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Age and Growth of the Northern Puffer, Sphoeroides maculatus (Bloch and Schneider)

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AGE AND GROWTH OF THE NORTHERN PUFFER,

<u>SPHOEROIDES</u> <u>MACULATUS</u> (BLOCH AND SCHNEIDER)

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ABSTRACT

The annuli on vertebral centra of the northern puffer, *Sphoeroides maculatus*, were shown to be true year marks. Age groups 0 to V were found in 1128 specimens collected from Chesapeake Bay in November 1969 and from April through November 1970. Females were significantly larger than males at each age. Most of the growth in length took place during the first growing season from June through October. Sexual maturity was reached at age I. The peak of spawning activity occurred in June and July. Spent fish were found to be heavier than gravid fish of the same length.

AGE AND GROWTH OF THE NORTHERN PUFFER,

SPHOEROIDES *MACULATUS* (BLOCH AND SCHNEIDER)

INTRODUCTION

The northern puffer, Sphoeroides maculatus (Bloch and Schneider), occurs on the Atlantic Coast of North America, from Newfoundland to Flagler County, Florida (Shipp and Yerger, 1969). It is the only tetraodontid which maintains a large breeding population along the middle Atlantic Coast; other species occur there as strays. The northern puffer comprises a large part of the spring and fall commercial catches in Chesapeake Bay. During the past eight years total annual landings from Chesapeake Bay have ranged from one to twelve million pounds. The steady northward progression of commercial landings in the spring from North Carolina into Chesapeake Bay and then the southward progression of catches in the fall suggests an annual migration along the coast.

Food habits, larval development, and weight-length relationships of puffers caught off New Jersey were presented by Welsh and Breder (1922). The taxonomy of the northern puffer was reviewed by Shipp and Yerger (1969). This paper describes a technique for determining the age of the northern puffer, and reports the rate of growth, weight-length relationship, age at sexual maturity, and time of spawning.

MATERIALS

Age and growth determinations were based on 123 fish collected during November 1969, and 1005 fish collected from April through November 1970. Fish were collected from lower Chesapeake Bay, including the mouths of the York and Rappahannock rivers, and Mobjack Bay. It is assumed that northern puffers represent a homogenous population in the area sampled. Commercial pound nets and haul seines were the principle source of fish. Other gear used were a push net, beach seine, trawls, and commercial crab pots.

Total length was measured from the tip of the snout to the center of the flared caudal fin. Weights of fish with a distended ventral sac were not taken because of the retention of water and air in the sac. Fish of both sexes were assigned to the following categories by gross inspection of the gonads: immature, gravid, ripe, and spent.

AGE DETERMINATION

Vertebrae and the saccular otoliths exhibited distinct growth marks, although only the growth marks on vertebral centra were found to be both distinct and consistent. Growth marks on otoliths were variable and ambiguous and could not be distinguished on otoliths from the largest fish because of reorientation in otolith growth. Cleithra, opercles, jaw bones, and fin rays exhibited no discernable growth marks.

A segment of the vertebral column containing vertebrae #2-#7 was removed and treated in the following manner. The segment was disarticulated and stained in a solution of 4-8% KOH and Alizarin Red S. KOH removed adherent flesh and the stain reduced glare from the centrum surface and increased the contrast between bands of growth. Warming unstained vertebrae in an oven at 100°C until they were slightly charred also increased contrast. The staining techniques described by Hollister (1934), Galtsoff (1952), Daiber (1960), and La Marca (1966) were attempted for differentially staining the growth marks, though none of these procedures were effective. Vertebrae of the northern puffer have deeply concave centra; therefore, in order to measure distances on the centra it was necessary to slice them longitudinally. A vertebra with the neural spine removed was placed, dorsal surface up, in a V-shaped slit cut into a block of wood. The vertebra was sliced lengthwise with a hand-held, single-edged razor blade. Vertebrae #3 and #4 from each fish were sliced, while vertebrae #2 and #5-#7 were left intact. Measurements were taken with an ocular micrometer in a dissecting microscope at 15X magnification under reflected light and were made on vertebra #4. Marginal width, the distance between the last annulus and the centrum edge, was measured on the posterior centrum face.

Vertebrae have been used to determine age in such diverse forms as elasmobranchs (Haskell, 1949; Ishiyama, 1951; Daiber, 1960; La Marca, 1966), scrombrids (Aikawa, 1938; Aikawa and Kato, 1950; Galtsoff, 1952), and catfishes (Marzolf, 1955; Hensel, 1966). The seasonal marks on black bullhead vertebrae are narrow, translucent bands alternating with broad, opaque bands (Lewis, 1949). These translucent bands or annual rings were associated with a depression in the centrum surface. However, narrow dark annual bands on the centra of channel catfish were usually associated with a ridge (Appelget and Smith, 1951).

Growth marks on vertebrae of the northern puffer form distinct steps on the centrum surface. These circular steps are best seen when the vertebra is held on end at a 45° angle from the vertical and is viewed looking down on the centrum face. Under magnification in reflected light the surface texture of the centrum within the narrow step appears coarser and more opaque than the rest of the centrum. On the inner side of each step is a narrow, dark, translucent ring. The step and narrow dark band form a continuous ring on the centrum and constitute the annulus. Broad opaque bands with uniform surface texture lie between the narrower annuli. Together these features constitute one year's growth. Age determination was based on the number of annuli. There was excellent agreement among vertebrae #3-#7 in the number and position of annuli and in less than 1% of the fish age could not be assigned because counts of annuli did not agree.

Age could not be determined in 7% of the fish because of false annuli, crowding of annuli at the centrum edge, and changes in surface texture of centra in older fish. False annuli appeared as faint, dark bands which were not associated with a distinct step. Another extraneous mark was a shallow depression which formed a continuous ring on the centrum but was not a definitive step. This feature was found on black bullhead vertebrae (Lewis, 1949). False annuli, if present, were usually adjacent to true annuli. False annuli were most frequent within the first growth zone (Fig. 1). With increasing age annuli became crowded at the centrum edge (Fig. 2) and the surface texture of centra became more coarse and irregular, especially near the edge (Fig. 3). Yet there was no indication that annuli at the centrum edge were being obscured by crowding in the 58 three-year-olds and 17 four-year-olds examined.

The annular step on vertebrae of the northern puffer met four of Hile's (1941) criteria for validating the annulus as a true year mark. First, a single annulus was formed each year. No annuli were present on the vertebrae of yearlings in April and early May. Late in May a distinct ring became visible at the outer edge of the centrum (Fig. 4). Annulus formation began in May when growth resumed in both yearlings and older fish (Fig. 5). By July all yearlings had formed annuli, but many older fish had not. The

Figure 1. Vertebrae from a two-year-old northern puffer captured in August showing a false annulus adjacent to the first annulus.

