International Commission for the Northwest Atlantic Fisheries

Serial No. 5204
(D.c.2)

ICNAF Res. Doc. 78/VI/42

ANNUAL MEETING - JUNE 1978

Back calculation of silver hake length at age from otoliths

by

J. J. Hunt and P. J. Stuart
Department of the Environment
Marine Fish Division
Biological Station
St. Andrews, N. B., Canada

Publ. in ICNAF Sel. Papers No. 5: 11-17

Introduction

Age and growth studies of silver hake (M. bilinearis) have been a subject of study for international researchers and have been discussed at several ageing workshops (Hunt, 1976, 1977). While progress has been made in attempts to resolve differing interpretation of otoliths, variation in juvenile growth rates, both within stocks and between stocks, has continued to cause problems in estimating age. To date, age validation studies have consisted of comparison of otolith-derived ages with age compositions generated from length frequency analysis (Hunt, 1978). Results of these studies have provided mean lengths at age and growth curves for silver hake which appear to adequately describe growth characteristics of this species in ICNAF Subarea 4.

Back calculation of length at age from otoliths, scales or other indicators of growth may also be considered a method of age validation subject to at least two limitations. First, some otolith dimension must be related to size of the fish and second, the zones measured must be related to a time scale. This study attempts to measure growth zones in silver hake otoliths, to relate these measurements to fish age at the time of formation, to generate a frequency distribution of these lengths and to relate the otolith growth zone and derived length to probable size.

Material and Methods

An international sampling program with Canadian observers aboard foreign fishing vessels was initiated in 1977 by Canada. These observers sampled catches of Cuba, Japan and the U.S.S.R. from April to September for length frequency distribution and collected otoliths on a length-stratified basis. Otoliths of silver hake were stored dry in envelopes with individual length and sex data and were available from most regions of commercial fishing along the Scotian Shelf area. Samples were selected at random by month from those available (87 samples, 2,143 fish) for age determination, and from these samples 30 were chosen by month and area for otolith measurement. These samples consisted of 689 otoliths collected from April to September of which 82 were discarded because of fragmentation. Date, location and number of fish sampled are summarized in Table 1 where location refers to the lower left corner of the 10-minute square in which the fish were caught.

The right and left otolith were assumed to be equivalent except in abnormal cases and whichever of the two was more complete (i.e. unbroken) was selected for examination. Dry otoliths were found to be unreadable (opaque) but, through trial and error, it was found that immersion in a saturated saline solution for a minimum of 24 hours cleared the otolith sufficient for examination. Otoliths prepared in this way were examined in alcohol using reflected light at 12x using a stereo microscope with a black background. Several techniques for measuring otoliths were considered and the most efficient was found to be use of a camera lucida attachment. A scale with fine increments was superimposed on the otolith through the camera lucida and the incident light on the otolith and scale matched for optimum viewing. Orientation of the scale on the otolith was facilitated since movement of the scale relative to the otolith was reduced by the magnification factor. This system provided a total magnification of 15x and one eye piece unit (EPU) was equal to 0.03387 mm with a resultant accuracy of $\pm$ 0.02 mm.

Measurements made on each otolith consisted of the total length (TL) when possible, the half length (HL) and the distance from the center of the nucleus to the middle of each hyaline zone (O_1, O_2, ...O_n).
Definition of these measurements are shown in Figure 1.

Regressions of otolith dimension and fish length (of the form Y=A+BX) were completed to establish if a linear relationship existed between the respective measurements. The relationship between total and half otolith length was also examined. The length at which respective hyaline zones were formed was then calculated using the equation:

$$FL_N = FL_T \times O_N / O_{HL}$$

Lengths determined in this way were not related to time but it was assumed that lengths corresponding to an annulus would represent the length at January 1 since measurement was made to the center of hyaline zones which form from late fall to early spring. As well, a frequency distribution of calculated lengths should indicate concentrations related to age groups, and lengths obviously outside of these concentrations might then be attributed to checks or false annulii. Comparison of mean lengths derived from these measurements with those fish which had been aged or for which a mean length at age had been derived using other techniques would allow assessment of age validity.

Results

Location and number of fish sampled are shown in Table 1. Most samples consisted of 20-30 fish and were collected in an area bounded by 42°40' and 44°00' latitude and 60°10' and 64°30' longitude. Otolith measurements are summarized in Figure 1.

