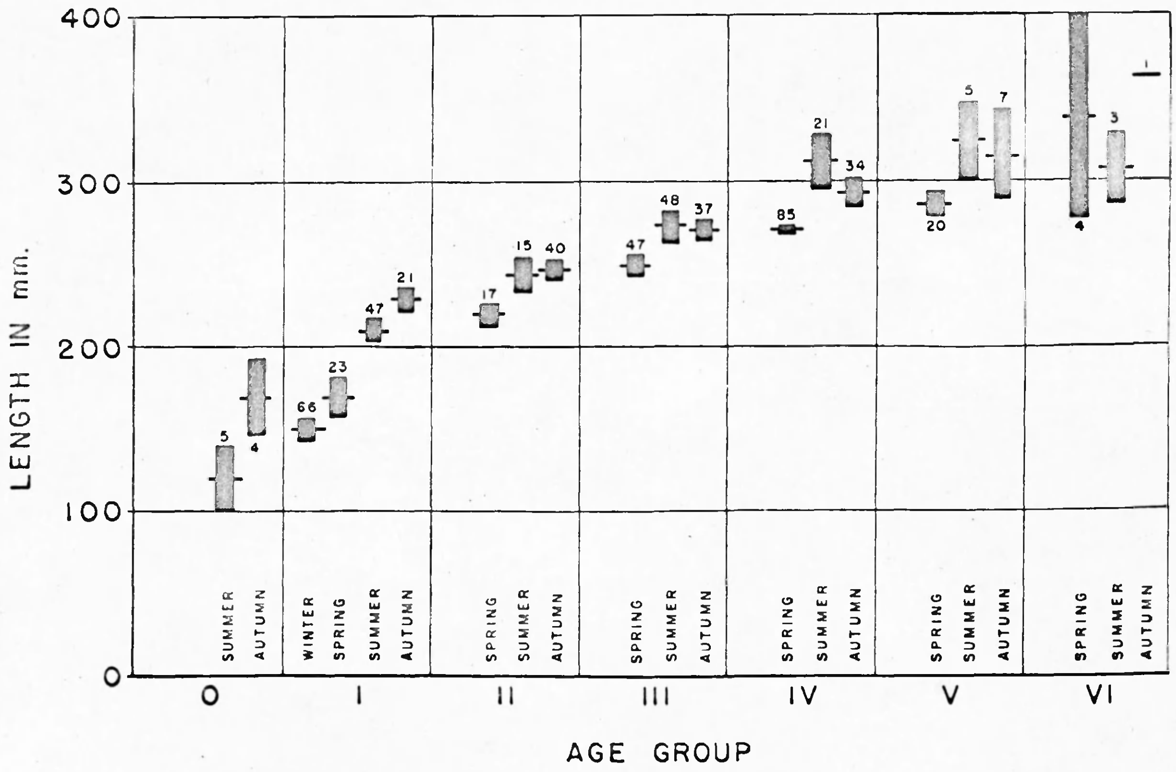
Fig. 4

Mean lengths and confidence interval of the means for age groups of striped searobins prior to growth in 1966.

Fig. 5

Mean lengths and confidence interval of the means for age groups of striped searobins during each season in 1966. Numbers adjacent to the bars represent sample size.


400
300
200
100
LENGTH IN mm.
I
II
III
IV
V
VI
AGE GROUP
1966
1967


400
300
200
100
0
LENGTH IN mm.
5
4
66
23
47
21
17
15
40
47
48
37
85
21
34
20
5
7
4
3
1
SUMMER
AUTUMN
WINTER
SPRING
SUMMER
AUTUMN
SPRING
SUMMER
AUTUMN
SPRING
SUMMER
AUTUMN
SPRING
SUMMER
AUTUMN
SPRING
SUMMER
AUTUMN
SPRING
SUMMER
AUTUMN
O
I
II
III
IV
V
VI
AGE GROUP

two year olds averaged 151 mm and 221 mm and in 1967 they averaged 173 mm and 237 mm. "Student's" t test (Snedecor, 1956) showed that these mean differences were statistically significant at the 5% level. The differences were probably due to a change in mesh size of the sampling gear. From 1966 to 1967 the trawl mesh was changed from 1/2 inch to two inches. There was no difference between the mean lengths of the three or four year olds. The three year olds averaged 249 mm in 1966 and 261 mm in 1967. The four year olds averaged 272 mm and 278 mm in the two years respectively. Age group V averaged 288 mm in 1966 and 315 mm in 1967. The means were significantly different at the 5% level. The difference was more likely due to sampling than to a difference between the year classes in rate of growth for a given age. The six year olds averaged 341 mm in 1966 and 323 mm in 1967. This mean difference was not significant. The largest fish taken was 415 mm and was judged to be seven years old.

Yearly growth of each age group was obtained by subtracting the mean length at the beginning of the growing season from that at the end of the growing season. According to Ricker (1958) the above procedure can be used to estimate yearly growth as long as several criteria are met: (1) there must be no difference between year-classes in respect to rate of growth at any given age; (2) the fish taken must constitute a random sample of each of the age classes involved; (3) and there must be no correlation between size of a fish within an age-group, and mortality rate to which it is subject.

Two of the criteria established by Ricker were met. Each age group had the same growth rate in 1966 as it did in 1967.

Random samples were obtained by limiting comparisons to samples taken with the same type of trawl and samples in which the particular age groups were well represented. However, data were not sufficient to determine whether or not size of an individual within an age group was an independent variable of mortality rate.

The seasonal and yearly growth is represented in Fig. 5. During 1966 the yearlings grew about 80 mm. The two year olds averaged 27 mm. The three and four year old fish grew about 22 mm. The five year old fish showed a 30 mm average increment. Why the mean length of age groups III, IV, and V was greater during the summer than during the following autumn was not apparent. Fish of older age groups were not taken in sufficient quantities to determine yearly growth. Data on growth of young-of-the-year were very sparse because otoliths were obtained from only nine specimens. They averaged 119 mm in the August-September sample and 169 mm in the November-December sample.

Striped searobins accomplished more than one-half of their linear growth during their first two years of life. Reduction of linear growth after the second year coincided with sexual maturity. Both sexes became mature during the spring of their third year.

Growth in length occurred during the period when crystalline material was found on the margin of the otolith. As inferred from the otoliths, the yearlings had a longer growing season than the older fish. Yearlings began linear growth in February or March and continued growing until November or December. The growing season of older fish extended from May to November or December.

Figure 5 further shows that the height of the growing season for all age groups occurred between May and August. The yearlings were the only age group with a significant increase in length between summer and fall.

