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Growth patterns on otoliths from young silver hake, Merluccius bilinearis.

by

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The central area of silver hake otoliths often shows considerable variation, making interpretation of the first winter ring difficult. Also early growth patterns differ somewhat between hake from southern New England and the Gulf of Maine. The results of studies of the hake otolith and the interpretation of various zones are reported herein.

Data Collection

Material and data used in this report were obtained during seasonal survey cruises of the Albatross IV, the Bureau of Commercial Fisheries research vessel of the Woods Hole Laboratory, Massachusetts, and from the Dolphin, the Bureau of Sport Fisheries vessel of the Sandy Hook Laboratory, New Jersey. Gear used on the Albatross IV included otter trawls, Isaacs-Kidd midwater nets, and plankton nets. In every case the otter trawl codend was lined with 1/2-inch mesh. The Isaacs-Kidd midwater net was lined with 3/8-inch net and had a fine mesh codend of 1 mm square aperture. Plankton tows were made with various size nets, all with less than a 1 mm mesh aperture. Collections from the Dolphin were made using a modified Cobb midwater net reduced to one-third the size of the standard net, the codend lined with 1/4-inch mesh. Dolphin collections were only from southern New England, while the Albatross IV ranged on the continental shelf from the Hudson Canyon northward to the Bay of Fundy. Each survey cruise of the Albatross IV required about one month to complete and entailed about 175 stations scattered over the Gulf of Maine and southern New England. An average of about 6,000 silver hake of all sizes was caught during each of the survey cruises.

Otoliths were stored in 60% glycerine with thymol or 4% formalin added as a preservative. The otoliths were examined by placing them on a black surface and illuminating the broad surface of the otolith. In this manner the winter, or hyaline growth, appeared as darkened rings and summer, or opaque growth, appeared white.

A stereoscopic microscope with a magnification of 7X was used, containing an ocular micrometer disc for measuring. Cross-sections of fractured otoliths were examined; however, no particular advantage was derived from this method, and since many measurements were contemplated, examination of whole otoliths was preferred.

Otolith - Fish Length Relationship

In Figure 1, the lengths of otoliths for fish up to 65 cm are plotted against total fish length. For the purposes of this study a linear relationship was assumed and back calculations were made on a simple proportional basis.

Growth as Indicated by Length Frequency Data

Preliminary examination of otoliths indicated a difference in the rate of growth between the populations sampled in the Gulf of Maine and on southern New England grounds. Because of this, length frequency data for the areas north and south of the 41°30'N latitude were examined separately. This line of division was chosen since it passes through an area where the abundance of hake is low and approximates the division between the two types of otoliths.

The most complete series of length frequency data of young-of-the-year silver hake were obtained from otter trawl samples made on Albatross IV survey cruises. There were 3 cruises per year for the period 1963-66, one each in the summer, fall, and winter for a total of 9 cruises. The length compositions from survey cruise samples are summarized in Figure 2. Young-of-the-year hake were caught in only one of the summer cruises, in the other years they first appeared in the fall

surveys. They are marked "O" in Figure 1. and "I" at the change of the calendar year when they became, by convention, one year old. In the southern data the modal length of young hake was 6 cm during both the summer and fall surveys; however, there was a change in the range of lengths. The range in the summer was 2-9 cm and in the fall 2-13 cm, indicating some growth. By winter, the modal length of hake in southern New England was 8-9 cm. In the northern data, the fall modal length was 8 cm, approximately 2 cm larger than those from the southern area. In the winter data the mode of northern hake was at 12 cm, 4 cm larger than southern New England hake.

In summary, the data of Figure 2 showed young hake ranged between 2-18 cm in length when they were approaching the period when the first winter zone was formed. At this time, the hake from the Gulf of Maine were about 4 cm larger than those off southern New England.

Catches of Small Hake with Midwater Gear

The survey data were probably biased towards the larger young-of-the-year, due to the large mesh of the body of the otter trawl. Table 1 is a summary of lengths of hake taken with fine mesh midwater gear. The earliest cruise that collected young hake was made the end of July and early August; the lengths ranged between 0. 5 - 4. 0 cm. In September, large numbers of hake ranging from 1-7 cm were caught. Later sampling through the fall of the year showed that very small hake were usually still present in midwater. The modal lengths of hake from individual survey cruises and midwater collections are plotted in Figure 3 to compare the trawl and midwater catches. The plots show that lengths of hake caught with midwater gear were consistently smaller than those in trawl catches during the summer and fall. It was not possible to determine from these data whether midwater or trawl catches were more representative of the young hake populations. We assume that all young-of-the-year were available to otter trawls by the time of the winter surveys.