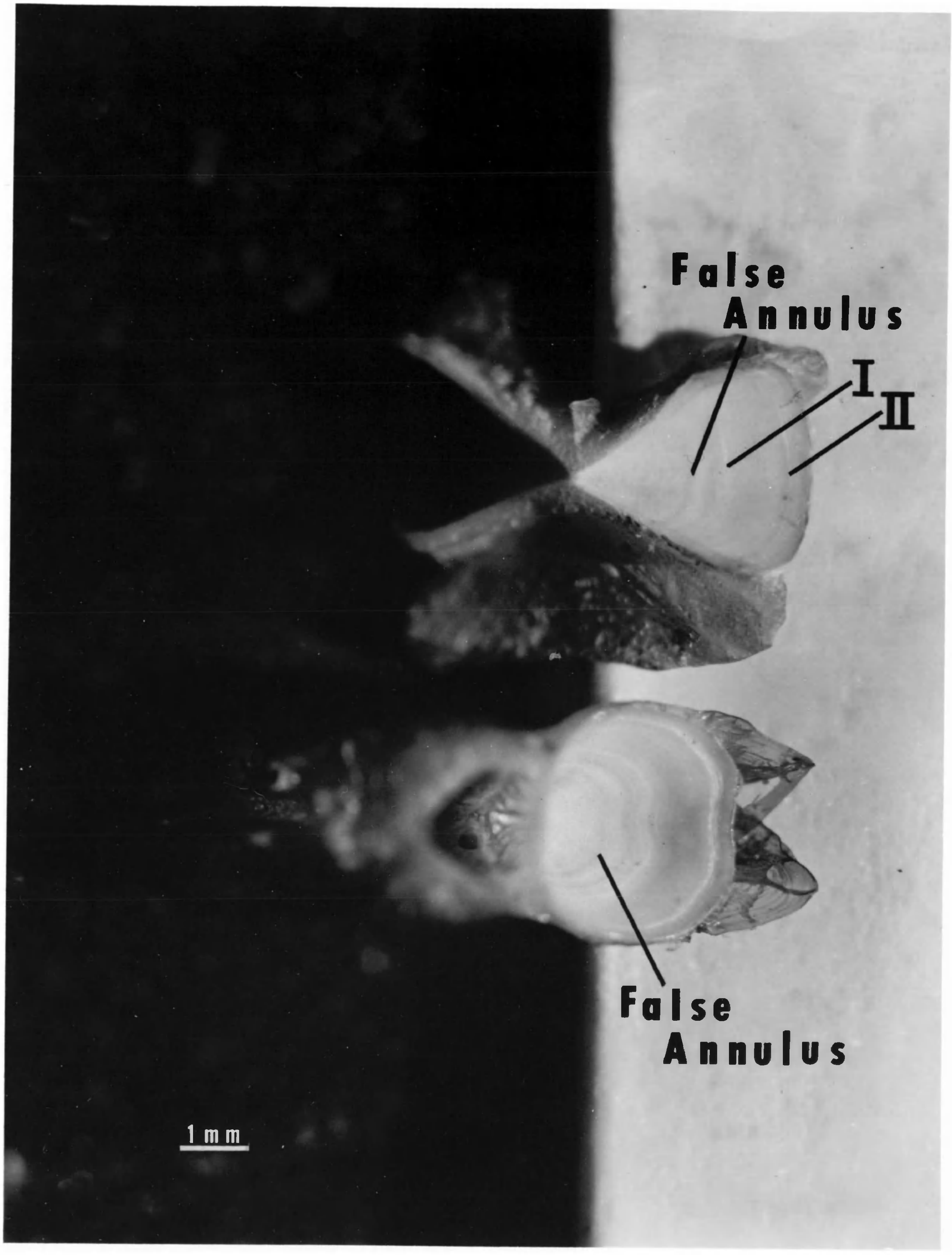

False Annulus
I
II
False Annulus
1 mm

Figure 2. Vertebrae from a five-year-old northern puffer captured in November 1969 on which the third annulus appears double because of the expanded step.

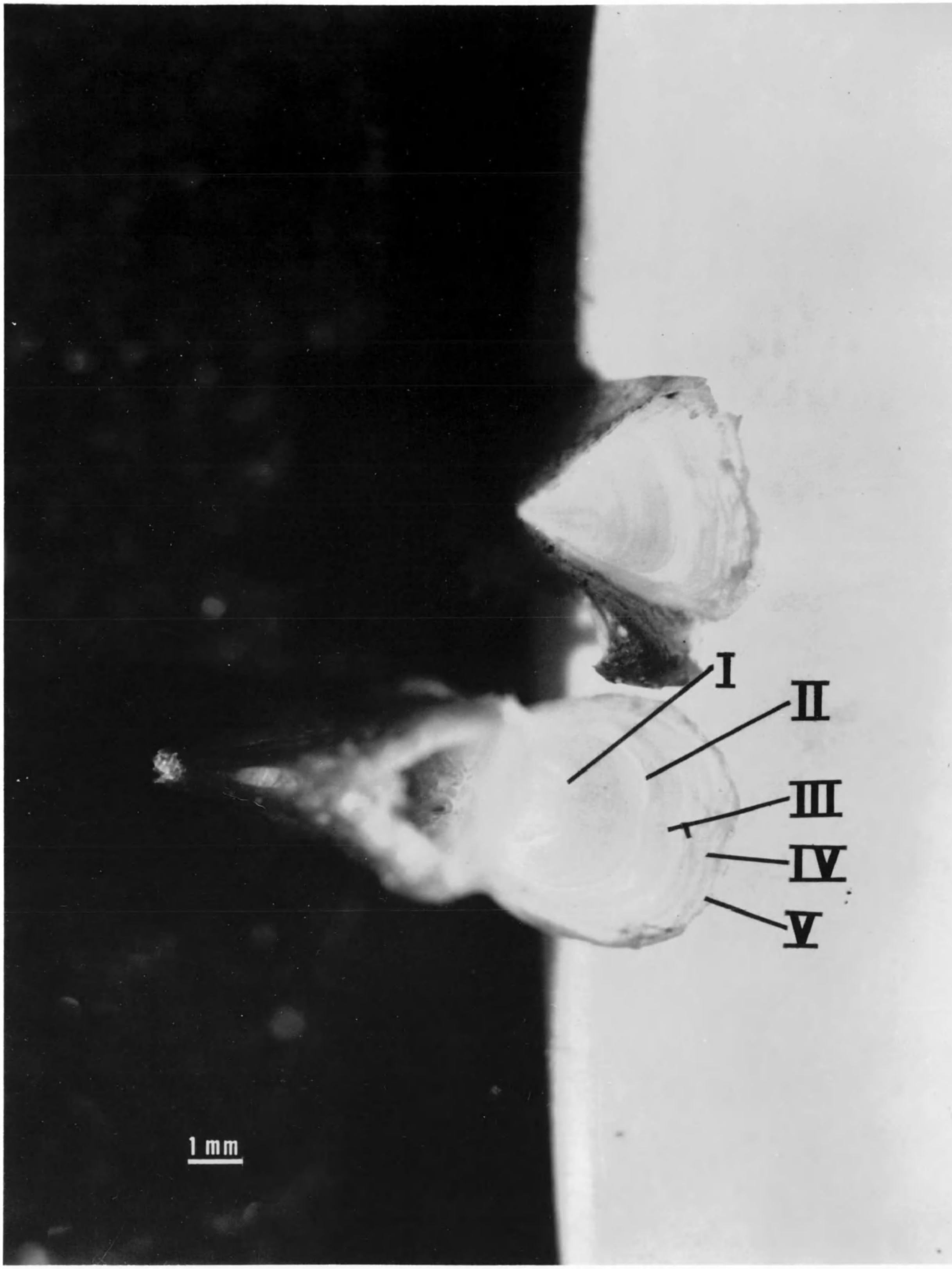

I
II
III
IV
V
1 mm

Figure 3. Vertebrae from a three-year-old northern puffer captured in June.

