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Age Determination of White Hake (*Urophycis tenuis*) in the Gulf of St. Lawrence

by

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Abstract

Examination of white hake (*Urophycis tenuis*) otoliths suggests reliable estimates of age can be obtained from thin cross-sections using reflected light. Divergent growth rates between males and females were found indicating that age length keys are required for each sex. Ages are validated by comparison of modal lengths derived from length frequency and mean lengths calculated from otoliths.

Résumé

L'étude des otolithes de la merluche blanche (*Urophycis tenuis*) laisse supposer qu'on peut obtenir des estimations fiables à partir de minces coupes transversales examinées à la lumière réfléchie. On a observé des taux de croissance divergeants entre mâles et femelles. Une clé âge-longueur est donc requise pour chaque sexe. On a pu vérifier les déterminations d'âge en comparant les longueurs modales dérivées des fréquences de longueurs et les longueurs moyennes calculées à partir des otolithes.

Introduction

White hake are a demersal gadoid species widely distributed in the Northwest Atlantic Ocean and commercially exploited in NAFO Subareas 3 and 4 with significant catches in the southern Gulf of St. Lawrence (Division 4T) (Liem and Scott 1966). Life history of this species has not been fully described with the exception of reports by Nepszy (1968) and Kohler (1971). Kohler (1971) concluded, on the basis of tagging studies, that the southern Gulf distribution was discrete and that the population could be considered a unit stock.

Catches of white hake in the Gulf have averaged about 5000 mt since 1972 with a reported catch in 1980 of 11619 mt (Metuzals and Fullerton 1981). Most of the catch is taken in July and August and is centered around the east end of Prince Edward Island. This is a small vessel fishery and otter trawlers less than 35 tons account for most of the landings (Beacham and Nepszy 1980). An increase in catch over recent years may indicate a more directed fishery for the species and diversion of effort from other species such as cod.

Nepszy (MS 1968) and Beacham and Nepszy (1980) examined some of the biological aspects of white hake and presented data on age determination from otoliths. However, both authors used small samples and results of their investigations must be considered preliminary. This study attempts to examine white hake otoliths using several techniques for interpretation of growth rings as indicators of age and to validate results through length frequency modal analysis.

Methods

Biological sampling of white hake is confined to low intensity sampling of commercial catches and to a research cruise conducted in September of each year. In 1981 two charter vessels were employed to survey the white hake population (Metuzals, unpubl.). Commercial samples consist of a random subsample of the catch to determine the length frequency from which a stratified sample (three per 3-cm interval for combined sexes) is examined for length, sex and otolith removal. Research cruises sample catches obtained in a depth-stratified random survey to determine length frequency from which a length-stratified subsample is examined for length, weight, sex, maturity stage and otolith age.

Maturity Stage and Otolith Age

Otoliths are removed at the time of sampling by a transverse cut through the head just posterior to the eyes. The otoliths are relatively large and can be located with little difficulty. After removal, the otolith pairs are cleaned of extraneous material and placed in dry paper envelopes for storage prior to ageing. No alternative storage methods, such as glycerin solutions, have been examined.

The standard technique for examining otoliths of most gadoid species (cod, haddock, etc.) requires breaking the otolith close to the center of focus and then examining the broken surface for evidence of annuli. For most specimens, this provides a good image of chronological growth from which age can be readily estimated. Otoliths of white hake were initially examined in this manner but the broken surface was assessed to be very difficult to interpret and frequently there was no evidence of growth rings. Enhancement of the surface was attempted with stains such as methyl violet blue (Albrechtsen 1968), burning and acid etching. Several authors have had success in estimating age from thin otolith cross sections (Butler 1977; Beamish 1979; Hunt 1980) and a similar technique was tried for white hake. This required mounting the otolith in paraffin and then cutting a section through the nucleus and at right angles to the long axis (see Hunt 1980 for more detail). Normally, two diamond grit blades with an appropriate spacer are used to obtain the section, but it was found more efficient to make two cuts with one blade.

The sections were mounted in black moulded plastic trays with fifty 10-mm diameter flat bottom 3-mm depressions per tray and cemented in place using a 25% mixture of Diatex (Fisher #M7638) in tolulene. They were then examined using polarized incident light at about 25 diameters after covering in alcohol.