Zonal Formation on Otoliths

The first zone to occur on the otoliths is hyaline, and is considered to represent the larval phase of growth. The length of the otolith at this time is 0.3 - 0.6 mm. This larval zone can be seen in the otoliths of fish smaller than 10 cm, but frequently disappears as the otolith thickens with age. Figure 4a contains a photograph that shows this zone as a dark point in the center of the small pair of otoliths.

The next hyaline zone to occur is present on young-of-the-year hake caught in early fall and is considered to represent the pelagic phase of growth. Otoliths from 10 fish, 2.5 - 4.5 cm in length taken in the fall in a midwater plankton tow, were examined and all had this pelagic zone developing, indicating that it was formed before the young hake descended to the bottom. It is normally composed of a series of thin hyaline checks starting from the very small hyaline zone mentioned earlier. The photograph in Figure 4a shows the pelagic zone (labeled "p") on otoliths from a 9 cm hake taken in the fall. An otolith from a larger fish (29 cm) shows the same structure now somewhat obscured by further growth. Back calculations made on otoliths from young-of-the-year hake taken in the otter trawl in October and November showed that the pelagic zone formed when they averaged about 4.5 cm long (Table 2).

Table 2. Back calculations of fish length at time of pelagic zone formation, and otolith edge condition of first year silver hake.

Samples From the Gulf of Maine

Cruise	Season Collected	Number Examined	Av. Length of Hake (cm)	Back Calculated Length at Pelagic Zone (cm)	Edge Condition S-Summer W-Winter
Alb IV 65-14	Oct-Nov	4	5.3	3.7	3-S, 1-W
Alb IV 65-2	Jan-Feb	17	11.2	4.8	3-S, 14-W
Alb IV 64-1	Jan-Feb	10	11.7	4.3	7-S, 3-W
	Total	31			
	Average		Fall: 5.3	4.3 Fall:	3-S, 1-W
			Winter: 11.4	Winter:	10-S, 17-W

Samples From Southern New England

Cruise	Season Collected	Number Examined	Av. Length of Hake (cm)	Back Calculated Length at Pelagic Zone (cm)	Edge Condition S-Summer W-Winter
Alb IV 65-14	Oct-Nov	33	5.7	4.2	25-S, 8-W
Alb IV 64-13	Oct-Nov	18	5.0	4.4	16-S, 2-?
Alb IV 63-7	Oct-Nov	21	7.7	5.7	21-S 0-W
Alb IV 66-1	Jan-Feb	50	8.6	4.0	6-S, 43-W, 1-?
	Total	122			
	Average		Fall: 6.8	4.6 Fall:	62-S, 8-W, 2-?
			Winter: 8.6	Winter:	6-S, 43-W, 1-?

The next hyaline zone to occur is the first year ring. This is the zone forming on the edge of hake otoliths collected in the winter. The relative amount of opaque material laid down between the pelagic zone and this ring complicates the determination of the first annulus. Generally, the width of the opaque "summer" zone tends to decrease from the Gulf of Maine southward. The photographs of otoliths in Figures 4a, 4c, and 4e show this transition from a large amount of opaque growth between the pelagic zone and first annulus to almost none. Otoliths in Figure 4a were from the Gulf of Maine and those in Figure 4e were taken west of the Hudson Canyon. In a sample of 24 one-year old hake taken off Chesapeake Bay, Maryland, by the Dolphin, all had an early growth pattern generally similar to Figure 4e.

The first winter ring, even when small, was usually stronger in appearance than the pelagic zone. The presence also of substantial opaque "summer" growth before the occurrence of the ring was influential in judging whether or not this zone was the hyaline "winter" zone.

Investigation of the early growth of silver hake is further complicated by the presence of a check or accessory ring which occurs after the winter annulus. This ring was sometimes mistaken for an annulus. It is most confusing when examining otoliths from one year old hake. Its presence sometimes leads one to believe that the fish is a two year old that has grown slowly. Examples of this type of mark are shown in Figures 4b, 4c and 4d labeled with a "C" in the photographs. These are examples showing well developed accessory rings. In most instances it is a weaker ring than the type usually recognized as an annulus.

The accessory ring is believed to form sometime in the spring. Otoliths taken from hake during a midwater cruise in early April off southern New England had the first winter zone completed, and most of them had started summer growth but did not show the accessory ring.

These fish averaged 7.7 cm when captured. Samples collected from a Dolphin cruise made in late May, however, had developed the accessory ring with various degrees of intensity. They averaged 11.1 cm when the accessory ring formed, and 13.6 cm when captured. These data are shown in Table 3. It is evident from the length-frequency data that this accessory zone forms at a length significantly smaller than the modal size of fish in their second winter (see Figure 2).