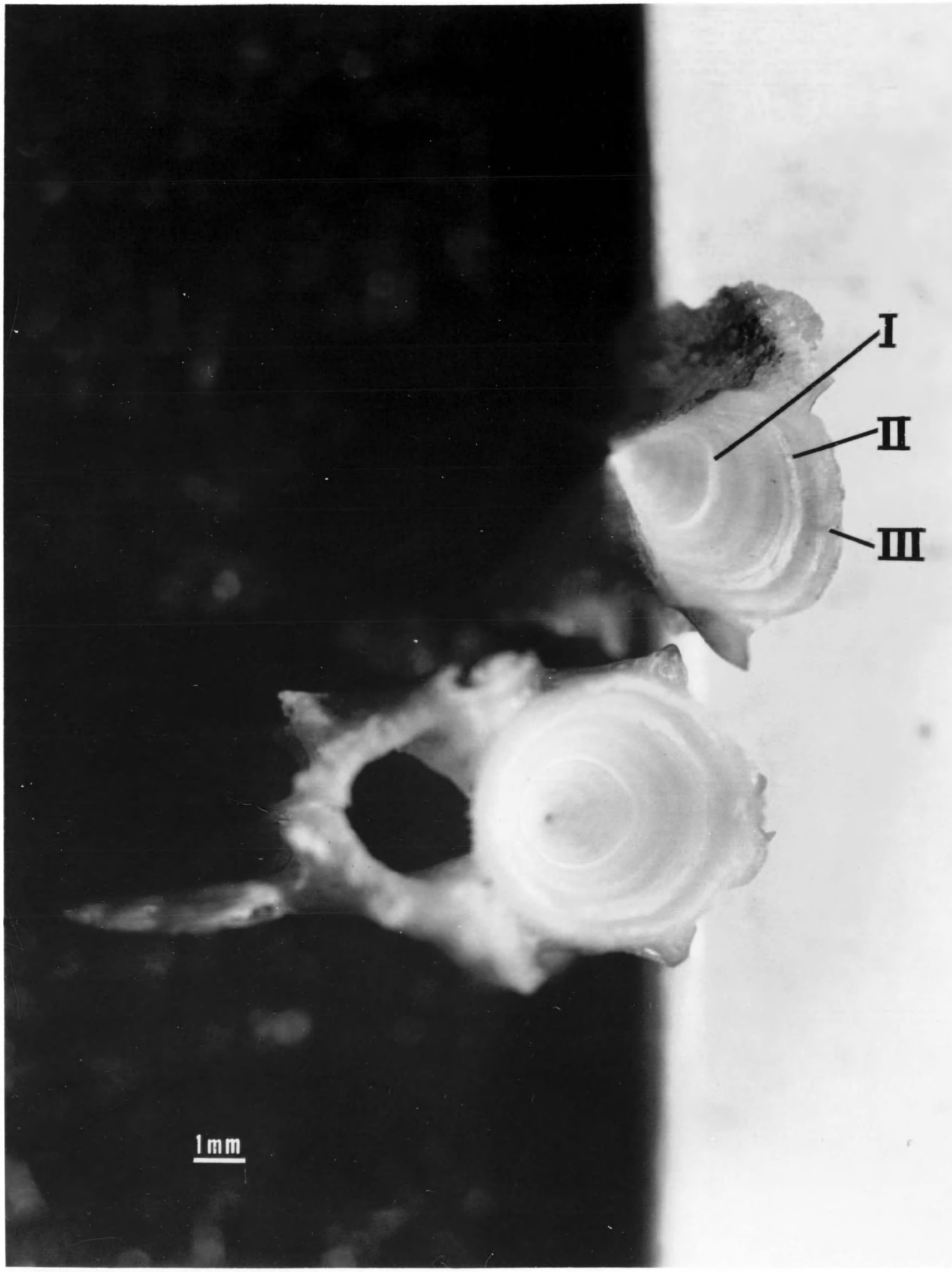
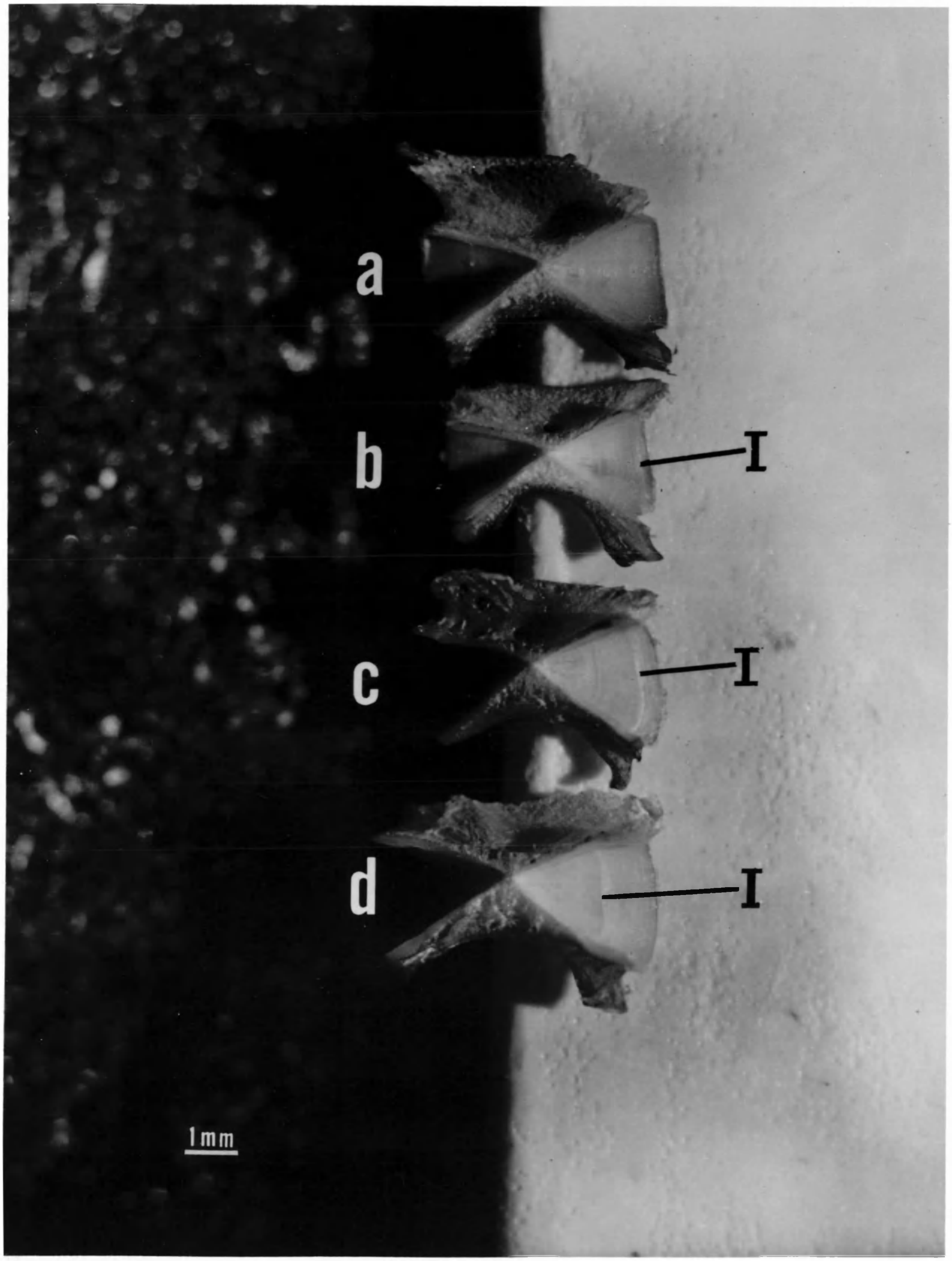