A total of 195 otoliths were measured for total length and a graph of these lengths against fish length in cm is shown in Figure 2. Visual inspection of the scatter diagram suggested a linear relationship and the line TL = 15.82 + 13.09 (FL) was found to be the best fit with a resultant R^2 value of 0.88 for fish from 15-45 cm in length. The mean fish length was 28.3 cm and the mean otolith length was 386.6 EPU and this range of lengths includes most fish caught in the fishery.

The scatter diagram of fish length (cm) and otolith half length (Fig. 3) also suggests a linear relationship and the line HL = 26.37 + 4.90 (FL) was found to give the best fit with R^2 equal 0.83 based on a sample size of 591 fish. Mean fish and otolith lengths were 30.5 cm and 175.5 EPU, respectively. This linear relationship established a direct proportionality between fish length and otolith length and allowed use of the equation:

$$FL_N = FL_T \times O_N/O_{HL}$$

from which the fish length at which zones were formed could be calculated. As a further check of consistent measurements, the relation between total and half otolith length was found to be linear (HL = 16.56 + 0.384 (TL), R^2 = 0.92) and Figure 4 shows this relationship.

A frequency distribution of the back-calculated lengths at age is presented in Table 2 and summarized in Figure 5. Of the 1,642 measurements taken, 692 were for males, 944 for females and the balance of 6 for unsexed fish. Graphs of these distributions (Fig. 5a, b) do not suggest significant variation between months but the totals by sex appear to consist of several modes. Visual inspection indicates a distinct break in frequency at about 20 cm with fish above and below this length divided into two or more groups. As well, the distribution of females appears to be shifted relative to males and suggests a larger length at age for this sex.

Otoliths had been aged prior to measurement and it was possible to assign ages to zones based on the estimated overall age of the fish. Prior research (Hunt, 1978) suggested the presence of a pelagic zone as well as frequent checks between annulli and zones were identified with respect to these criterion to yield a series of back-calculated lengths corresponding to PZ, 1, C, 2, C etc. for each otolith. Results are summarized, by sex, in Table 3 and include an estimated mean length for respective hyaline zones. The lengths at age one for both males and females appear to be extended which suggests either incorrect age, sampling error or combination of fast- and slow-growing individuals. Of these, incorrect age seems more probable implying that a fish aged, for example, 3 years was actually 4 and the zone identified as 1 should have been 2 and the pelagic zone, if present, called 1 and so forth. This being the case, the possibility of confusing the pelagic zone with the first annulus may occur but this is probably limited to less than 5% of the total.

To compare back-calculated length at age with other estimates, von Bertalanffy curves were fit for males and females assuming the age at formation of the first annulus was 0.5 years based on a January 1 date and a July spawning period. Other annulli were equated to 1.5, 2.5, etc. years.

Results are shown below:

	K	L inf.	t_o
Males	0.674	35.38	−0.160
Females	0.566	40.54	−0.177

Curves illustrating this growth pattern are shown in Figure 6 and indicate a good fit to the data with apparent differences between sexes.

Otolith dimensions calculated from the mean and standard deviation of length at age are shown in Table 4 and these values were used to construct a generalized otolith indicating the relative position and variation of hyaline zones. This hypothetical otolith is shown in Figure 7 with the location and range of hyaline zones indicated. The estimated size of the pelagic zone is probably larger than the true value since it is generally obscured in larger fish and may not appear as a distinct hyaline zone when small in size.

Conclusions

Analysis of otolith dimensions relative to fish length suggest that a linear relationship exists between both the total and half otolith length and the fish length of silver hake. This proportionality allows back calculation of length at age from otoliths from which a frequency distribution can be generated. This distribution should consist of components corresponding to some physiological event in the life of the fish which was reflected in the otolith by formation of a hyaline zone. For the most part, these zones may be assumed to indicate winter growth and may thus be equated to annulli and the length associated with the zone related to time or age in years.

Results indicate that an age-length key derived from back-calculated lengths is consistent with those based on total age with adjustment for time of year. Growth rates of males and females appear to diverge above 25 cm and females reach a larger asymptotic length and age. A von Bertalanffy growth curve appears to adequately describe growth of this species in the initial 5 years and parameters of these curves are comparable with those derived from total age.

References

Hunt, J. J. MS 1976. Report of the silver hake ageing workshop. ICNAF Summ. Doc. No. 21, Serial No. 3850.