There was no difference in the growth rate between the sexes. However, chi-square tests showed males predominating at lengths less than 300 mm and females more numerous at lengths greater than 300 mm. Below 300 mm 62% of the fish were males and above 300 mm 66% were females. The change in the sex ratio may have been due to the fact that large females had a slightly lower mortality rate than large males.

Length Frequency Method

The length frequency method has often proved useful in determining the age of fishes. This method is based on the premise that lengths of fish in an age group tend to form a normal distribution (Rounsefell and Everhart, 1953). The lengths of fish of successive age groups form a polymodal curve (Lagler, 1956). The age structure of the population is determined from the number of modes. However, this method is useful for determining the age of younger fish only. Polymodal distribution in length frequency curves is obscured for larger fish because of reduction of growth rate with time (Van Oosten, 1941).

Lengths of the striped searobin were plotted separately for each sampling period to prevent growth between sampling periods from obscuring the modal distribution. Length frequency comparisons were restricted to fish taken with the same gear. Only fish taken with the semi-balloon trawl were used in 1966 and only fish taken with the Atlantic western trawl were used in 1967. The length frequencies for 1966 showed polymodality and seasonal progression of modal size (Fig. 6). The growth of age groups 0 and I could be followed during the year. The winter sample was unimodal and consisted entirely of yearlings. By spring this age group consisted of fish from 118 mm to 197 mm. Yearlings had a modal length of 220 mm during summer and 240 mm during autumn. Age group 0 was first seen in summer and by autumn it ranged from 148 mm to 187 mm. The length frequency distributions were less helpful for identifying older age groups. Polymodal distribution was clearly evident only in the summer sample. The modes at 250 mm, 275 mm, and 300 mm probably represented age groups II, III, and IV respectively.

Two adequate length frequencies were obtained during 1967 (Fig. 7). The bimodal curves gave an indication of growth and size of the yearlings during the spring. Between the sampling periods in March and May this group showed a modal increase from 165 mm to 188 mm. The second mode in each of these samples consisted of the older age groups which, because of reduction of growth rate, could not be individually discerned.

The results of the length frequency method supported those of the otolith method. Table 3 shows that the mean length of yearlings determined by the length frequency analysis were very close to those determined by the otolith analysis. Both methods indicated that linear growth was reduced after the first year. After age I the means of successive age groups were separated by less distance; therefore, the age groups could not be differentiated on the histograms in Fig. 6 and Fig. 7.

Fig. 6

Length frequencies of the striped searobins during each of the seasons of 1966.

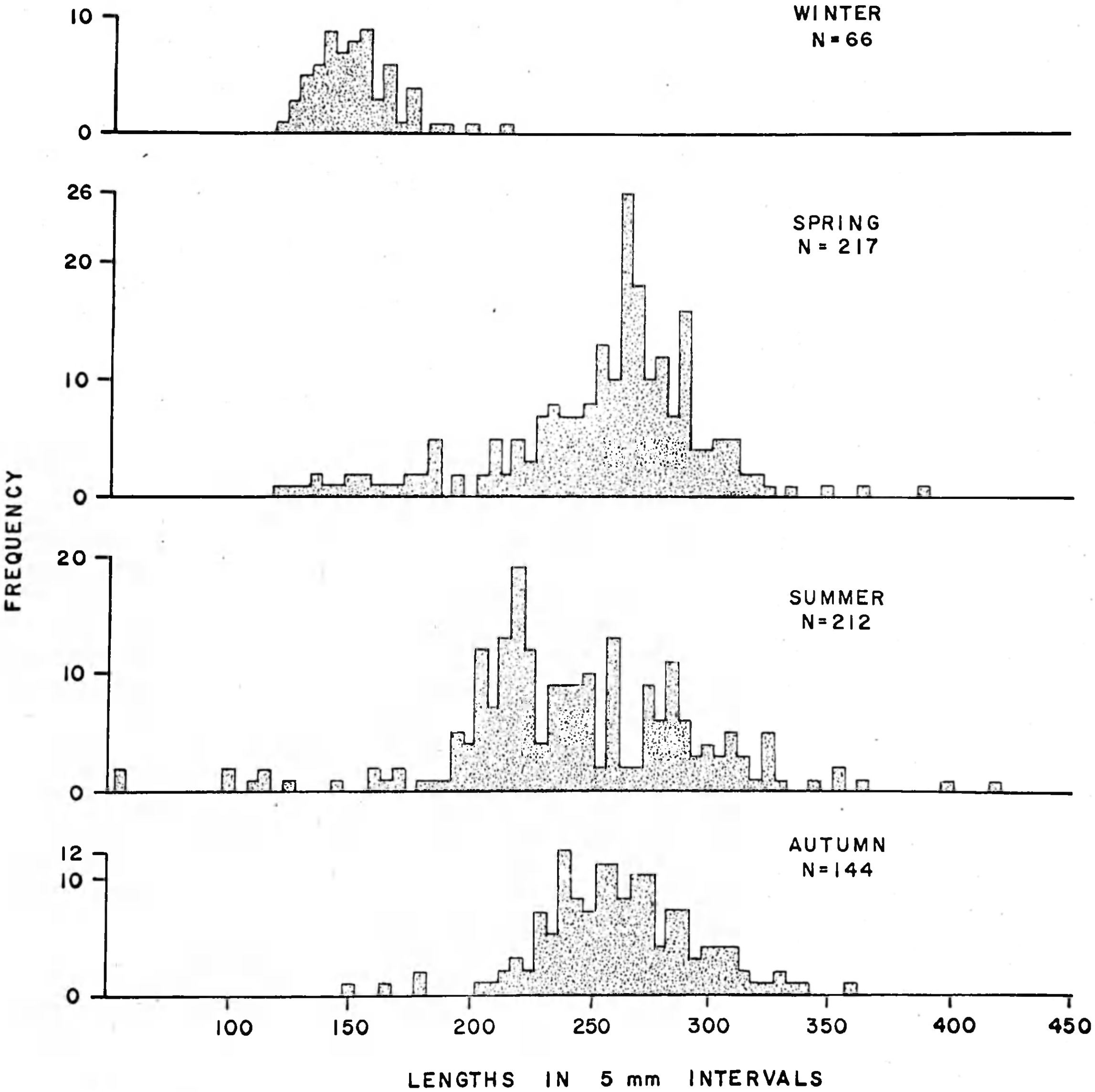
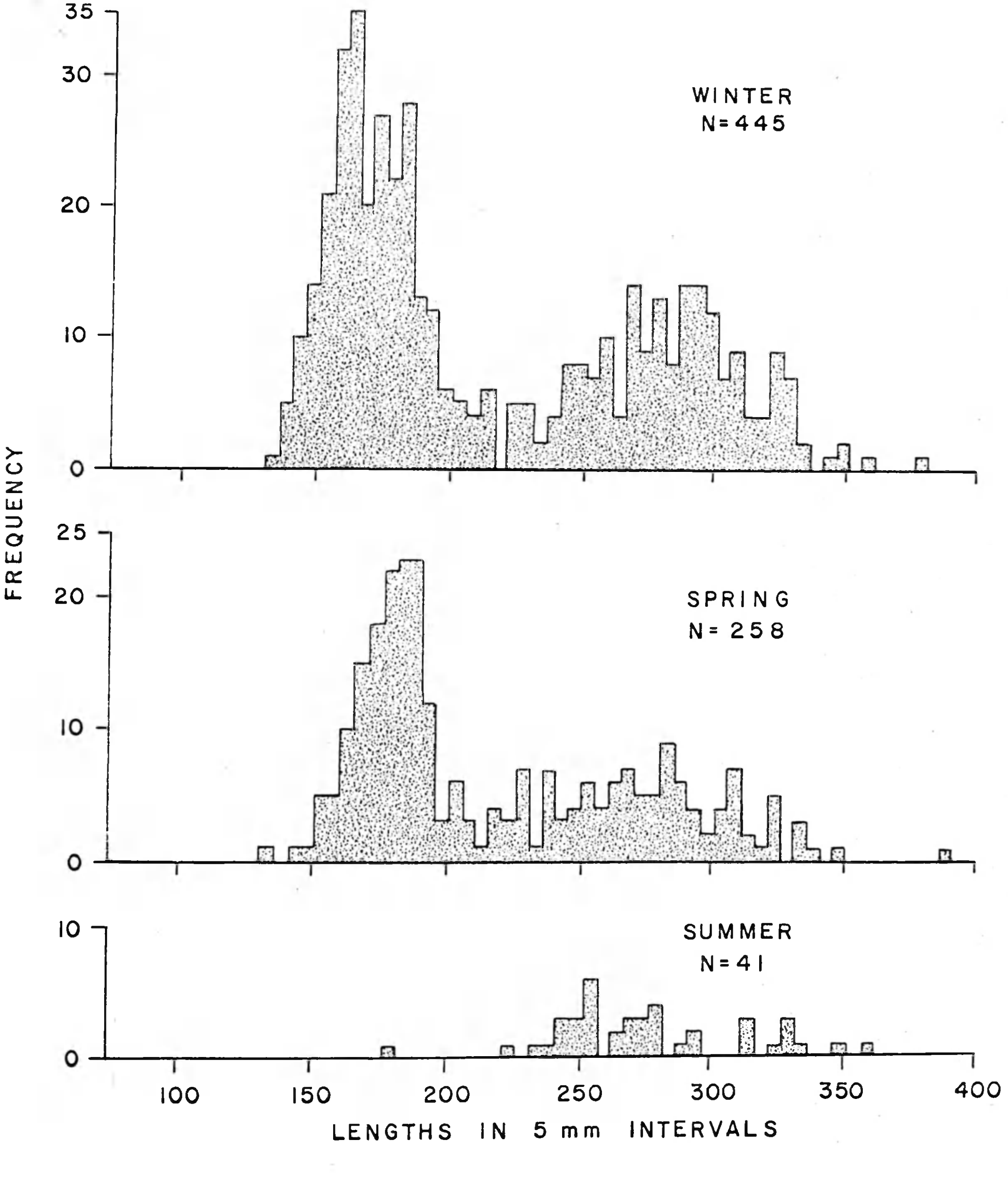