I
II
III
1mm

Figure 4. Vertebral sections of the northern puffer showing the increase in marginal width after formation of the first annulus: (a) young-of-the-year female captured in November, (b) female captured in May with the first annulus just visible at the centrum edge, (c) male captured in September, (d) male captured in November 1970.


a
b
I
c
I
d
I
1mm

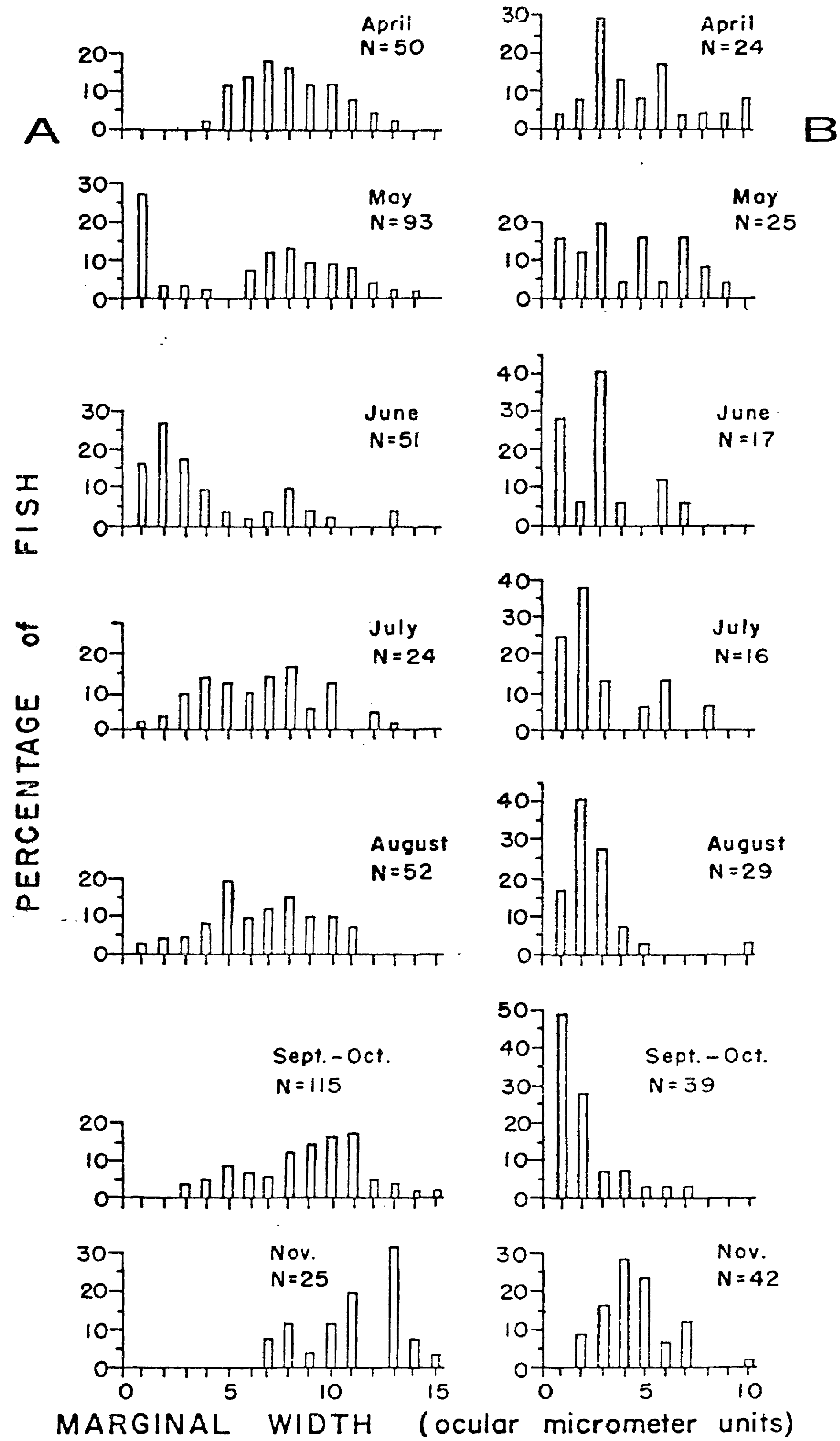


Figure 5. Frequency distributions of marginal widths of vertebral centra from the northern puffer: (A) with a single annulus, (B) with two annuli.

greatest percentage of fish with the second annulus at the centrum edge occurred in September. The formation of a definitive annulus on the vertebral centrum may take longer than on scales and otoliths because vertebrae are larger and structurally more complex than either scales or otoliths. Yasuda (1940) showed that annuli on the vertebrae of Scombrops sp. were formed 1.5 months later than on the otoliths. In older fish the length of time for annulus formation may be extended further because of the decreasing annual addition to vertebral length as body length increments decrease.