Age was estimated by counting distinct hyaline zones assessed to represent over-winter growth and the nucleus was included in the total. A number of different radii were considered for counting zones and that giving the most consistent and clear image selected for actual innumeration of zones. Otoliths from three research cruises, one in 1980 and two in 1981, were examined in this manner.

Resolution of catch length frequencies was accomplished using the technique described by Hunt (1980) which requires transforming the frequency into natural logarithms and then fitting parabolas to appropriate sections of the distribution.

Results

Examination of broken otoliths showed very little evidence of hyaline growth zones and polishing, straining (methyl violet blue), acid etching (1% HCl) and burning (5 min at 285°C) yielded only marginal improvement. Use of transmitted light was also found to be ineffective and the otoliths were assessed to be unreadable using conventional methods. A broken polished surface and section from the same fish are shown in Fig. 1 and indicate the substantial difference in appearance of growth zones.

Otolith sections of approximately 1 mm were obtained with a Buehler Isomet saw and required two cuts with a diamond grit blade. Preparation included mounting in paraffin, securing in the saw vise, making two cuts, removing the section, mounting in plastic trays, and it was found that approximately 15 otoliths could be completed per hour. Proper orientation of the otolith at right angles to the saw blade and locating the cut at or close to the focus were assessed to be very significant in obtaining acceptable sections. The effect of distance from the focus was examined by taking serial sections from several otoliths and results are shown in Fig. 2. It is apparent from this series that relative diameter of the first hyaline zone is closely related to distance from the focus and that the other zones may have varying intensity in different sections. Both of these factors are important in counting zones as annuli and it should be emphasized that sections must be taken close to the focus if consistent criteria for determining age are to be applied.

Spawning of white hake in the Gulf may take place from June through September (Nepszy 1968; Faber 1976) and it is assumed that peak spawning occurs in the month of July. It was therefore decided to consider the nucleus as representing early juvenile and first winter growth and to include it as an annulus.

Examination of prepared sections at about 25 diameters and immersed in alcohol revealed the presence of many hyaline zones as shown in Fig. 2 and 3. Many of these zones were interpreted as "checks" since they were generally weak in appearance and did not follow a consistent pattern and they were consequently excluded as annuli. Other more pronounced hyaline zones were assessed to represent over-winter growth and were counted as annuli. The relative spacing of annuli was found to vary considerably in different regions of the otolith and the most consistent pattern was observed along the radius noted as "A" in Fig. 2.

Examination of a number of otoliths revealed two characteristics common to most specimens. The presence of a hyaline zone between the nucleus and second annulus was frequently noted but the relative spacing and intensity of this zone was inconsistent with other overall patterns in the otolith and it was therefore judged to be a check. It was assumed that some physiological event caused this check similar to that described by Hunt (1980) as a "pelagic zone" for silver hake (Merluccius bilinearis). The edge of the otolith was usually observed to be wide hyaline (WH) or very narrow opaque (VNO) which does not conform to expected types since the samples were collected in July and September at which time the edge should be composed of mostly opaque material representing summer growth. It was assumed that a significant time lag existed between growth of the fish and growth of the otolith and therefore the hyaline edge was included as an annulus.

Otoliths from three research cruises were sectioned and aged. A total of 1596 were examined, 549 from September 1980 (P244) and 1047 from July 1980 (RC01 and MT01), of which approximately 10% could not be aged due to breakage, crystallization or inconsistency. Mean length-at-age derived from these data are shown in Table 1 for age groups 2 through 9 for males and females. Based on these results, it is apparent that males and females grow at different rates and that their mean lengths become divergent after 4 yr of age. The age-length key shown in Table 2 for combined otolith ages indicates considerable overlap in the distribution of length-at-age for adjacent age groups.

White hake length frequency data from research cruises are normally recorded in centimeters and later combined for sexes into 3-cm intervals. It was felt that any normal components in the frequency distribution might be obscured by this treatment and it was therefore decided to extract from the original cruise records length frequencies by 1-cm intervals for males and females. This was completed for 11 cruises and results are shown graphically in Fig. 4. It was noted that some variation in length distribution existed between years and that the sample size was relatively small for most cruises. It was assumed that length-at-age would not vary enough to affect dominance of modes and therefore the frequencies were combined for all years and treated as being representative of a population length frequency for white hake in the Gulf. This provided a sample size of 1760 males and 1373 females ranging in length from about 10 cm to more than 100 cm. The frequency for cruise #P244 (September 1980) was also treated as a unit since the corresponding otoliths have been aged and the number of fish measured was relatively high (481). Length frequencies from the two July 1981 cruises were not presently available.