Hunt, J. J. MS 1977. Report of the silver hake ageing workshop, March, 1977. ICNAF Summ. Doc. No. 13, Serial No. 5073.

Hunt, J. J. 1978. Age growth and distribution of silver hake on the Scotian Shelf. ICNAF Selected Paper No. 3.

Table 1. Date, location and number of fish sampled for Otolith measurement.

MONTH	LOCATION*	NUMBER OF FISH	NUMBER OF OTOLITHS
April	425 625	17	13
	432 604	26	25
	431 635	25	23
	424 634	31	22
Total		99	83
May	432 604	25	25
	425 615	33	29
	425 624	27	24
	424 635	36	33
	435 634	33	26
Total		154	137
June	425 622	15	14
	425 620	22	21
	425 622	21	8
	432 603	21	21
	425 620	20	17
	425 622	24	18
	425 621	17	15
	423 643	20	19
	424 641	29	22
Total		189	155
July	440 583	15	15
	431 612	25	25
	432 603	25	24
	435 601	22	20
	430 612	21	21
Total		108	105
August	440 583	21	19
	433 630	32	29
	425 630	8	8
	432 604	18	17
	433 630	17	16
Total		96	89
September	430 620	25	22
	425 610	18	16
Total		43	38
TOTAL		689	607

* Refers to lower left corner of 10' square in which fish were caught. 425 625 means 42°50' latitude and 62°50' longitude.

Table 2. Back-calculated lengths by month and sex. Totals include unsexed fish

Length (cm)	April ♂	April ♀	April T	May ♂	May ♀	May T	June ♂	June ♀	June T	July ♂	July ♀	July T	August ♂	August ♀	August T	Sept ♂	Sept ♀	Sept T	Total ♂	Total ♀	Total T
5	.	1	1	.	.	.	1	1	2	.	.	.	1	.	1	.	.	.	2	2	4
6	.	.	.	1	2	3	2	2	4	1	3	4	1	1	2	.	.	.	5	8	13
7	3	2	5	1	1	2	2	1	3	1	.	1	1	2	5	.	.	.	8	6	16
8	1	4	5	1	3	4	2	1	3	1	5	6	1	3	4	1	.	1	7	16	23
9	3	2	5	2	3	5	3	5	8	6	3	9	1	1	3	2	.	2	17	14	32
10	6	5	11	5	1	6	5	.	5	.	5	5	2	3	5	1	3	4	19	17	36
11	2	5	7	3	7	10	8	7	15	5	5	10	6	8	14	3	1	4	27	33	60
12	2	4	6	7	3	10	11	2	13	8	4	12	7	5	12	2	2	4	37	20	57
13	3	4	7	10	8	18	6	7	13	10	4	14	7	5	14	.	.	.	36	28	66
14	2	3	5	5	8	13	3	9	12	4	4	8	4	2	7	4	4	8	22	30	53
15	3	3	6	4	7	11	3	4	7	3	6	9	1	2	3	1	3	4	15	25	40
16	4	3	7	7	8	15	2	1	3	3	.	3	4	2	6	2	1	3	22	15	37
17	3	2	5	5	5	10	2	3	5	2	3	5	3	2	5	1	1	2	16	16	32
18	1	6	7	2	1	3	3	2	5	1	1	2	1	1	2	.	.	.	8	11	19
19	6	4	10	7	4	11	2	2	4	1	1	2	.	3	3	1	1	2	17	15	32
20	3	7	10	2	2	4	4	4	8	5	3	8	5	1	6	1	.	1	20	17	37
21	4	8	12	5	5	10	7	3	10	4	2	6	3	4	7	2	1	3	25	23	48
22	3	6	9	9	4	13	6	6	12	3	9	12	3	2	5	1	2	3	25	29	54
23	4	5	9	6	9	15	8	8	16	14	6	20	3	5	8	4	4	8	39	37	76
24	9	6	15	5	6	11	9	6	15	14	8	22	5	8	13	1	5	6	43	39	82
25	4	7	11	9	6	15	13	12	25	11	8	19	5	8	13	5	2	7	47	43	90
26	5	6	11	12	10	22	11	18	29	12	18	30	10	8	18	1	3	4	51	63	114
27	8	6	14	9	7	16	14	14	28	5	18	23	3	5	8	1	1	2	40	51	91
28	5	9	14	4	5	9	6	12	18	10	5	15	4	7	11	3	3	6	32	41	73
29	4	7	11	6	5	11	6	13	19	11	15	26	3	7	10	2	4	6	32	51	83
30	2	7	9	6	9	15	11	7	18	9	15	24	3	6	9	2	.	2	33	44	77
31	3	7	10	2	6	8	5	14	19	6	10	16	3	7	10	1	4	5	20	48	68
32	.	9	9	2	7	9	4	14	18	4	10	14	.	8	8	1	2	3	11	50	61
33	.	3	3	2	3	5	3	11	14	1	11	12	1	7	8	.	1	1	7	36	43
34	.	4	4	.	3	3	1	8	9	1	9	10	.	2	2	.	1	1	2	27	29
35	1	5	6	.	5	5	1	8	9	1	10	11	.	3	3	.	3	3	3	34	37
36	.	2	2	.	1	1	.	6	6	.	6	6	.	4	4	.	2	2	.	21	21
37	.	1	1	.	1	1	1	2	3	.	4	4	.	.	.	.	1	1	1	9	10
38	.	2	2	.	.	.	.	1	1	.	.	.	.	.	.	.	2	2	.	5	5
39	.	.	.	.	1	1	.	2	2	.	1	1	.	.	.	.	1	1	.	5	5
40	.	2	2	.	.	.	.	1	1	.	2	2	.	.	.	.	1	1	.	6	6
41	.	1	1	.	.	.	.	2	2	.	1	1	.	.	.	.	.	.	.	4	4
42	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
43	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	1	1
44	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
45	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	1	1
TOTAL	94	153	253	139	157	296	166	222	388	159	215	374	91	132	229	43	59	102	692	944	1642