WINTER
N=66
SPRING
N=217
SUMMER
N=212
AUTUMN
N=144
FREQUENCY
10
0
26
20
10
0
20
10
0
12
10
0
100
150
200
250
300
350
400
450
LENGTHS IN 5 mm INTERVALS

Fig. 7

Length frequencies of the striped searobins during first three seasons of 1967.



WINTER
N=445
SPRING
N=258
SUMMER
N=41
FREQUENCY
35
30
20
10
0
25
20
10
0
10
0
100
150
200
250
300
350
400
LENGTHS IN 5 mm INTERVALS

TABLE 3

MEAN LENGTHS OF YEARLINGS AS DETERMINED BY LENGTH FREQUENCY METHOD AND BY THE OTOLITH METHOD.

	Winter 1966	Spring 1966	Summer 1966	Fall 1967	Winter 1967	Spring 1967
$\bar{X}$ Length Frequency method	149	155	203	228	171	182
$\bar{X}$ Otolith method	151	172	211	230	173	185

The estimate of growth of age groups 0 and I may have been biased by the capture of only the large members of these age groups. All of the specimens used for age analysis were taken over the continental shelf and these fish were considerably larger than those taken at the same time from the estuaries and inlets (Table 4).

Earlier studies also indicate that the growth of age groups 0 and I was over estimated. Smith (1898) stated that striped searobins reach about 4 inches (102 mm) by their first autumn. Nichols and Breder (1927) obtained young fish averaging 68 mm fork length in August and 86 mm fork length in October. Warfel and Merriman (1944) collected fish averaging 44 mm in early August, 57 mm in late August, one fish 108 mm in early September, and fish ranging from 66 mm to 108 mm in mid-September. A conversion factor (1.23) was used to convert standard length, used in the previous studies, to fork length.

Comparison of this Study with an Earlier Study

Marshall (1946), using scales, found growth of the striped searobin more variable and more rapid than was indicated by analysis based on heated otoliths (Table 5). The spring and summer samples of 1966 were combined in order to compare with Marshall's sample which was collected during most of the summer. Also it was necessary to convert the standard lengths taken by Marshall to fork lengths. Heated otoliths were a better indicator of age than scales. From scales Marshall could determine age for only the first three years and he discarded 44% of fish longer than 314 mm because of obscurity of annuli. However, from processed otoliths, age could be determined for the first seven years and only 20% of the fish longer than 314 mm were discarded because of irregularities in the otoliths.

TABLE 4

NUMBER AND FORK LENGTHS OF STRIPED SEAROBINS OBTAINED FROM INLETS AND ESTUARIES DURING 1966-67.

	May	June	July	August	September	October
Yearlings						
Number	11	8	1	2		
Length range[1]	61-156	154-200	195	150-190		
Mean length	115	177	195	170		
Young-of-the-year						
Number				3	3	2
Length range[1]				54-73	57-104	57-62
Mean length				65	87	60

[1] lengths in mm.