Table 3. Average length from back calculations of the pelagic and first winter ring, and spring check (accessory ring). Samples were taken in midwater.

Cruise	Season	No. Exam.	Length Hake (cm)	Back Calculated Length at Pelagic Zone (cm)	Back Calculated Length at Winter Zone (cm)	Back Calculated Length at Spring Check (cm)	Edge Condition S-Summer W-Winter
Alb IV 66-4	April	33	7.7	3.5	7.2	---	24-S 6-W, 3-?
Dolphin 66-5							
Off Atlantic City, N.J.	May	10	13.5	2.8	7 4	10.8	10-S, 0-W
Off Delaware Bay, Del.	May	18	13.8	3.4	6.2	11.4	18-S, 0-W

The otoliths of larger fish were measured for the purpose of back calculating the length of fish at each annulus present and at the time the pelagic zone was formed. These data are presented in Figures 5a and 5b. A separate growth plot has been derived for Bulf of Maine and southern New England. The data show that hake from the Gulf have greater growth between the center and first winter ring than those from southern New England. The average length at which the first winter zone occurred in

both areas was essentially similar to the winter length frequency composition of Figure 2. Southern hake also showed a smaller amount of summer growth between the pelagic zone and first winter ring. These results support our interpretation of the pattern of otolith growth described here. Further studies validating adult growth and resolving the problems encountered in aging silver hake are being undertaken.

Length MM	Jul/ .g-57 North	South	Aug-65 North	South	Sep-57 North	South	Se, 8 North	South	Oct-66 North	South	Nov-66 North	South	Nov North	South	April-66 North	South	May-66 South	South	South
0-4				20						1	None	1					Off	Off	Off
5-9			5	35					11	42		21		37			N. J.	Del.	Md.
10-14							102			10		12		12					
15-19	3						419					9		1			Dolphin 66-5 (Cobb)		
20-24	25		1		9		1018					24							
25-29	56				16		940					32							
30-34	50		Alb Cruise		36		520			1		32	Alb Cruise						
35-39	12		65-10		60		139					17	65-14						
40-44	2		(P)		236		70					17	(I-K)						
45-49					285		45		Alb Cruise						1				
50-54					181		28		66-14		Alb Cruise				1				
55-59					62		6		(P)		66-14				7				
60-64					45						(P)				6				
65-69	1				14		Alb Cruise								12				
70-74					4		117								8		1		
75-79							(I-K)								15				
80-84					Alb Cruise										17			6	
85-89					102										10				
90-94					(I-K)										9		1	32	
95-99	1														5				
100-104															6		4	43	1
105-109															7				
110-114	Alb Cruise																1	42	
115-119	99 and 116														6				
120-124	(I-K)														3		1	39	
125-129															5				
130-134															3		2	25	2
135-139																			
140-144															1			11	7
145-149															1				
150-154																		7	6
155-159															1				
160-164																		5	7
165-169																			
170-174																Alb Cruise		4	3
175-179																66-4			
180-184																(I-K)		1	3
185-189																			
190-194																		1	3
195-199																			
200-204																			2

Table 1. Summary of data of midwater catches of young silver hake.

P-Plankton net, I-K - Isaacs-Kidd net, Cobb - Cobb mid-water net. "None" indicates sampling undertaken but none were caught.