The four frequencies for males and females were resovled into normal components following Hunt's (1980) method and the resultant calculated means, standard deviations and numbers are given in Table 3. An example of the transformed length frequency for combined cruise data for males and females is shown in Fig. 5 and the calculated normal components are shown by fitted parabolas. In all cases, the first significant mode was observed at about 33 cm and resolution of components yielded as series consistent between cruises. For males, the last observed mode occurred at about 75 cm while that for females was found to be greater.

The close agreement in calculated means for all cruises justified averaging values which were assessed to represent the same age groups and these are also shown in Table 3 and are assumed to be the best estimates of mean length for adjacent age groups. Visual inspection of the means, considered separately for males and females, suggested a linear relationship with a time scale of 1 yr separating adjacent modes and it was decided to regress the length at age "t+1" on length-at-age "t." The resultant regression line, fitted by least squares, takes the form of the Ford-Walford line described by Ricker (1975) from which the asymptotic length (L_∞) and Brody growth coefficient (K) can be determined. Regression parameters and derived growth characteristics are shown below.

	Intecept	Slope	L_∞	K
Males	11.27	0.899	110.6	0.11
Females	11.10	0.918	135.3	0.09

Ages used in the calculation of L_∞ and K were relative and to determine absolute age of the modal lengths, it was necesary to adjust the intercept of the growth curve to fit observed values. Using the calculated values of Linf and K, with a t-zero (t0) equal zero, lengths at ages 1-8 were determined from the VonBertalanffy growth equation. The relation between these calculated lengths and the observed modal lengths appeared to be linear and a regression of calculated on observed length was found to be highly significant. The slopes of the lines were determined to be negative, and were assumed to represent the amount by which relative age used in the initial calculation should be adjusted and were therefore identified as t0 and the calculations repeated using these values. The calculated mean lengths-at-age and observed modal lengths are shown in Table 4 and appear highly correlated. Given the above assumptions, the mean length-at-age from length frequency analysis is therefore validated. Comparison of these mean lengths with those derived from otolith interpretation (Table 4) indicates good agreement and confirms the ages assigned from otoliths as correct, subject to the normal intra- and inter-age reader variation.

VonBertalanffy growth curves, using values given in Table 4, are shown in Fig. 6 with the calculated and observed values of mean length. The curve for males appears to closely fit the observed values while that for females appears to be less accurate for ages over 7 yr. This could be a result of incorrect ageing, modal analysis or that growth of females is not adequately described by the VonBertalanffy relationship.

Acknowledgements

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Table 1. Mean length-at-age for Division 4T white hake derived from otolith interpretations.

Age group	Sex	Research cruise number P244	MT01	RC01	Weighted Average
2	Male	33.7	-	-	33.7
	Female	35.0	31.0	-	34.8
3	Male	40.7	44.0	43.8	41.4
	Female	39.2	49.0	45.9	41.0
4	Male	48.2	48.0	49.1	48.3
	Female	48.4	50.9	49.6	49.3
5	Male	55.1	55.1	55.6	55.3
	Female	57.0	58.4	59.6	58.2
6	Male	60.2	59.7	60.5	60.1
	Female	63.6	68.0	67.5	67.0
7	Male	65.2	65.3	64.0	64.7
	Female	72.7	73.7	73.7	73.6
8	Male	67.1	68.0	70.4	68.8
	Female	79.4	82.8	80.9	82.0
9	Male	71.0	69.2	70.7	69.9
	Female	82.8	89.6	86.9	87.2

Table 2. Age length key for white hake derived from research cruise #P244 for males and females. Three-centimeter interval.

Length (cm)	Age: Males 2	3	4	5	6	7	8	Total	Females 2	3	4	5	6	7	8	Total
25								–								–
28	3							3								–
31	4	1						5	1							1
34	9	3						12	9	5	1					15
37	4	7	1					12	4	12	1					17
40	1	8	2					11	1	5	1					7
43		2	9					11		6	6					12
46		5	9	1				15		2	19	1				22
49		1	20	9				30		1	15	2				18
52			15	22	3			40			7	6				13
55			4	26	8	1		39			8	13	2	1		24
58				18	16			34			2	20	3			25
61				10	16	2	1	29			1	14	5			20
64				1	8	5	2	16				2	9	1		12
67					6	9	1	16					4	3		7
70						1	3	4					4	1	1	6
73					1			1						4	1	5
76								–						2		2
79								–						3	1	4
82								–						2		2
85								–								–
88								–							2	2
Total	21	27	60	87	58	18	7	278	15	31	61	58	27	17	5	214

Table 3. Results of modal analysis for research cruise length frequency data.