Table 3. Back-calculated lengths by age group. (P=pelagic, C=check)

MALES

Length	P	1	C	2	C	3	C	4	T
3	.								.
4	3								3
5	2								2
6	4	1							5
7	8	.							8
8	2	5							7
9	5	11							16
10	1	19							20
11	1	25							26
12	.	35							35
13		35							35
14		22							22
15		17	.	.					17
16		19	1	1					21
17		11	1	3					15
18		4	.	5					9
19		7	1	11					19
20		5	.	14					19
21		.	.	25	.				25
22		.	.	27	1	.			28
23		2	3	31	.	1			37
24		2	2	34	.	3			41
25		1	4	36	.	6			47
26		1	4	27	4	12		1	49
27		.	2	20	4	18		.	44
28			.	13	3	16		.	32
29				5	1	22	1	3	32
30				2	.	30	.	3	35
31				1	.	16	1	2	20
32				.	1	7	1	2	11
33					.	2	.	7	9
34						1		1	2
35						1		2	3
36						.		.	.
37								1	1
38								.	.
39									.
40									.
41									.
42									.
43									.
44									.
45									.
TOTAL	26	222	18	255	14	135	3	22	695
MEAN (mm)	76	140	242	242	276	293	312	324	216

FEMALES

Length	P	1	C	2	C	3	C	4	T
3	1								1
4	2								2
5	2								2
6	7								7
7	6	.							6
8	8	6							14
9	1	12							13
10	2	16							18
11	1	31							32
12	.	23							23
13		29							29
14		30							30
15		25							25
16		15	.	.					15
17		13	.	2					15
18		8	1	3					12
19		8	.	7					15
20		6	.	10					16
21		3	4	16					23
22		5	.	20		1			26
23		1	1	38		.			40
24		.	.	38	.	1			39
25		2	1	35	2	3			43
26		2	.	50	4	2			58
27		1		37	4	10			52
28		.		14	4	25			43
29				14	6	29	.	1	50
30				7	5	26	1	3	42
31				4	1	38	.	6	49
32				2	3	32	1	13	51
33				1	.	20	2	10	33
34				.	1	6	.	18	25
35					1	16	1	15	33
36					.	6	.	14	20
37						3	1	5	9
38						2	.	3	5
39						.		5	5
40						.		5	5
41						1		4	5
42						.		.	.
43								1	1
44								1	1
45								.	.
TOTAL	30	236	7	298	31	221	6	104	933
MEAN (mm)	75	145	219	253	293	314	338	355	247