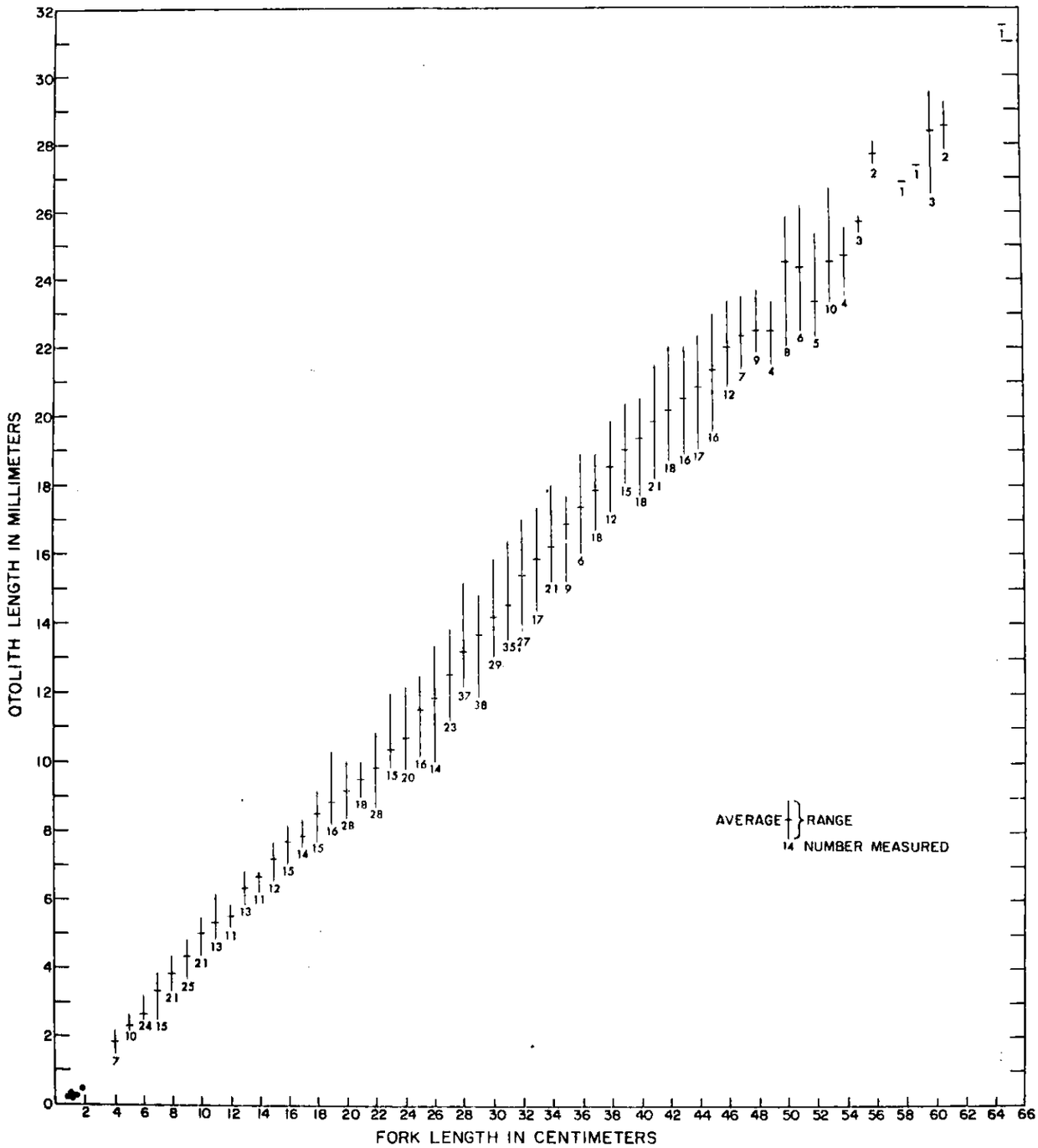


Figure 1. Otolith length-fish length relationship. Measurements of fish under 2 cm were not summarized.