TABLE 5

LENGTHS OF AGE GROUPS 0-III OBTAINED BY THE PRESENT STUDY AND THOSE OBTAINED BY MARSHALL'S STUDY

Age Group	0	I	II	III
Fork lengths				
Present study[1]	<124	134-242	208-276	219-301
Marshall's study[1]	<123	154-283	209-326	271-344

[1] lengths in mm

DISTRIBUTION

Striped searobins make an annual onshore-offshore migration, probably in response to changing water temperatures. During the coldest period of the year, February and March, the striped searobins are in warmer offshore water. With onset of vernal warming the fish move inshore and remain there until the coastal waters begin to cool in autumn. In winter, 1966 the fish were dispersed between the 11 and 100 fathom contours. Figure 8 shows that fish were most abundant between 21 and 30 fathoms. In this depth range an average of 5.4 fish were caught per tow. By spring the fish were concentrated in shallow water (Fig. 9). Water shoaler than 11 fathoms yielded an average of 16.8 fish per tow. In summer all of the fish were found in water shoaler than 21 fathoms (Fig. 10). Tows between shore and 10 fathoms averaged 9.1 fish per tow, tows between 11 and 20 fathoms averaged 8.0 fish. By autumn the fish had dispersed and were caught between shore and the 40 fathom isobath (Fig. 11).

Because the range of the striped searobin extends a considerable distance to the north and south of Chesapeake Bight and because fish were captured over the entire Bight during all periods, it could not be determined if there was an annual north-south migration.

The presence of smaller young-of-the-year striped searobins in inlets suggests that age group 0 used this area as a nursery ground. However, since large concentrations of young-of-the-year have not been taken this hyptothesis is tentative.

Fig. 8

Distribution of striped searobins in Chesapeake Bight during winter 1966. Distribution of striped searobins according to depth and bottom water temperature during winter, 1966.

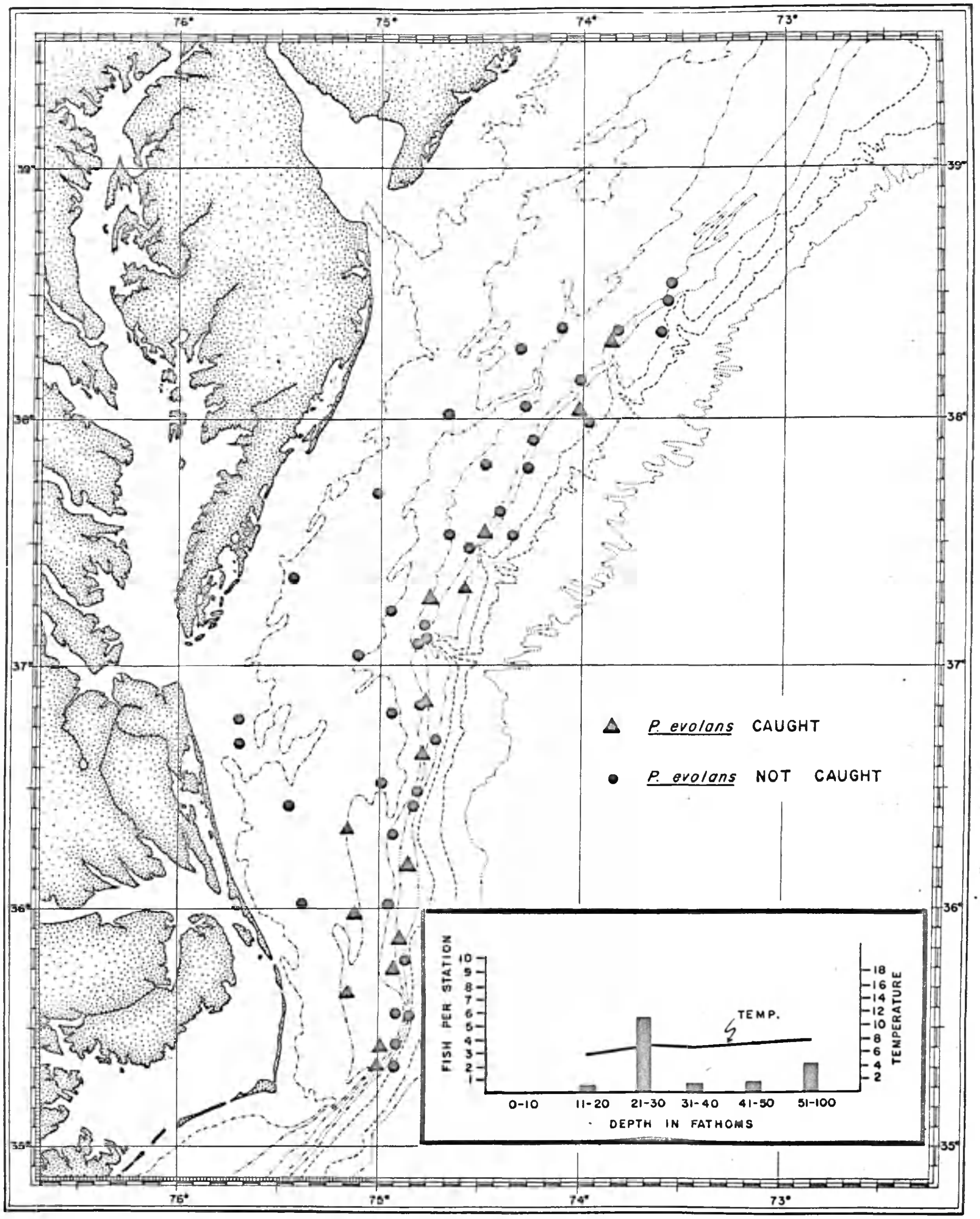
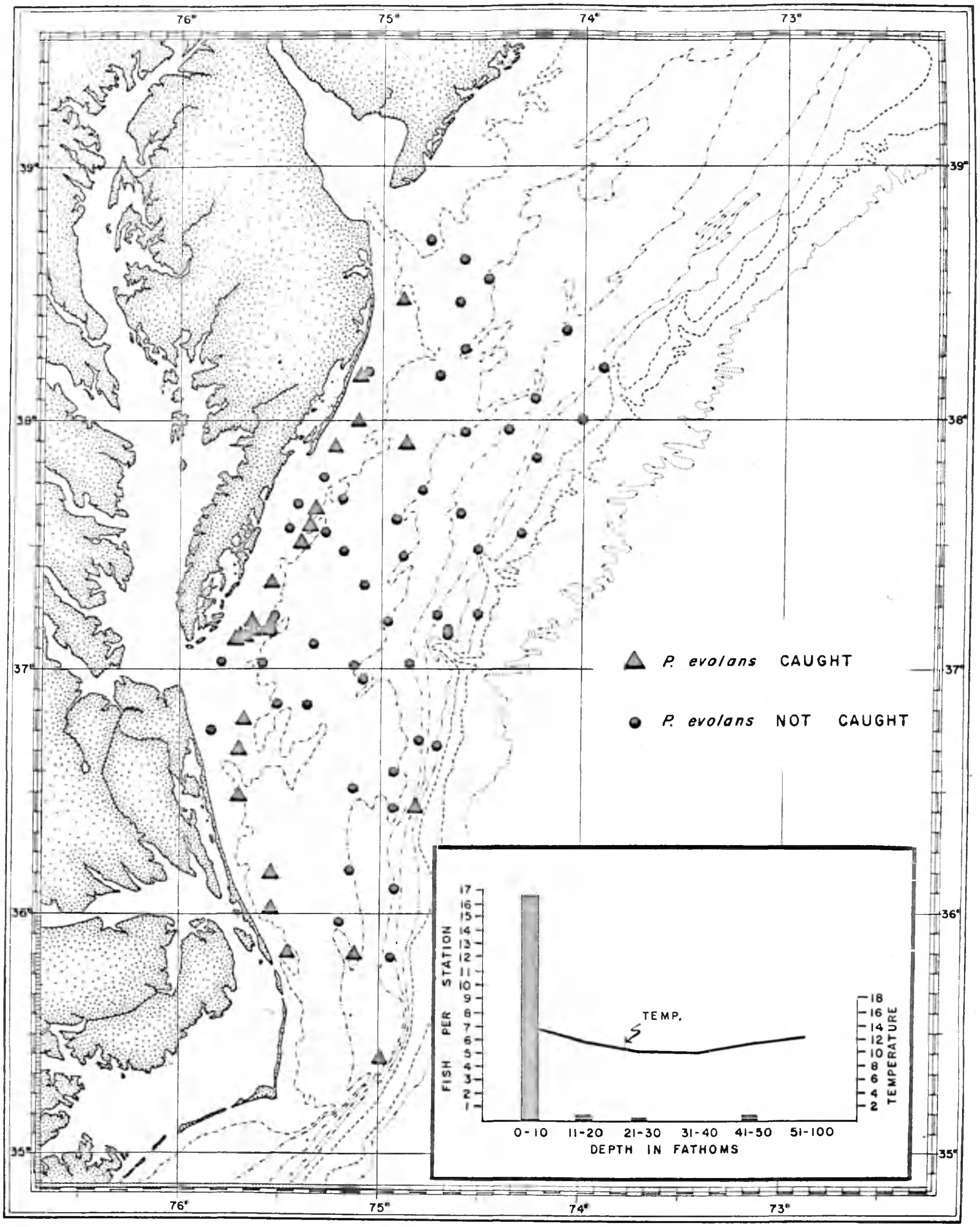