	Males						Females					
	P244			Combined*			P244			Combined		
Mode	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
A	33.1	1.5	8	33.1	3.4	544	-	-	-	33.7	3.1	439
B	38.1	2.1	32	41.2	2.5	255	38.4	1.3	13	42.4	2.9	315
C	46.5	2.6	69	47.1	3.0	425	48.0	2.1	62	48.1	2.0	292
D	53.3	2.7	147	54.3	2.7	485	57.0	2.9	99	54.5	2.8	297
E	59.4	2.2	72	60.7	2.2	334	63.7	2.7	43	62.5	3.2	263
F	65.8	2.0	49	65.9	2.5	318	69.0	1.4	13	70.0	3.3	144
G	-	-	-	69.8	2.7	87	-	-	-	78.5	2.1	42
H	-	-	-	76.5	1.4	22	-	-	-	87.5	2.6	80

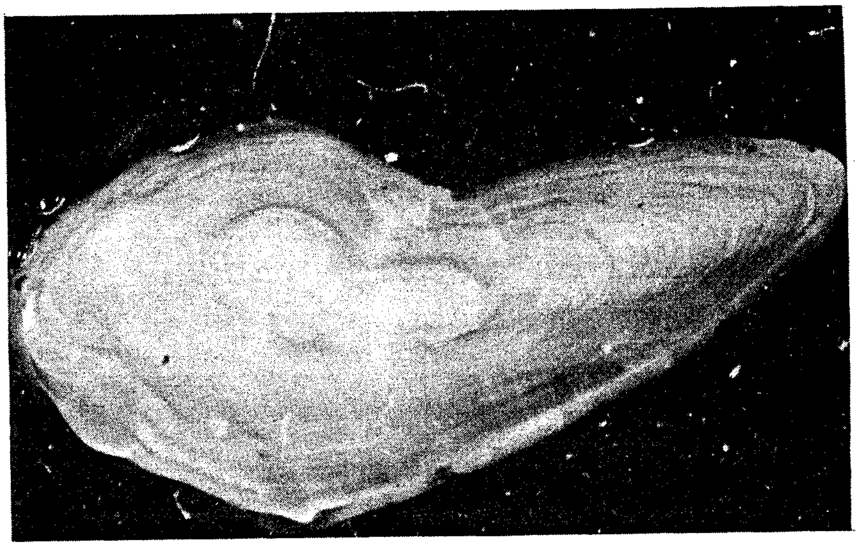
*Sum of all September research cruise length frequencies from 1970-80.

Table 4. Calculation of absolute age for observed modal lengths.

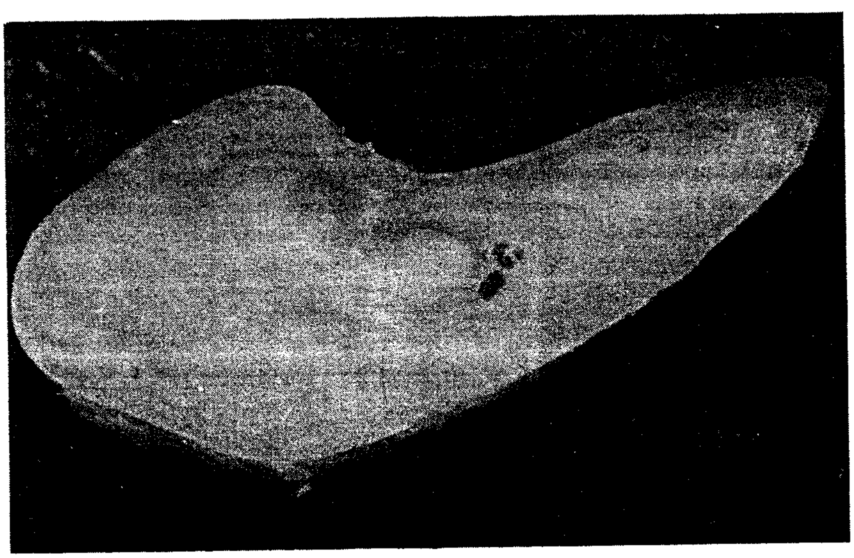
	MALES K = 0.11 Linf = 110.6 t0 = 1.17*					FEMALES K = 0.09 Linf = 135.3 t0 = -0.89*			
Age	A	B	C	D	Age	A	B	C	D
1	11.2	-	-	-	1	11.1	-	-	-
2	21.4	31.9	33.1	33.7	2	21.3	29.7	33.7	34.8
3	30.5	39.9	41.2	41.4	3	30.7	38.3	42.5	41.0
4	38.6	47.1	47.1	48.3	4	39.3	46.3	48.1	49.3
5	46.0	53.6	54.3	55.3	5	47.1	53.6	54.5	58.2
6	52.6	59.4	60.7	60.1	6	54.4	60.3	62.5	67.0
7	58.5	64.6	65.9	64.7	7	61.0	66.5	70.0	73.6
8	63.8	69.3	69.9	68.8	8	67.1	72.1	78.5	82.0
9	68.5	73.5	-	-	9	72.7	77.3	87.5	87.2