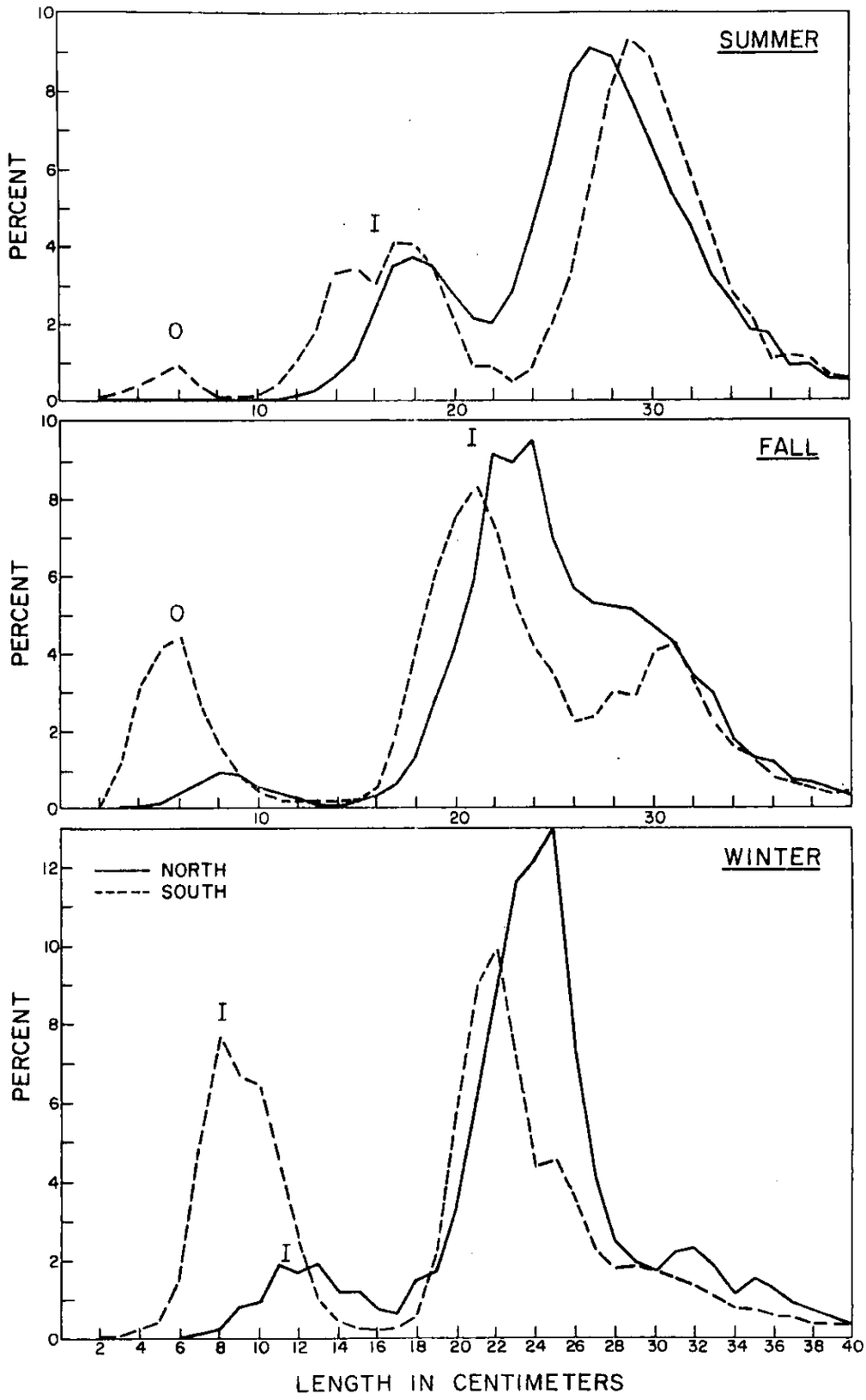


Figure 2. Summary of silver hake length frequencies by percent including fish up to 40cm length from 9 Albatross IV survey cruises. North (——) includes all hake taken north 41°30' (Gulf of Maine), and south (----), below 41°30' (Southern New England).