A second criterion was met by the agreement of measured lengths with length at age as calculated by the Lee method (Lagler, 1956) (Table 1). Mean weighted lengths at age coincided closely with the measured length for fish one year younger because the majority of fish were taken in the fall and late spring after the previous growing season and before the start of the next. Total vertebral length and the distance between annuli across the center of the vertebra were used to calculate length at age. These measurements were made along the shortest straight line connecting the midpoints of the annuli and the centrum edge (Fig. 6). The distance between annuli could not be measured with certainty in 5% of the fish because the annular step was expanded into a broad, opaque shelf without a distinct endpoint (Fig. 7). The plot of vertebral length on total length was linear and the regression describing this relationship was $X = 27.52 + 3.28\ Y$ with a correlation coefficient of 0.9827 where X is total length in millimeters and Y is vertebral length in ocular micrometer units

Table 1. Calculated total length at end of each year of life of male and female northern puffer.

Age group	Number of fish		Mean Length at capture (mm)		Mean total length at end of year of life							
					1		2		3		4	
					M	F	M	F	M	F	M	F
I	190	315	181	200	133	151	---	---	---	---	---	---
II	88	99	204	235	125	141	183	208	---	---	---	---
III	22	32	224	256	125	128	178	194	208	237	---	---
IV	7	9	236	274	146	137	185	194	213	238	227	259
Weighted Mean Length					131	147	182	204	209	237	227	259
$S_x\ t_{.05}$					± 2.5	± 2.2	± 3.5	± 4.2	± 6.8	± 6.1	± 18.4	± 15.6
Length Increment					131	147	52	58	27	33	19	22
Calculated Length Range					93-191	90-203	140-231	161-260	172-246	197-279	201-250	236-289
Measured Length Range					120-225	125-259	161-232	181-264	199-256	223-292	211-263	246-295

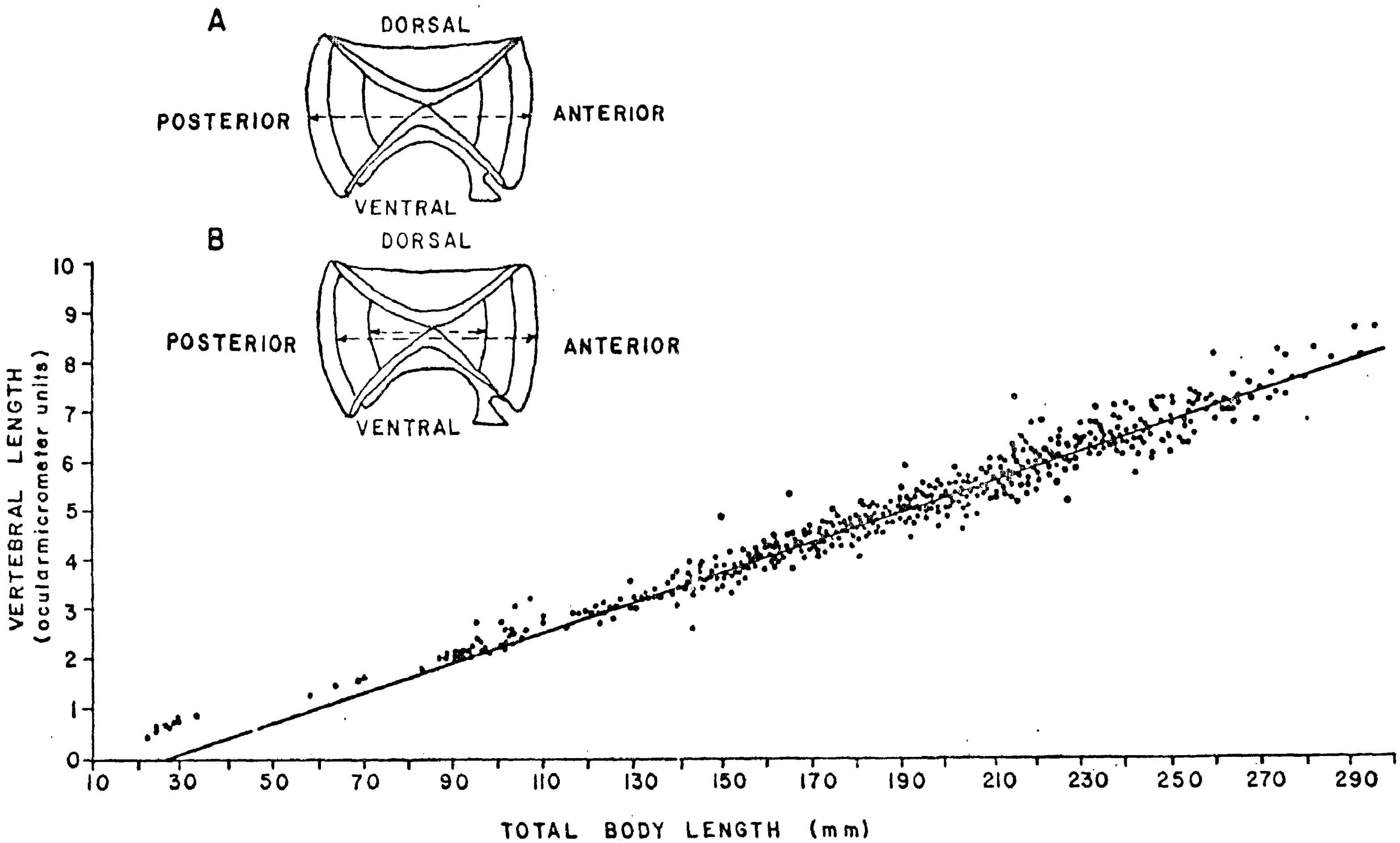
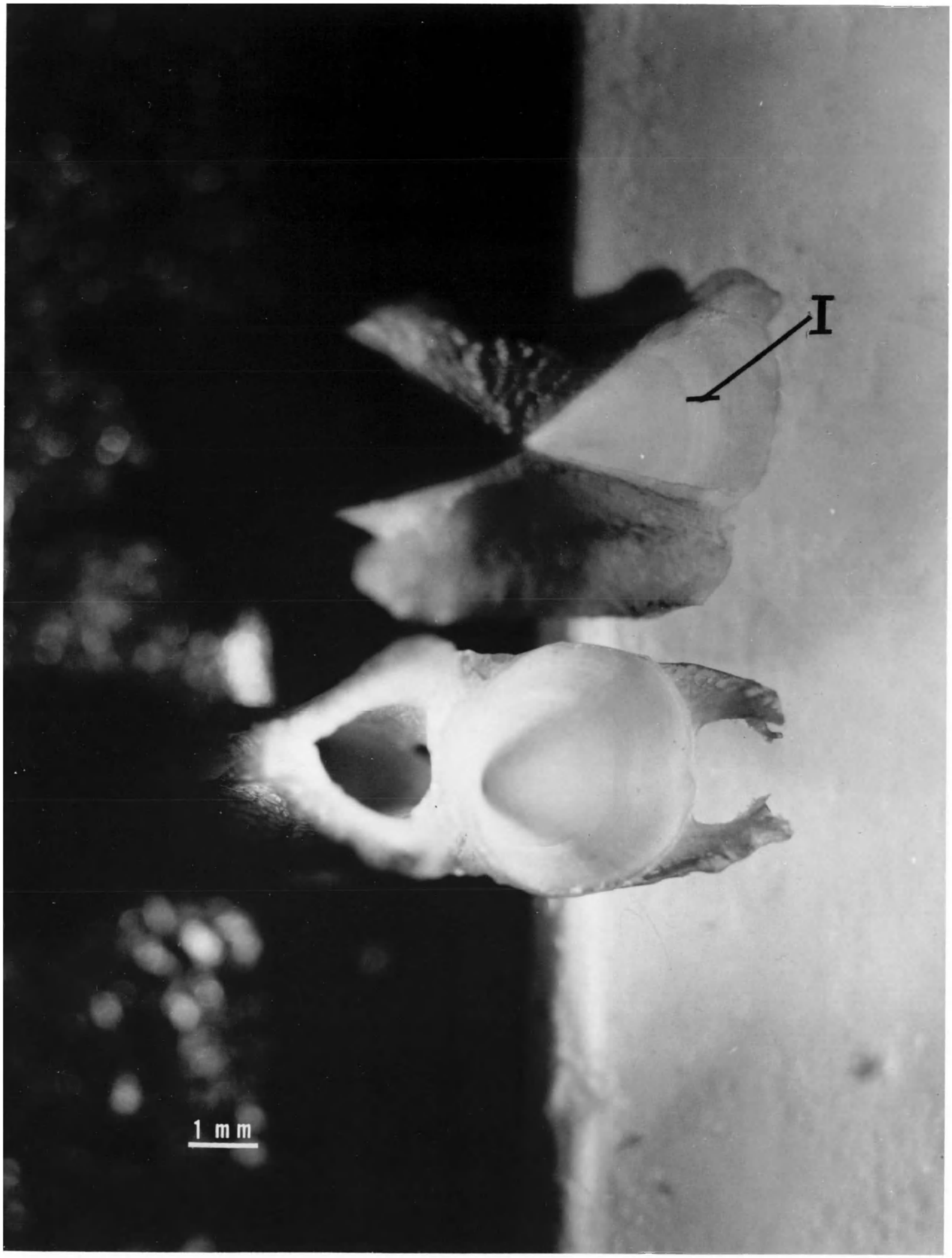