A - calculated from VonBertalanffy equation with t0 = 0.
B - " " " " " t0 = -1.17 and -0.89.
C - observed modal length from length frequencies.
D - observed mean length from otolith ageing.
* - negative slope derived from regression of "A" on "C."

FIGURE 1. COMPARISON OF POLISHED SURFACE AND SECTIONED OTOLITH FOR CLARITY OF RING AND EASE OF INTERPRETATION.

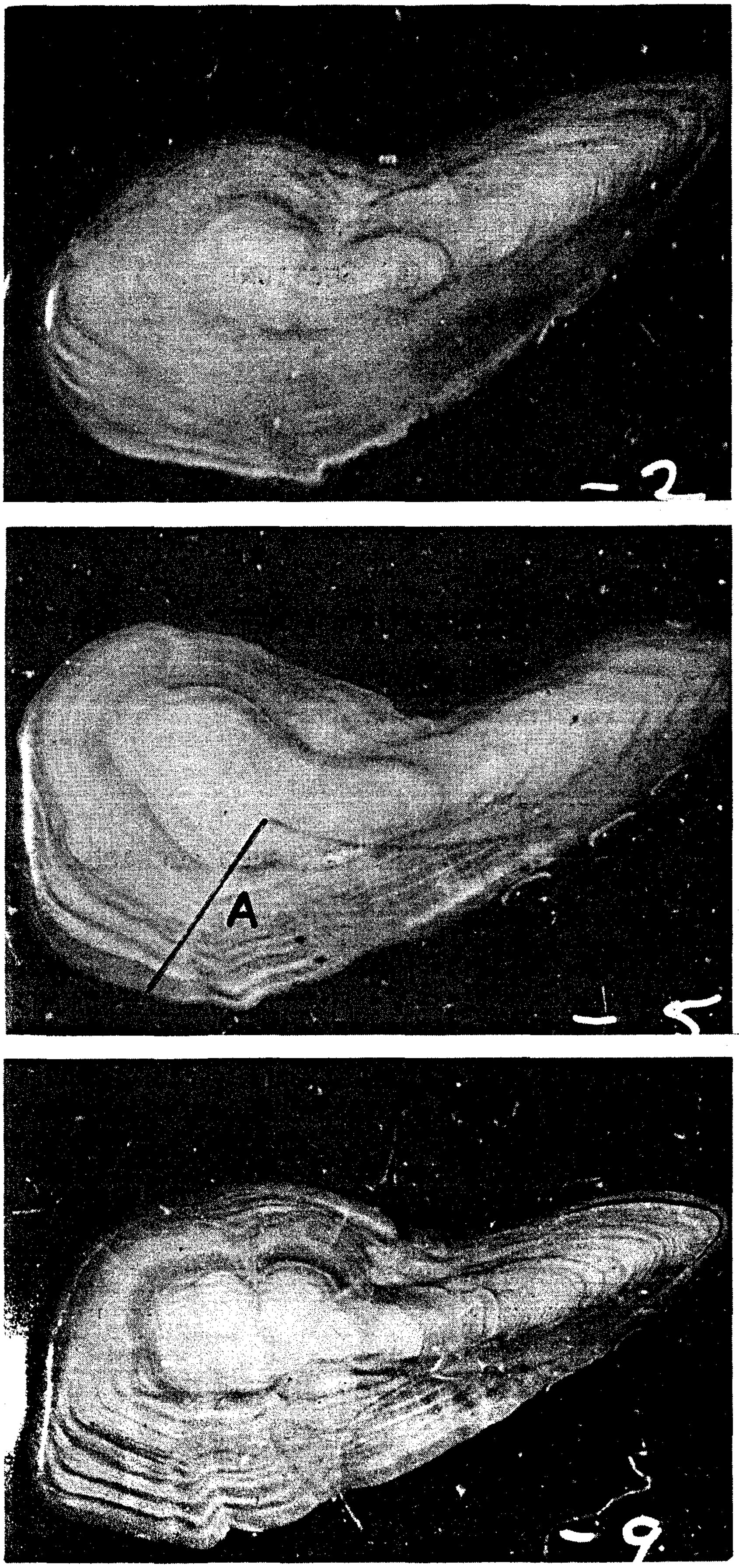


(A) SECTION



(B) POLISHED SURFACE

FIGURE 2. EFFECT OF DEVIATION FROM OTOLITH FOCUS ON THE APPEARANCE OF RINGS AND INTERPRETATION.

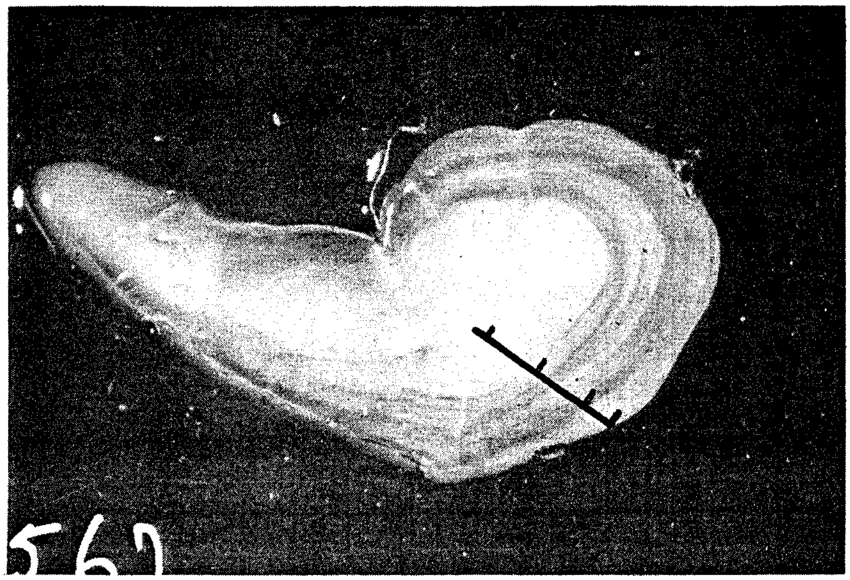


(A) ANTERIOR SECTION

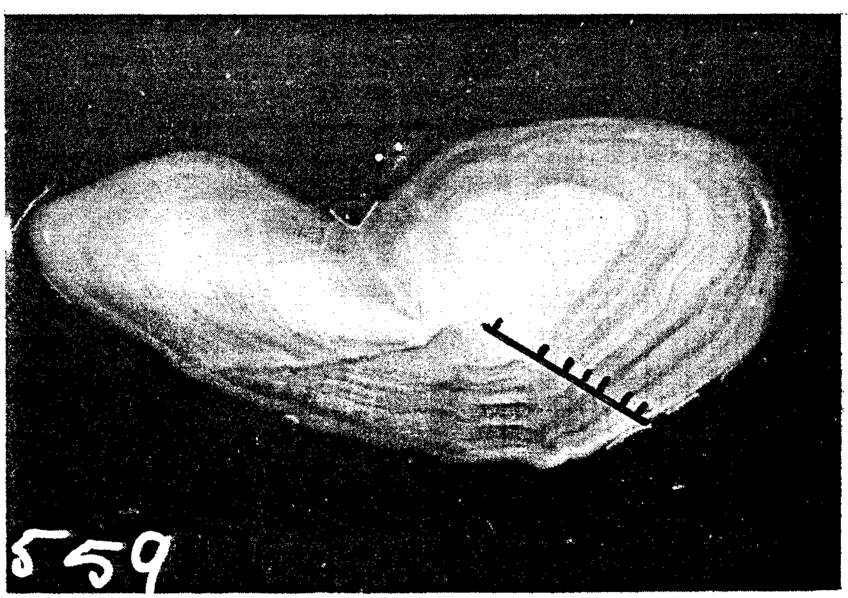
(B) FOCUS SECTION

(C) POSTERIOR SECTION

FIGURE 3. SECTIONED WHITE HAKE OTOLITHS AND ESTIMATION OF AGE.