76°
75°
74°
73°
39°
38°
37°
36°
35°
▲ *P. evolans* CAUGHT
● *P. evolans* NOT CAUGHT
FISH PER STATION
1
2
3
4
5
6
7
8
9
10
TEMPERATURE
2
4
6
8
10
12
14
16
18
TEMP.
0-10
11-20
21-30
31-40
41-50
51-100
DEPTH IN FATHOMS

Fig. 9

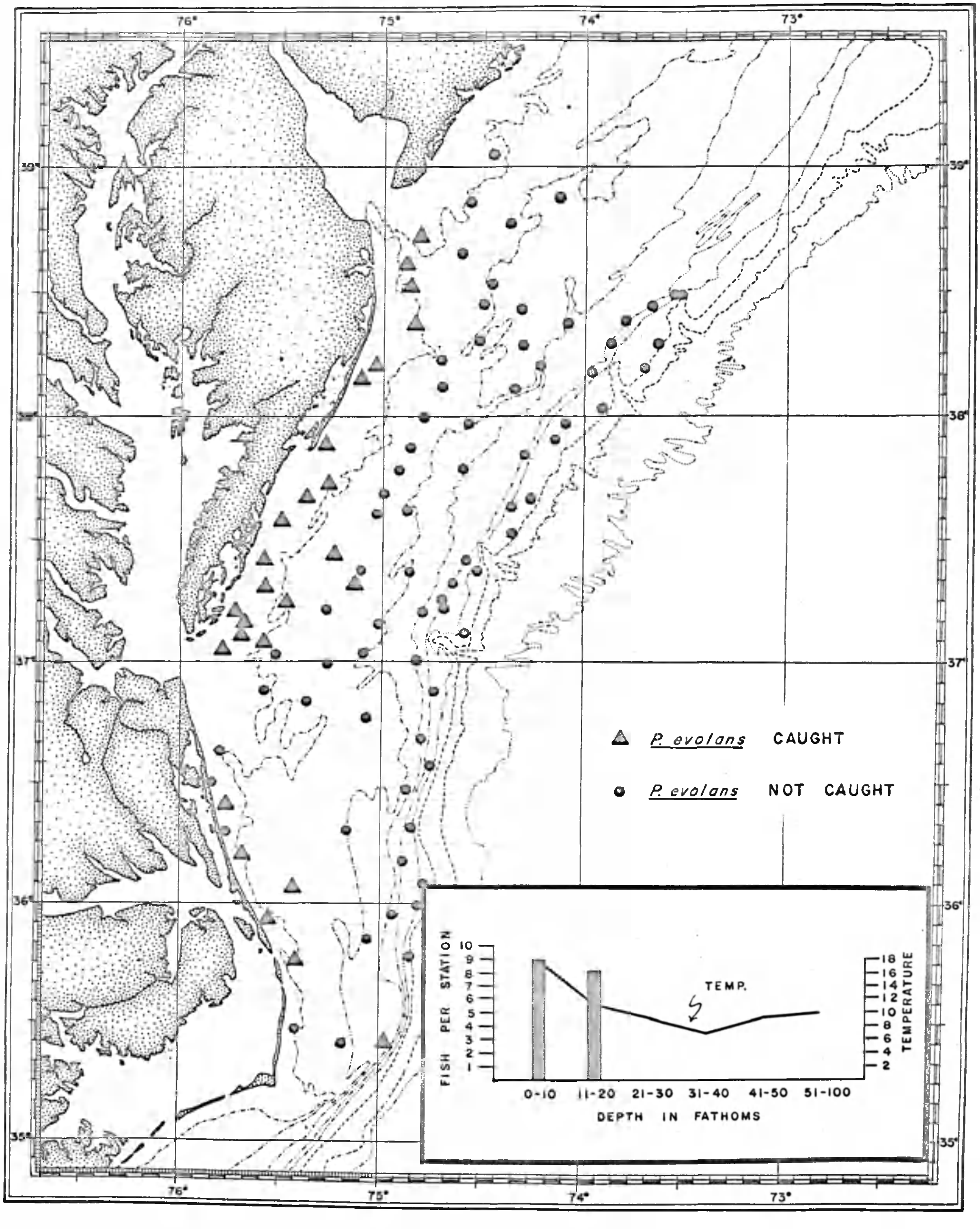
Distribution of striped searobins in Chesapeake Bight during spring, 1966. Distribution of striped searobins according to depth and bottom water temperature during spring, 1966.