Figure 6. The relationship between vertebral length and total body length (dashed lines on the diagrams of vertebral sections indicate dimensions used in calculating length at age: A) vertebral length, B) distance between annuli across center of vertebra).

Figure 7. Expanded annular step on the vertebrae from a one-year-old northern puffer.


I
1 mm

(Fig. 6). All calculations were done with an IBM 1130 computer.

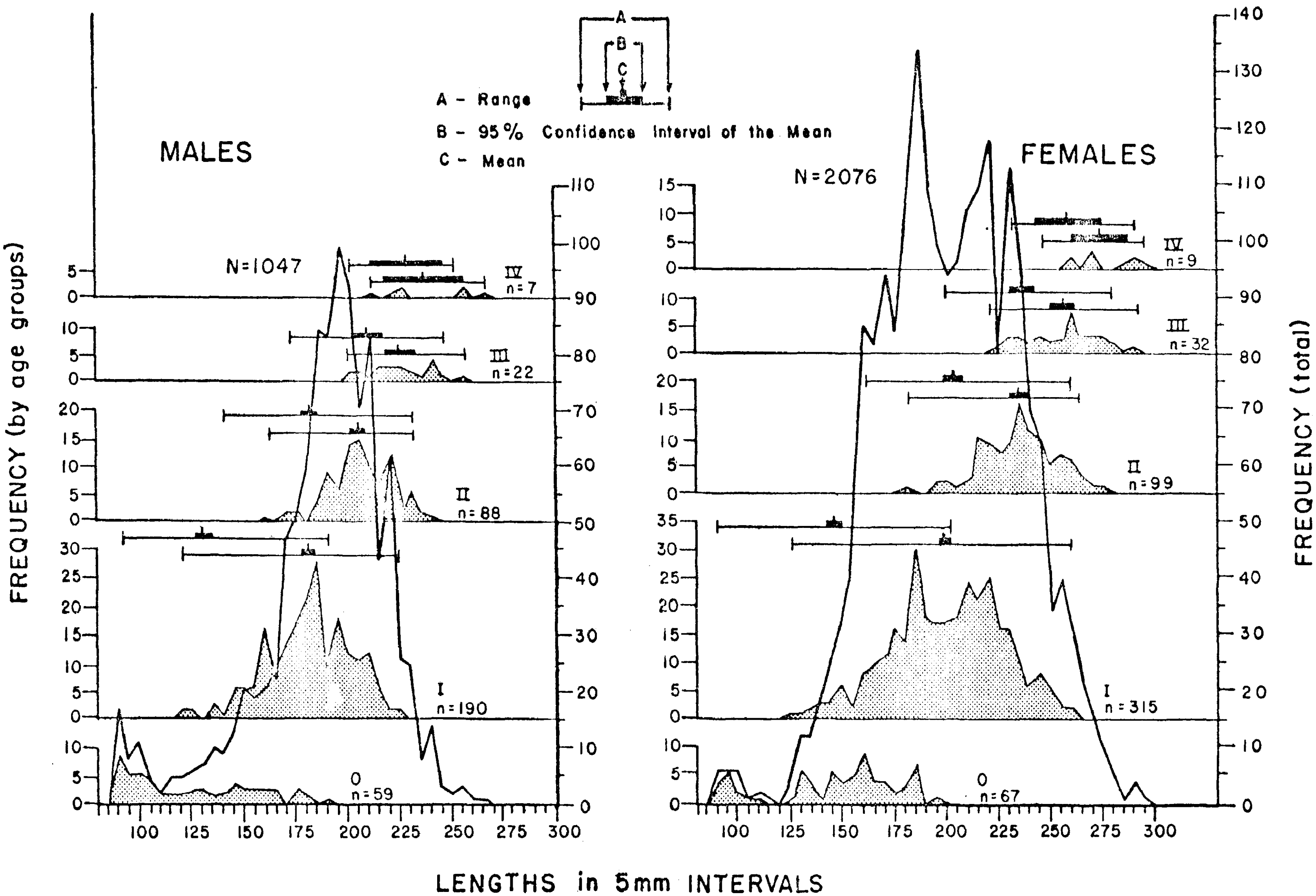
The third and fourth criteria were met by the correspondence of peaks in the length-frequency plots for each age group with peaks in the overall plot, and by the regular increase in number of annuli with increasing body length (Figs. 8 and 9). The overlap among age groups was caused by early summer annulus formation in yearlings, the extended period of annulus formation in older age groups, and the wide range of lengths attained in the first growing season. The bimodal distribution of females in age group I was caused by the great number of fish larger than 210 mm taken in April and May from culled and sorted commercial pound net catches. Throughout the rest of the sampling period the majority of fish came from unculled pound net and haul seine catches.