COMBINED

Length	P	1	C	2	C	3	C	4	T
3	1								1
4	5								5
5	4								4
6	11	1							12
7	15	1							16
8	10	11							21
9	7	23							30
10	3	35							38
11	2	56							58
12	.	58							58
13		66		1					67
14		53		.					53
15		42	.	.					42
16		34	1	1					36
17		24	1	5					30
18		12	1	8					21
19		15	1	18					34
20		11	.	24					35
21		3	4	41					48
22		5	.	47	1	1			54
23		3	4	69	.	1			77
24		2	2	72	.	4			80
25		3	5	71	2	9			90
26		3	4	77	8	14		1	107
27		1	2	57	8	28		.	96
28		.	.	27	7	41		.	75
29				19	7	51	1	4	82
30				9	5	56	1	6	77
31				5	1	54	1	8	69
32				2	4	39	2	15	62
33				1	.	22	2	17	42
34				.	1	7	.	19	27
35					1	17	1	17	36
36					.	6	.	14	20
37						3	1	6	10
38						2	.	3	5
39						.		5	5
40						.		5	5
41						1		4	5
42						.		.	.
43								1	1
44								1	1
45									
TOTAL	58	462	25	554	45	356	9	126	1635
MEAN (mm)	76	142	236	248	288	306	329	349	234

Table 4. Mean length at age and otolith dimensions derived from back-calculated lengths based on a January 1 date. Upper and lower limits of length indicate ± 3 standard deviations.

	Age	Length (cm) Mean	SD	Lower	Upper	Otolith (mm) Mean	SD	Lower	Upper
Males	0.5	14.0	3.29	4.1	23.9	3.22	1.44	1.58	4.85
	1.5	24.2	2.81	15.6	32.6	4.91	1.36	3.51	6.31
	2.5	29.3	2.19	22.7	35.9	5.76	1.26	4.67	6.85
	3.5	32.4	2.44	25.1	39.7	6.27	1.30	5.06	7.49
Females	0.5	14.5	3.66	3.5	25.5	3.30	1.50	1.48	5.12
	1.5	25.3	2.85	16.8	33.9	5.09	1.37	3.67	6.51
	2.5	31.4	2.77	23.1	39.7	6.10	1.35	4.73	7.48
	3.5	35.5	3.03	26.4	44.6	6.78	1.40	5.28	8.29
Combined	0.5	14.2	3.5	3.7	24.7	3.25	1.47	1.51	4.99
	1.5	24.8	2.92	16.0	33.6	5.01	1.38	3.56	6.46
	2.5	30.6	2.77	22.3	38.9	5.97	1.35	4.59	7.35
	3.5	34.9	3.17	25.4	44.4	6.69	1.42	5.11	8.26

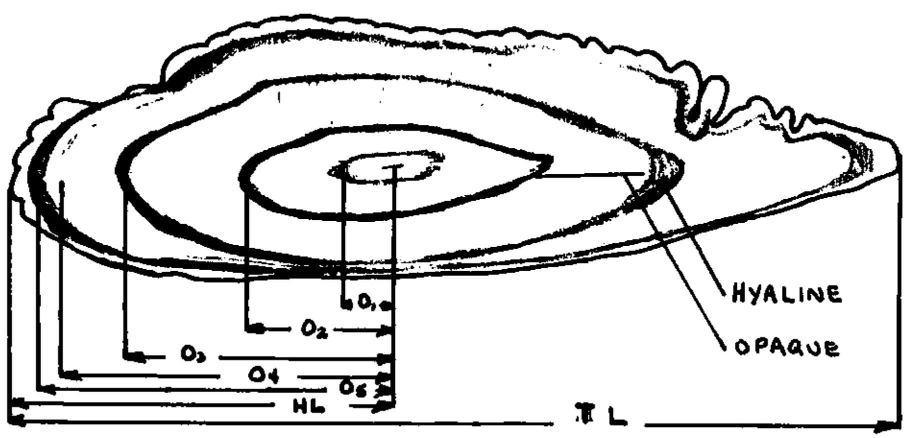

Fig. 1. Otolith dimensions measured.