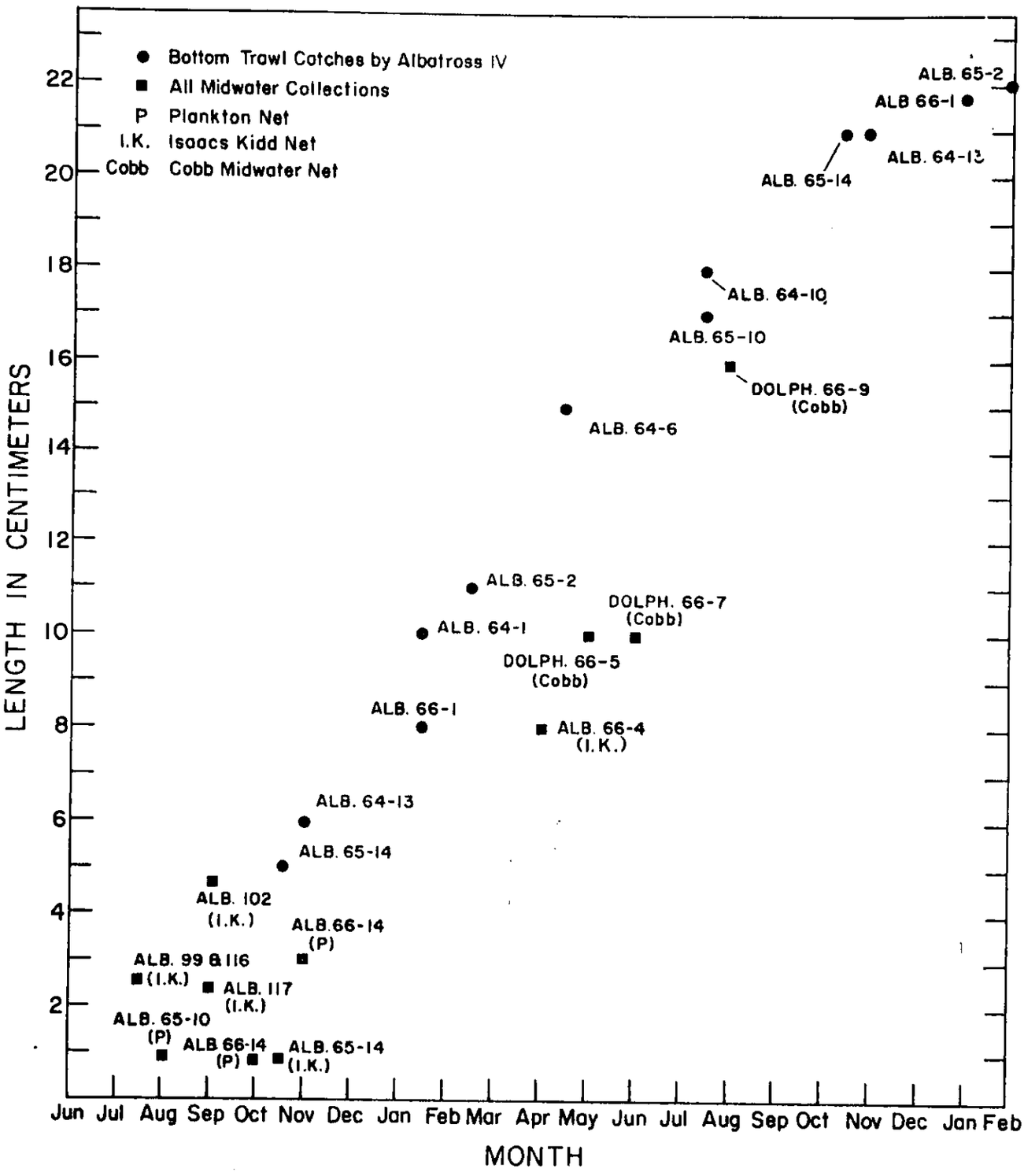


Figure 3. Plot of modal lengths of young silver hake through age 1 to show differences between catches by midwater gear and bottom trawl.