76°
75°
74°
73°
39°
38°
37°
36°
35°
▲ P. evolans CAUGHT
● P. evolans NOT CAUGHT
FISH PER STATION
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
TEMP.
TEMPERATURE
2
4
6
8
10
12
14
16
18
0-10
11-20
21-30
31-40
41-50
51-100
DEPTH IN FATHOMS

Fig. 10

Distribution of striped searobins in Chesapeake Bight during summer, 1966. Distribution of striped searobins according to depth and bottom water temperature during summer, 1966.


76°
75°
74°
73°
39°
38°
37°
36°
35°
▲ P. evolans CAUGHT
● P. evolans NOT CAUGHT
FISH PER STATION
10
9
8
7
6
5
4
3
2
1
TEMP.
TEMPERATURE
18
16
14
12
10
8
6
4
2
0-10
11-20
21-30
31-40
41-50
51-100
DEPTH IN FATHOMS

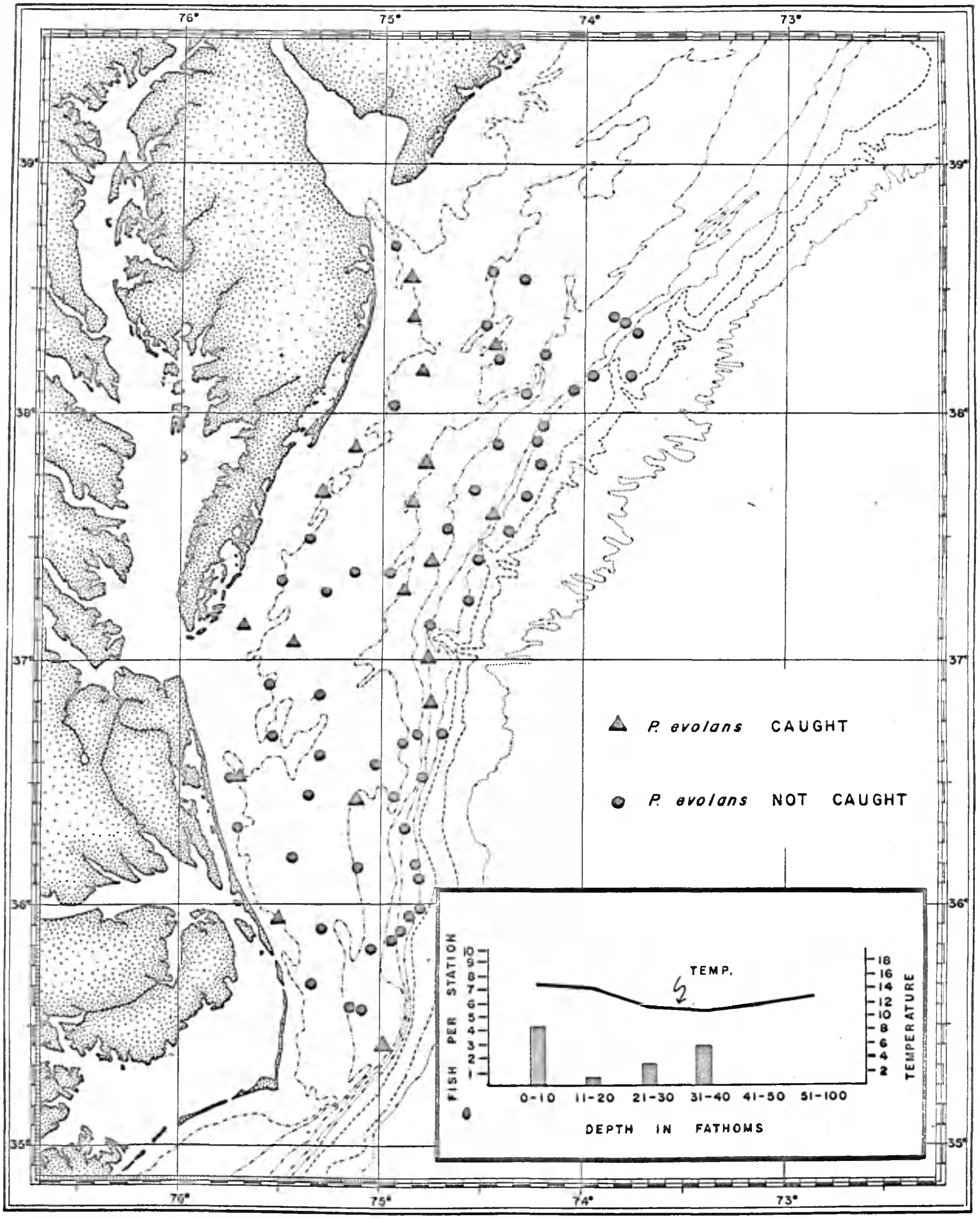

76°
75°
74°
73°
39°
38°
37°
36°
35°
▲ P. evolans CAUGHT
● P. evolans NOT CAUGHT
FISH PER STATION
TEMPERATURE
TEMP.
10
9
8
7
6
5
4
3
2
1
18
16
14
12
10
8
6
4
2
0-10
11-20
21-30
31-40
41-50
51-100
DEPTH IN FATHOMS

Fig. 11

Distribution of striped searobins in Chesapeake Bight during autumn, 1966. Distribution of striped searobins according to depth and bottom water temperature during autumn, 1966.

GONAD DEVELOPMENT, MATURITY, AND SPAWNING

Maturation of the gonads began during the second spring or summer for both sexes, one year before reaching sexual maturity. Prior to development, the gonads consisted of transparent tubules about 1 mm in diameter. During development, the tubules increased in size and became opaque; the testes became white and the ovaries yellow-orange. Small eggs were visible under a magnification of 14X shortly after the start of gonadal enlargement. Maturation began in April and by November 100% of the yearlings showed signs of enlargement of the gonads. Gonadal development was apparently related to size of the fish. Yearlings that underwent early maturation were considerably larger than the mean length for their age group. Yearlings with enlarged gonads in April were longer than 200 mm and the majority of those which had not begun development by May were less than 185 mm.