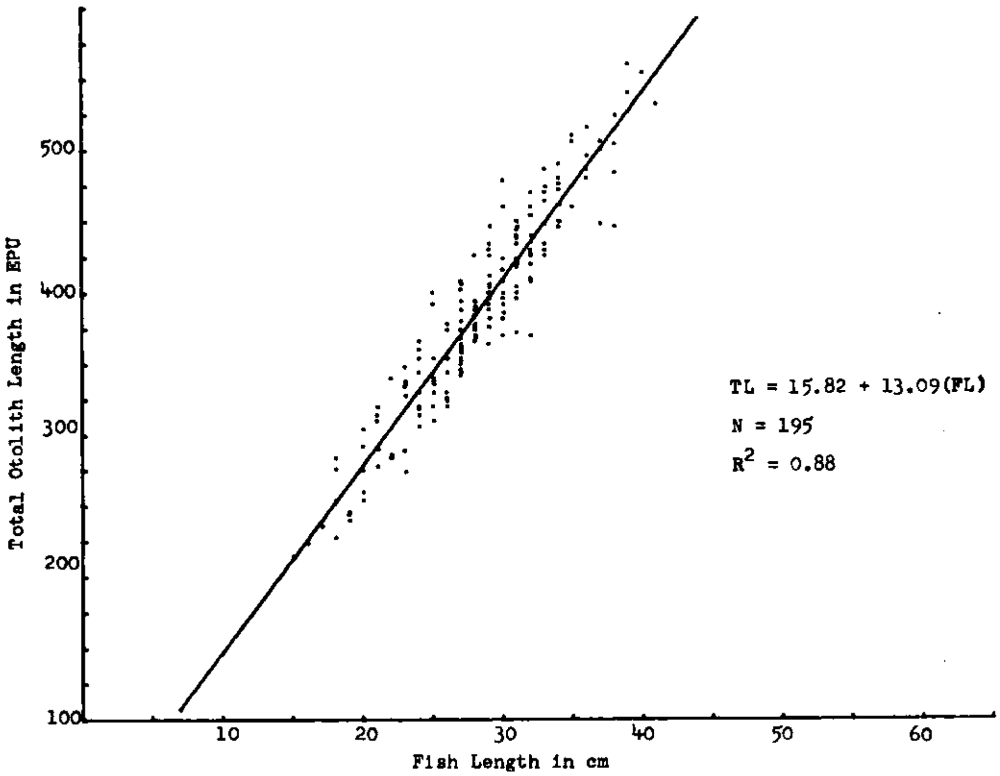

Figure 2. Regression of total otolith length on fish length

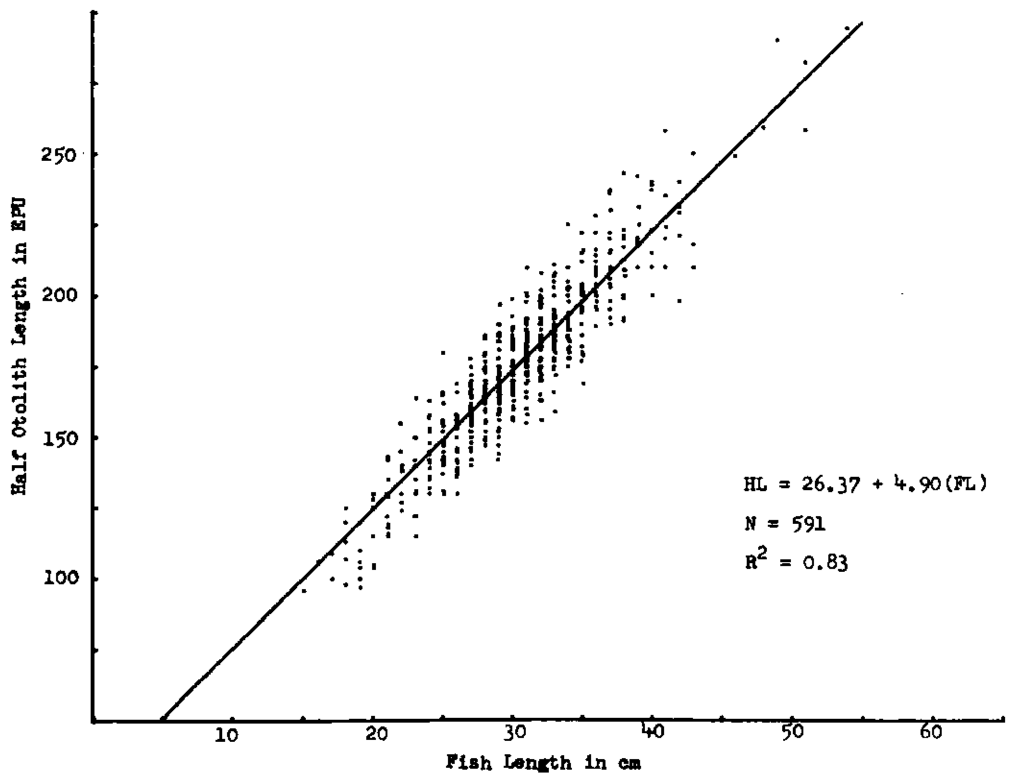