Figure 4a

Figure 4b

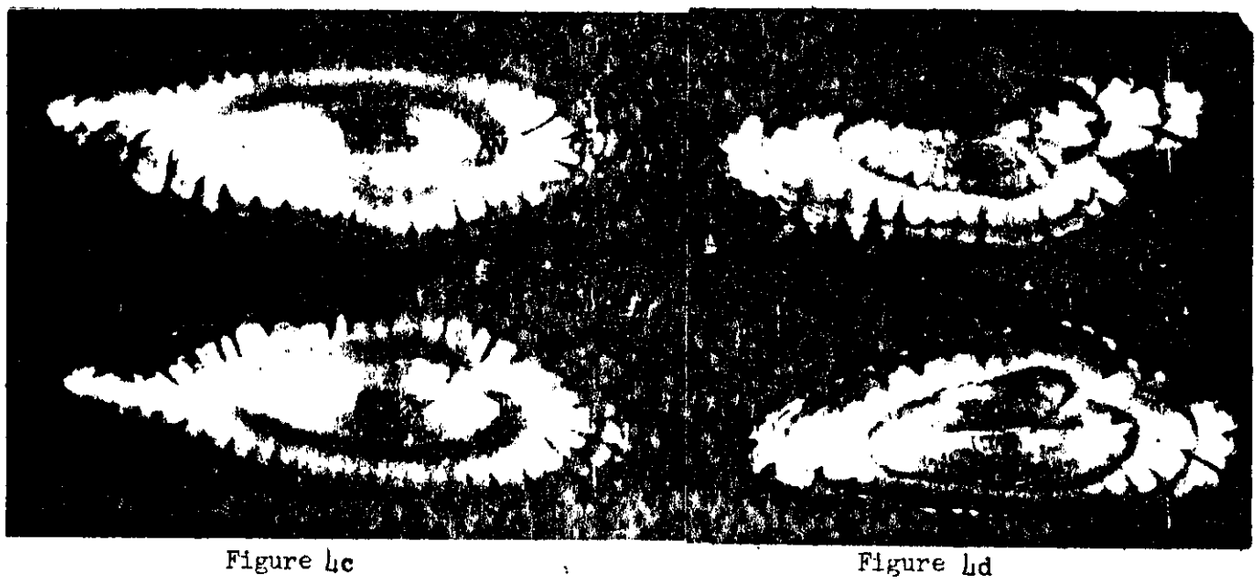


Figure 4c

Figure 4d

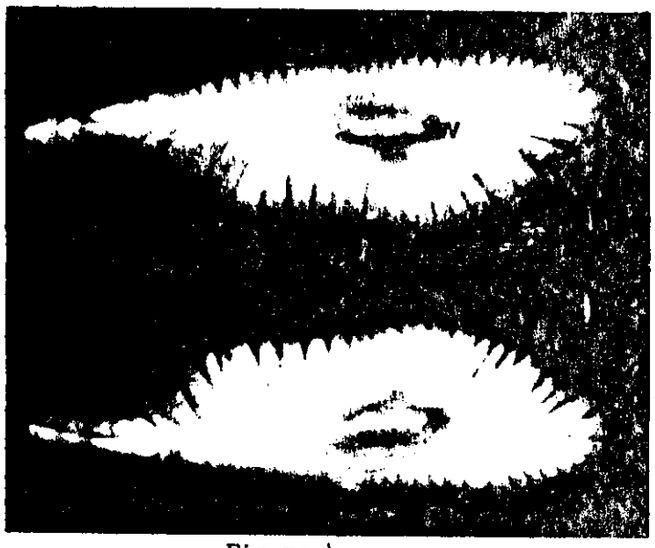


Figure 4e

L-Larval
P-Pelagic Zone
W-First Winter
C-Spring check zone

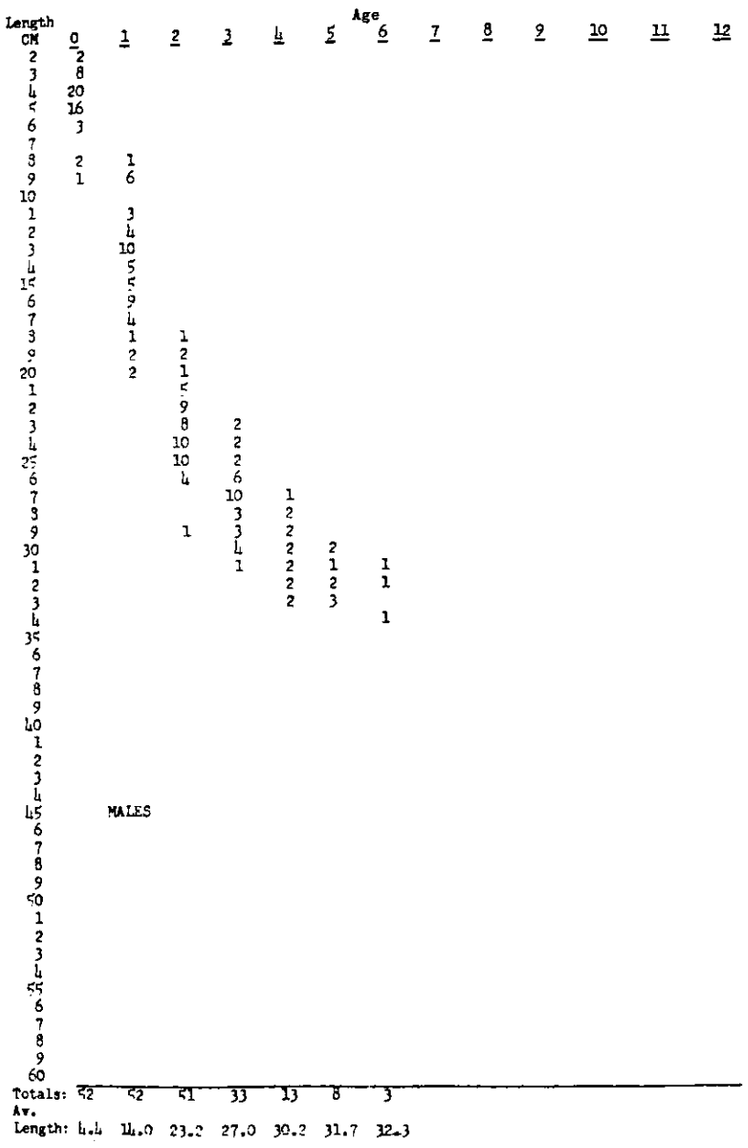
Figure 4a Comparison of center growth in northern hake. Checky hyaline in center of small otolith is the pelagic ring; small dark center zone is first zone to occur. Large otoliths are from 29cm female captured in the Fall, small otoliths from 9.5cm hake Immature, captured in Winter.

Figure 4b Type having small first winter zone and a spring check; 14.1cm Immature, caught August.

Figure 4c Type with large first winter and possible spring check or annulus. Zone was called an accessory ring here. This type was found difficult to age. Length 22cm male, captured in winter.

Figure 4d Type having a large first winter and the spring check scarcy. Pelagic zone is weak checks emanating from center. Length 18.5cm, Immature, captured August.

Figure 4e Type having the first winter zone in the center of otolith; 29cm, female, caught August.