All striped searobins were sexually mature by their third spring. During March and April the gonads of fish two years old and older enlarged until they occupied a major portion of the abdominal cavity. Gonads were running ripe from May through July, with the highest incidence of ripe fish occurring in mid-June. Fish were judged to be running ripe if slight pressure on the abdomen extruded milt or transparent eggs. Males and females ripened at about the same time. Fish obtained in August had completed spawning because the gonads were either spent or were recovering from the spent condition. Spent gonads were greatly reduced in volume. The recovering gonads were also reduced in volume but immature sex products occupied the anterior section of the gonads. Segments of the striped searobin population had slightly different spawning times. The estuarine samples obtained during April, 1966 and May, 1967 had a higher incidence of gravid and ripe fish than did the samples taken from continental shelf at the same time.

According to previous authors striped searobins from the northern part of the range also spawned during the spring and summer. Perlmutter (1939) obtained pelagic eggs, thought to be those of striped searobins, from May to July off Long Island. Wheatland (1956) collected eggs of this species in Long Island Sound during May and July. Sumner, et al. (1913) stated that in the southern New England region development of the gonads began in May and spawning occurred during the summer. Marshall (1946) found spawning extending from June to early August in New England waters.

Marshall also reported that yearlings, about 223 mm fork length, produced ripe eggs. However, 223 mm is closer to the mean length of age group II than to that of age group I in this study. Age group II averaged 221 mm prior to spawning while age group I averaged 172 mm. Thus it is likely that the mature fish were age two rather than one year old.

WEIGHT/LENGTH RELATIONSHIP

Linear plots of weights on lengths revealed that weight increased exponentially with length, fitting the formula: $\text{Log } W = \log a + b \text{ Log } L$. Log plots revealed no difference between the sexes in the weight/length relationship. Covariance tests (Mottley, 1941) were run to determine if the relationship changed significantly during the year (Table 6). The results indicated that all data taken prior to and during spawning could be pooled into one regression and all data taken after spawning could be pooled into a second regression. The former regression, representing 1095 fish, was: $\text{Log } W = -5.3371 + 3.1941 \log L$ and had a correlation coefficient of 0.9943. The latter regression, representing 288 fish, was: $\text{Log } W = -4.175 + 2.72 \log L$ and had correlation coefficient of 0.9768.

TABLE 6.

RESULTS OF COVARIANCE TESTS RUN BETWEEN SEASONAL SAMPLES.

	Feb-Mar 1966	April 1966	May 1966	Aug-Sept 1966	Nov-Dec 1966	March 1967	May 1967	June 1967
Feb.-March '66		NS	NS	S	S	NS	NS	NS
April '66	NS	-	NS	S	S	NS	NS	NS
May '66	NS	NS	-	S	S	NS	NS	NS
Aug-Sept. '66	S	S	S	-	NS	S	S	S
Nov-Dec '66	S	S	S	NS	-	S	S	S
March '67	NS	NS	NS	S	S	-	NS	NS
May '67	NS	NS	NS	S	S	NS		NS
June '67	NS	NS	NS	S	S	NS	NS	-

NS - Nonsignificant

S - Significant

Figure 12 shows that the slope of the regression for fish in the pre spawning and spawning condition was much steeper than that for fish in the post spawning condition. Fish were significantly more robust before completion of spawning than after spawning. The condition of the gonads thus had an important effect on the weight/length relationship.