(A) FEMALE 46 CM, 4 YEARS



(B) MALE 67 CM, 7 YEARS

Figure 4. Length frequency distribution of white hake from combined September research cruises in NAFO Division 4T.

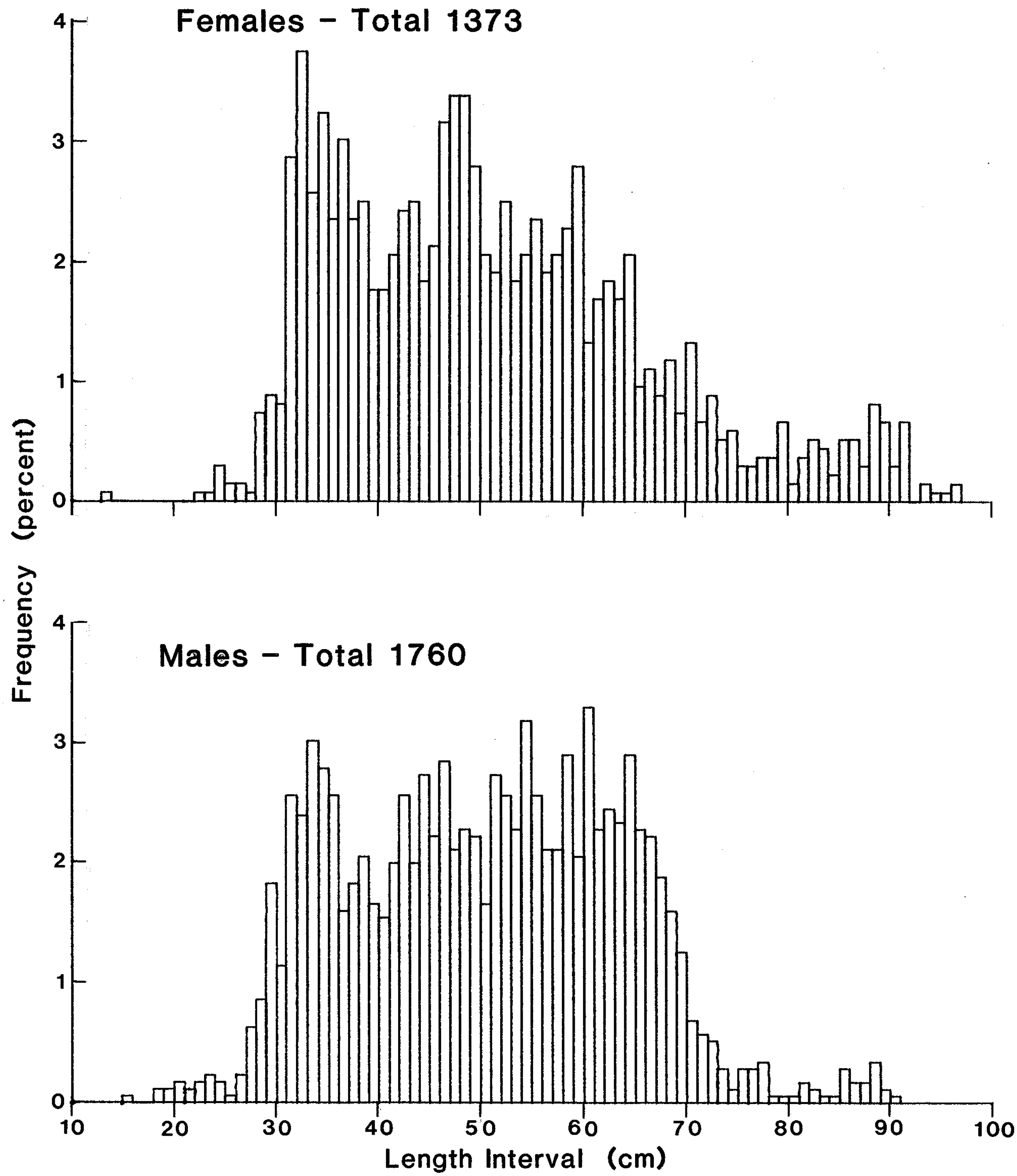


Figure 5. Results of length frequency modal analysis for males using combined data.