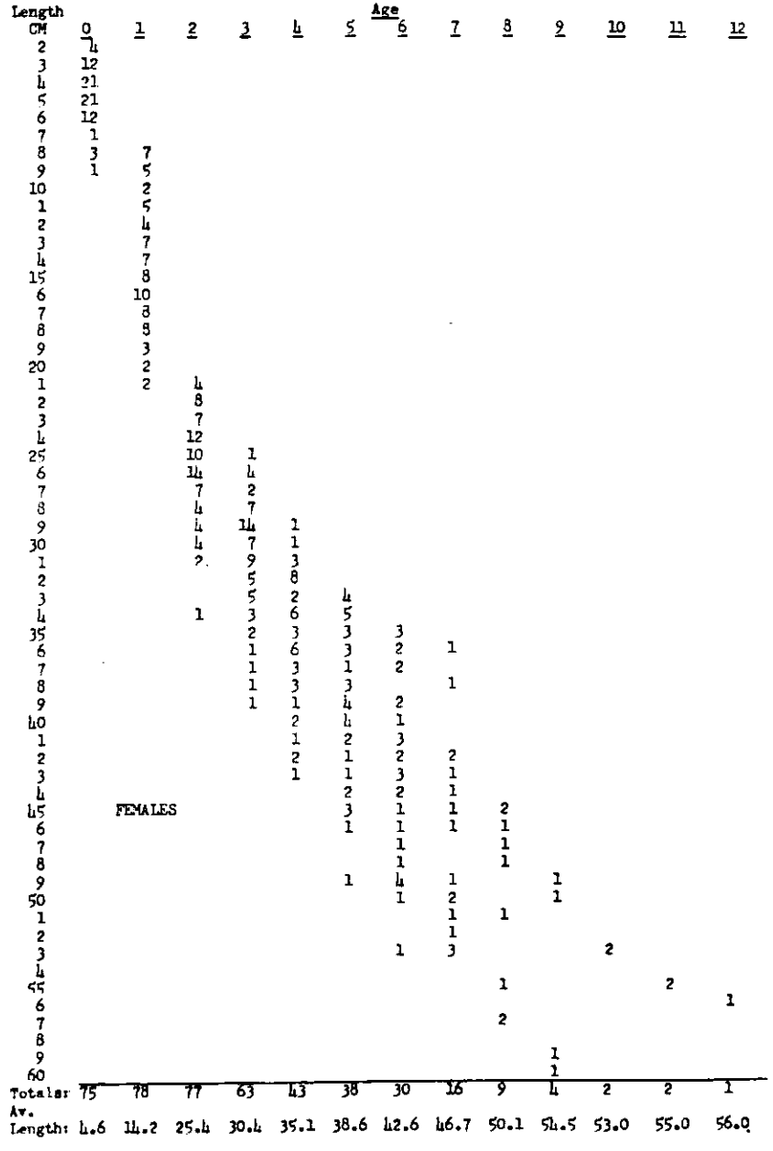


Figure 5a Growth of male and female silver hake from the Gulf of Maine based on calculated lengths from otoliths. "0" ring is the pelagic zone.

Length CM	Age 0	1	2	3	4	5	6	7	8	9	10	11	12
2													
3	3												
4	15												
5	14												
6	9												
7	6	3											
8	4	3											
9		4											
10		6											
1		8											
2		11											
3		9											
4		7											
15		4											
6													
7													
8			1										
9			1										
20			4										
1			5										
2			1										
3			2										
4			3	1									
25			3	2									
6			4	2									
7			1	3									
8				3	2								
9				6									
30					2								
1				1	3	1							
2					2	1							
3						1							
4						1							
35													
6													
7													
8													
9													
40													
1													
2													
3													
4													
45		MALES											
6													
7													
8													
9													
50													
1													
2													
3													
4													
55													
6													
7													
8													
9													
60													
Totals:	81	55	25	18	9	4							
Av. Length:	5.2	11.6	22.7	27.6	30.3	32.5							

Length CM	Age 0	1	2	3	4	5	6	7	8	9	10	11	12
2	1												
3	6												
4	29												
5	19	2											
6	16	2											
7	6	3											
8	4	8											
9		13											
10		18											
1		8											
2		8											
3		8											
4		6											
15		5											
6		2											
7		4											
8		1	2										
9			3										
20			4										
1			3										
2			2										
3			9										
4			11	1									
25			9	1									
6			3	1									
7			9	4									
8			6	4									
9			3	1									
30			2	6									
1			2	7	1								
2			4	4									
3				5	1								
4				8	10								
35				2	2								
6				2	2	1							
7					2	1							
8				1		4							
9				1		3							
40					1		2						
1						1							
2					1	1		1					
3													
4							1						
45		FEMALES											
6							1						
7								1					
8													
9													
50													
1													
2													
3													
4													
55													
6													
7													
8													
9													
60													
Totals:	81	88	72	48	20	11	4	2					
Av. Length:	5.0	11.0	25.0	31.3	35.1	38.6	42.5	44.5					

Figure 5b Growth of male and female silver hake from Southern New England based on calculated lengths from otoliths. "0" ring is the pelagic zone.