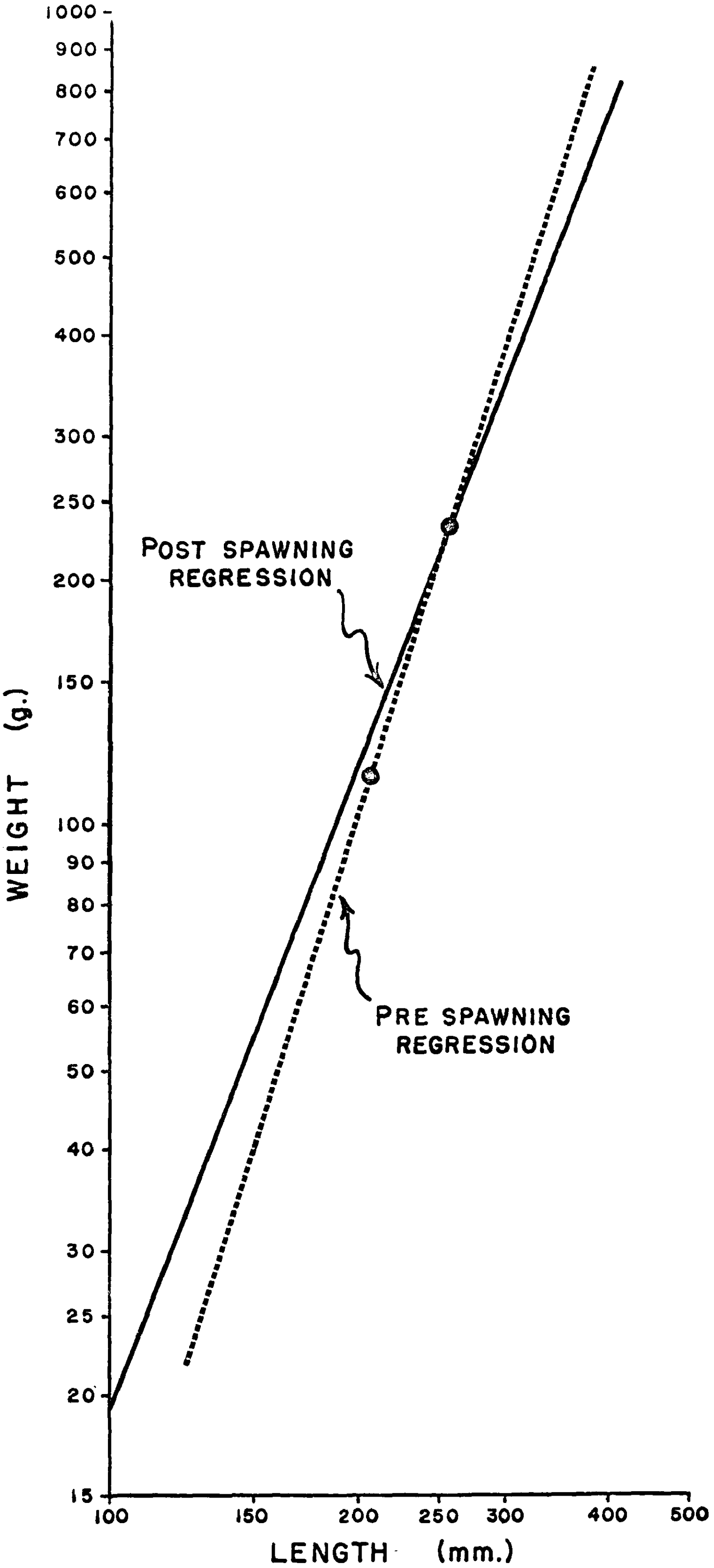
RELATIVE CONDITION

The coefficient of condition, based on the generalization that weight of a fish is a function on the cube of the length, $K = 1000W/L^3$ (Hile, 1936), failed to demonstrate the change in the weight/length relationship exhibited by the regressions (Fig. 12). K was computed for each age group during each of the sampling periods. K for each of the age groups increased during the year. Apparently the increase in length during the year masked the change in robustness resulting from the condition of the gonads. To illustrate the effect of spawning, the relative condition factor derived by Le Cren (1951) was used. Relative condition (K_n) is based on the relationship of the observed weight of a particular length group (W) to the weight predicted from the weight/length regression for the length group ($\hat{W}$) so that $K_n = W/\hat{W}$. The relative condition factor demonstrates all changes in condition not dependent on length.

Relative condition was computed for fish in pre spawning and spawning condition. This group was chosen because it represented the greater number of fish and the greater time interval. The fish were divided into classes of 10 mm fork length and relative condition was computed for each class (Fig. 13). The observed weight of each length class was obtained from the average weight of the fish within the 10 mm increment. The average length in the 10 mm increment was used to calculate the predicted weight.

Fig. 12

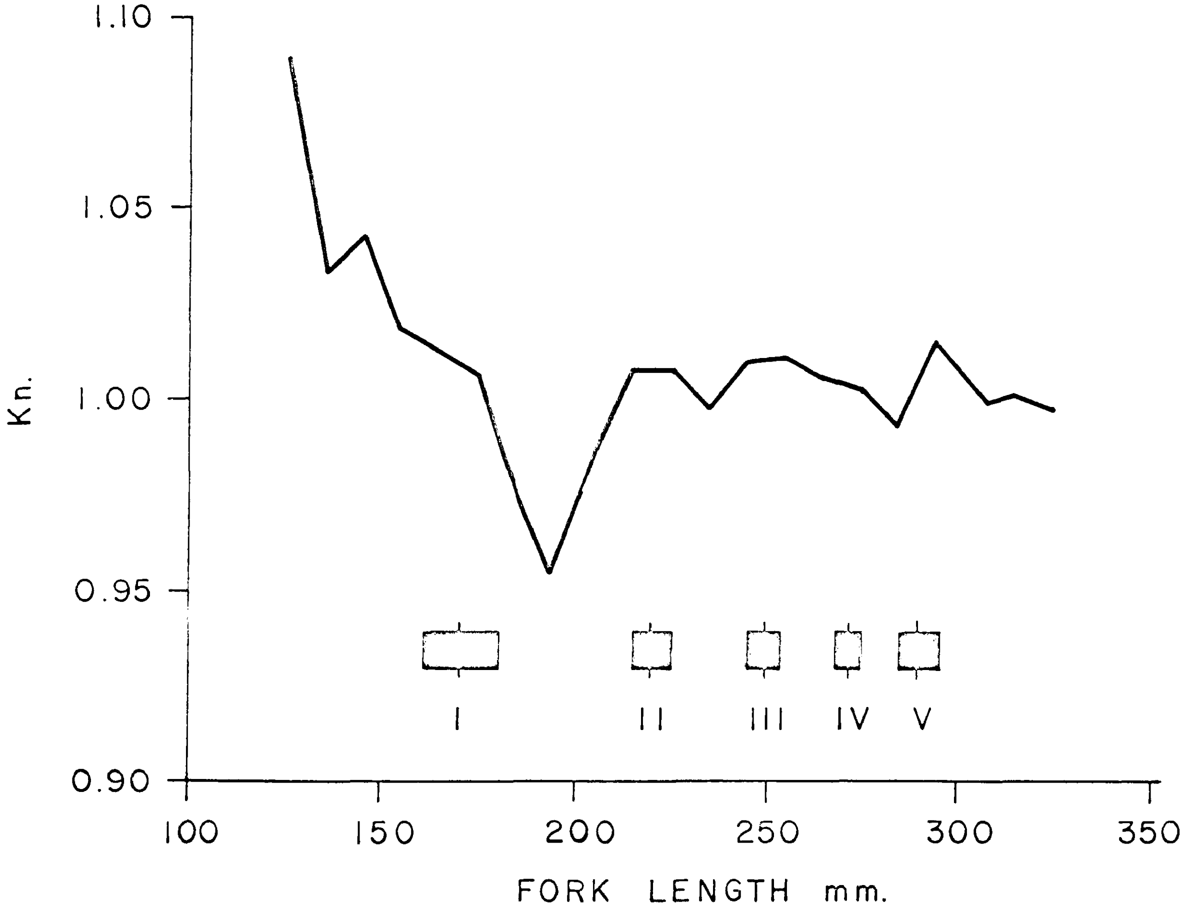
Weight/length relationship for striped searobins in pre spawning condition and in post spawning condition.


1000
900
800
700
600
500
400
300
250
200
150
100
90
80
70
60
50
40
30
25
20
15
WEIGHT (g.)
POST SPAWNING REGRESSION
PRE SPAWNING REGRESSION
100
150
200
250
300
400
500
LENGTH (mm.)

K_n declined sharply between 125 mm and 194 mm and then climbed to a value slightly above unity at 214 mm. After 214 mm, fluctuations were slight. Two peaks were formed at 254 mm and 294 mm. Evidently the fish grew disproportionally more in length than in weight between 125 mm and 194 mm. The increase in robustness between 194 mm and 214 mm may be attributed to gonadal development. The peak between 214 mm and 225 mm corresponded to the mean length of age group II prior to spawning. The second and third peaks coincided with the mean lengths of age groups III and V prior to spawning. Age group IV was only vaguely indicated by a change in the slope between 264 mm and 284 mm. The above relationship of high K_n values with gonadal buildup lends support to Pantulu's (1963) statement that the number of 'peaks' and 'valleys' in the relative condition curve may be an index of the number of spawnings during the life of the fish. Thus relative condition may be an indicator of the length of a fish at sexual maturity and length at each succeeding age.

Fig. 13

Relative condition (Kn) for striped searobins in pre spawning condition.


1.10
1.05
1.00
0.95
0.90
Kn.
100
150
200
250
300
350
FORK LENGTH mm.
I
II
III
IV
V

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