GROWTH

Young-of-the-year were first collected in June from shallow eel grass beds (Zostera marina) in the York River and averaged 28 mm in length. In the fall of 1970 young-of-the-year (as determined from vertebrae) ranged from 88-184 mm (Table 2). The November sample came from a sorted and culled pound net catch and therefore, 153-193 mm is not a true indication of the range of lengths exhibited by puffers after the first full growing season. A better estimate is 83-195 mm which is the range in length of yearlings without an annulus taken in April and May. These fish were taken from trawl and unculled pound net catches. The length range, 83-195 mm, corresponds closely to the calculated

Figure 8: Length-frequency distributions of male northern puffer (shaded polygons for each age group, unshaded polygon represents fish from the entire 1970 collection, N = 1047; distribution characteristics for each age group are shown above polygons with calculated values above measured values).

Figure 9: Length-frequency distributions of female northern puffer (shaded polygons for each age group, unshaded polygon represents fish from the entire 1970 collection, N = 2076; distribution characteristics for each age group are shown above polygons with calculated values above measured values).



A - Range
B - 95% Confidence Interval of the Mean
C - Mean
MALES
N=1047
FEMALES
N=2076
IV n=7
III n=22
II n=88
I n=190
0 n=59
IV n=9
III n=32
II n=99
I n=315
0 n=67
FREQUENCY (by age groups)
FREQUENCY (total)
LENGTHS in 5mm INTERVALS

Table 2. Length-frequency of young-of-the-year northern puffer.

Total Length (mm)	Jun	Jul	Aug		Sep		Oct		Nov		Dec
	Unknown	Unknown	M	F	M	F	M	F	M	F	Unknown
18- 22	1										
23- 27	6										
28- 32	3										
33- 37	1										1
38- 42											
43- 47											
48- 52											
53- 57											
58- 62											
63- 67		1									
68- 72		2									
73- 77											
78- 82											
83- 87											
88- 92		2			5	4					
93- 97					2	6					
98-102		3	1		4	2					
103-107					1	1					
108-112			1			1					
113-117					1	1					
118-122					1						
123-127					1						
128-132					1	3					
133-137					2	3					
138-142					2	3					
143-147					1	4	1	1			
148-152						1					
153-157											
158-162									1	1	
163-167						1			1		
168-172										2	
173-177										1	
178-182										1	
183-187										2	
N	11	8	2		21	30	1	1	2	5	1

range of lengths at age I for all fish (Table 1). In December a 37 mm juvenile was found swimming at the surface near the mouth of the York River. Fish of this size have been collected in the fall on the east side of Chesapeake Bay. It is not known whether these small fish were hatched late in the season in Chesapeake Bay or were spawned to the north and entered the Bay in the course of their southward migration.

The closeness of the mean calculated and measured lengths of age groups III and IV indicates that little additional growth takes place after the fourth year of life (Figs. 8 and 9). Puffers appear to have a life span of at least five years.

The von Bertalanffy mathematical expression of growth as outlined by Ricker (1958) closely fit the weighted mean length at age for age groups I to IV (Fig. 10). The weighted mean length for age group I was calculated from age groups II, III, and IV because commercial gear is selective for the larger fish of age group I. At all ages females were larger than males and appeared to grow at a faster rate. Covariance tests on the Ford-Walford lines for males and females indicated a significant difference in the lengths attained by males and females in the first growing season but the difference in growth after the first season was not significant at the 5% level (Ricker, 1958; Mottley, 1941; Snedecor, 1956). The decrease in yearly increment of length for males and females was similar (Fig. 10).

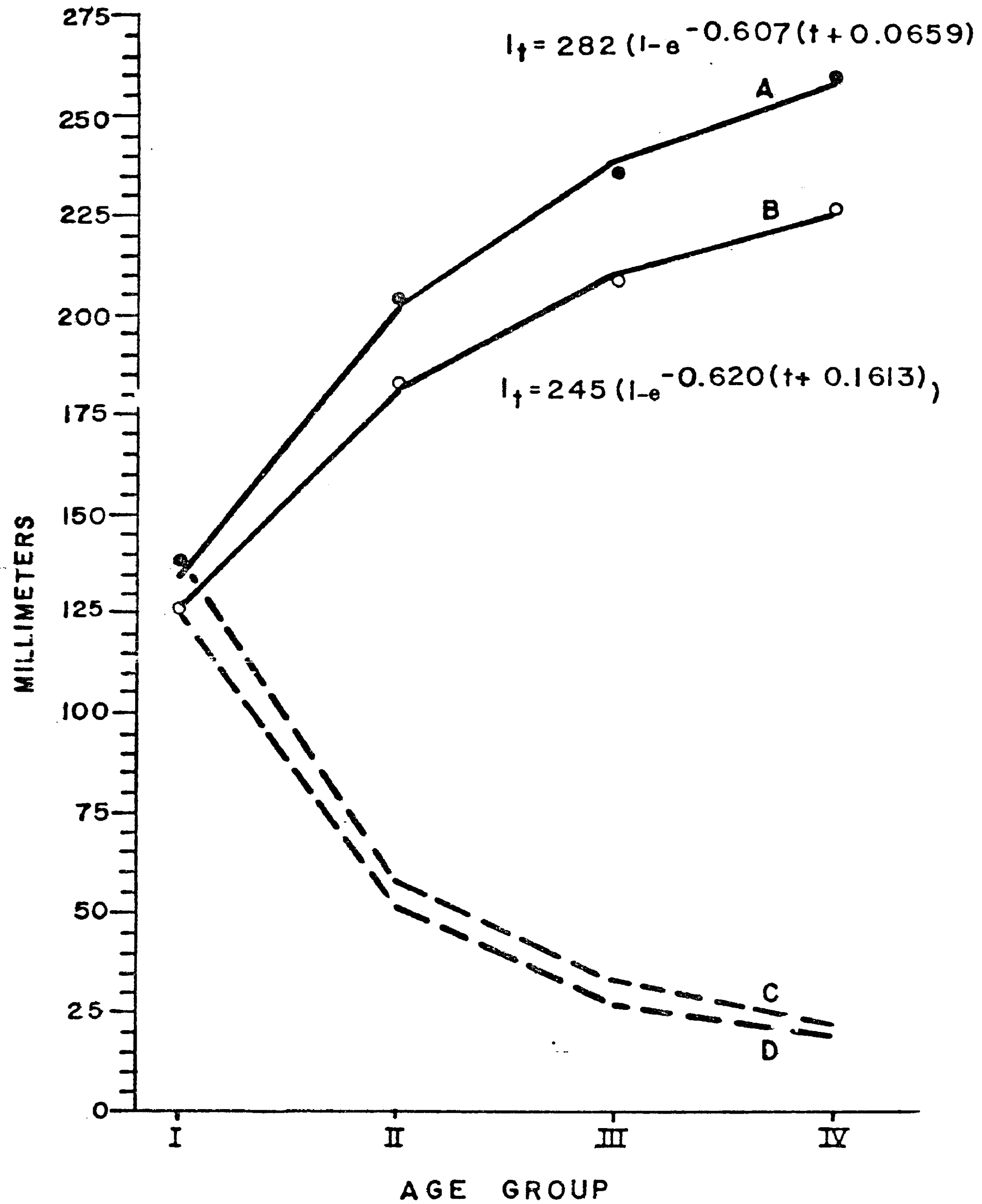


Figure 10. Growth curves of female (A) and male (B) northern puffer fitted by the von Bertalanffy growth equation and plots of increments in length of females (C) and males (D) (circles represent calculated lengths).