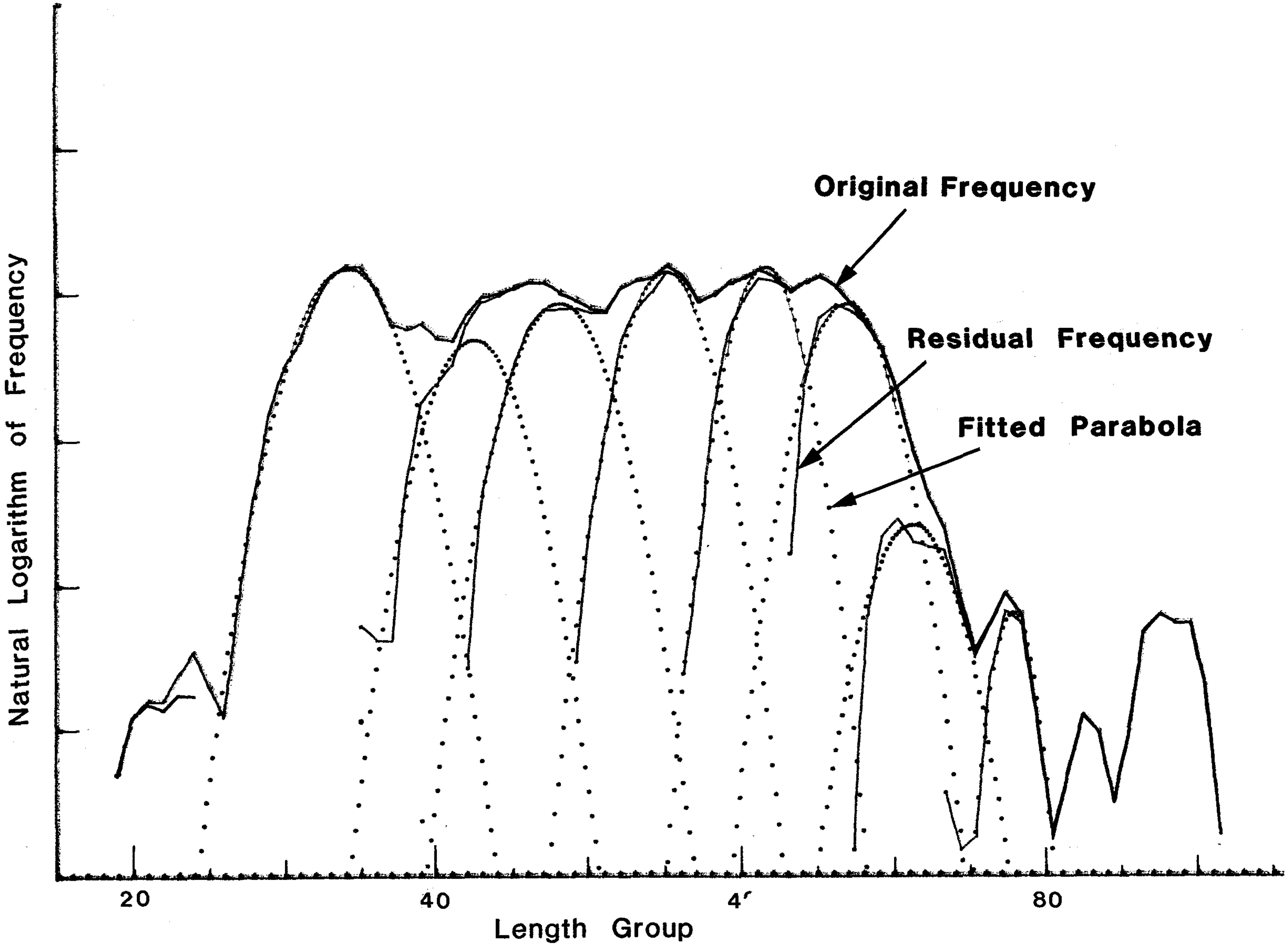


Figure 6. Calculated VonBertalanffy growth curves for white hake in NAFO Division 4T.