WEIGHT-LENGTH RELATIONSHIP

Weight increased exponentially with increasing length. Logarithmic functions describing the weight-length relationship according to sex and gonadal condition were calculated (Fig. 11). In both sexes spent puffers were heavier than gravid puffers of the same length. Covariance tests (Mottley, 1941) indicated a significant difference in weight between spent and gravid males at the 5% level but the difference between spent and gravid females was not significant. A considerable increase in muscle and liver tissue was observed throughout the growing season but not quantified. In the fall fish appeared more robust and had larger livers than in the spring.

GONADAL DEVELOPMENT AND SPAWNING

Gross structural differences between testes and ovaries became apparent in young-of-the-year by early September. Both sexes reached sexual maturity at the start of the second growing season. In April the gonads of fish as small as 88 mm contained either milt or ova. Running ripe males were first obtained during the last week of May and remained running ripe through the first week of July. Females were gravid during May but from June through the first week of July they were found in all three conditions, gravid, ripe, and spent. Few running ripe females were taken. Males remain running ripe longer than females and may spawn a greater number of times. By late July gonads of the majority of fish taken from the mouth of the York River, Mobjack Bay, and

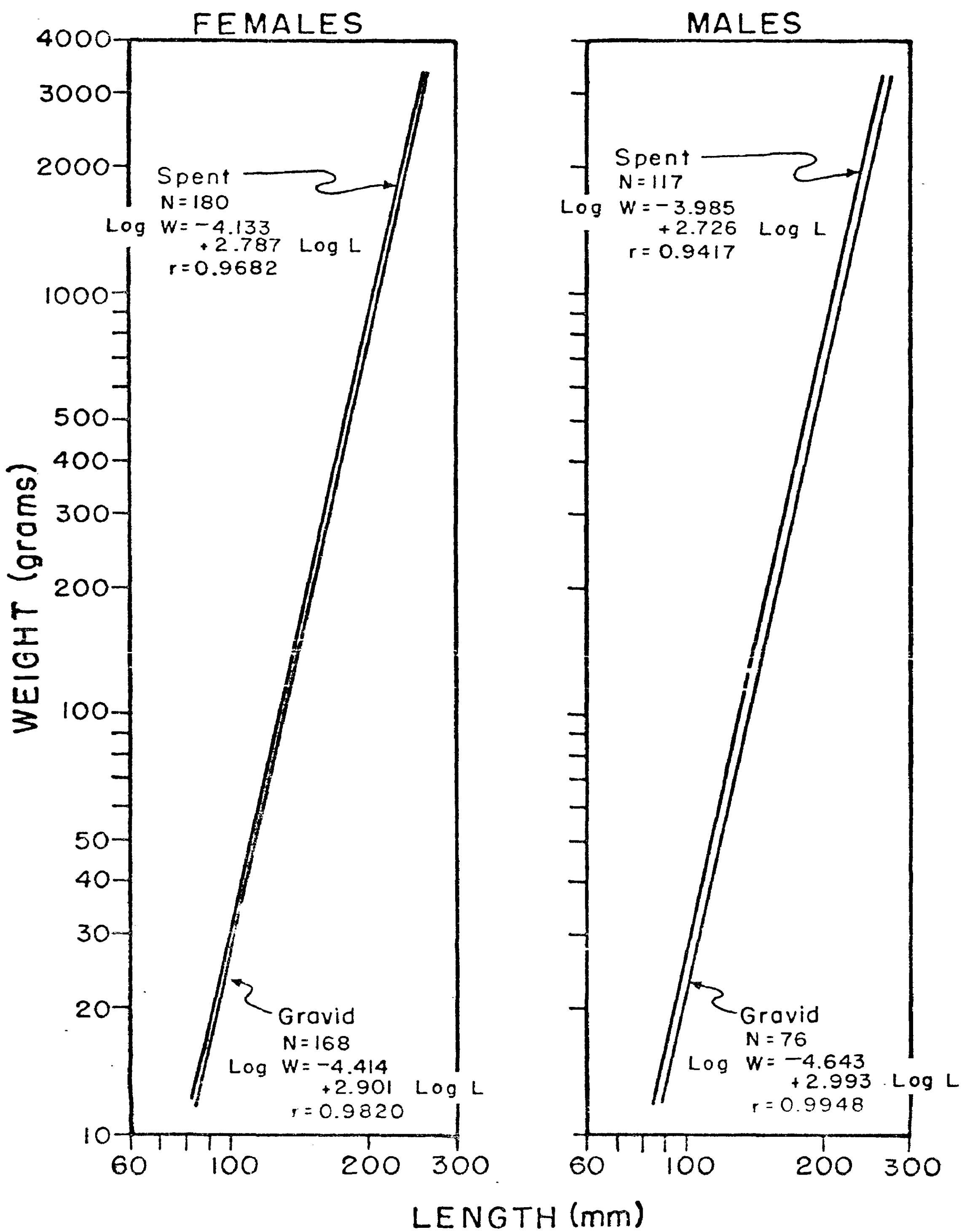


Figure 11. Weight-length relationships of spent and gravid northern puffers of both sexes.

lower Chesapeake Bay were spent and in various stages of recovery. However, males taken from the mouth of the Rappahannock River in mid-August were still running ripe and many females were gravid. Welsh and Breder (1922) took ripe females along the New Jersey coast from July 30th to August 27th. Wheatland (1956) reported the northern puffer spawning from late May until August in the area of Long Island Sound. It appears that the time and duration of spawning of the northern puffer varies within Chesapeake Bay and along the middle Atlantic Coast. By September gonads of puffers from lower Chesapeake Bay were fully recovered and no developing gametes were visible during October and November.

Males and females were found in equal numbers only in May and November. Throughout the summer and early fall females were consistently taken in greater numbers. Males were taken in the lowest numbers during the peak of spawning in June and July. The differences observed in the relative numbers of males and females caught during the season may have been related to the reproductive behavior.

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