Figure 3. Regression of half otolith length on fish length

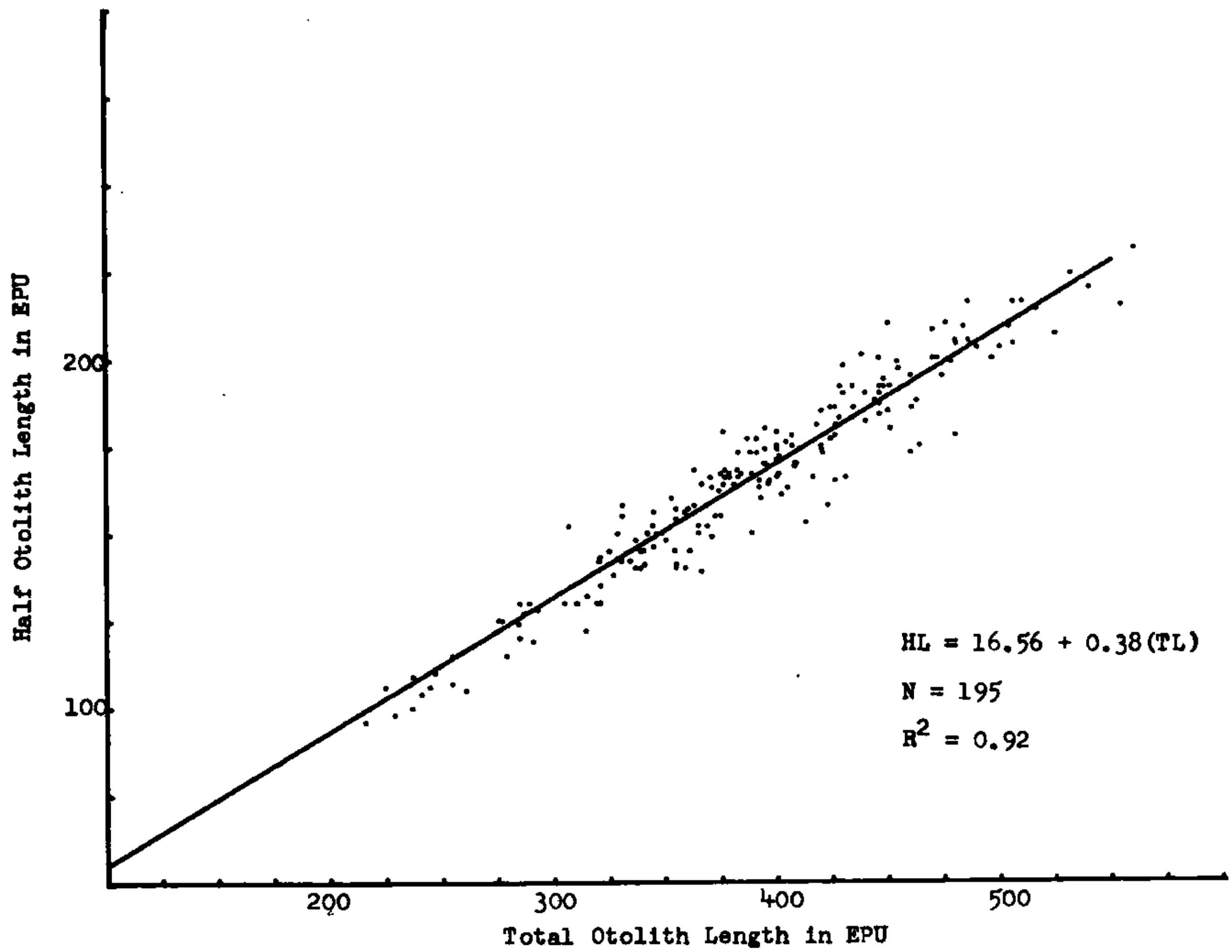

Figure 4. Regression of half otolith length on total otolith length

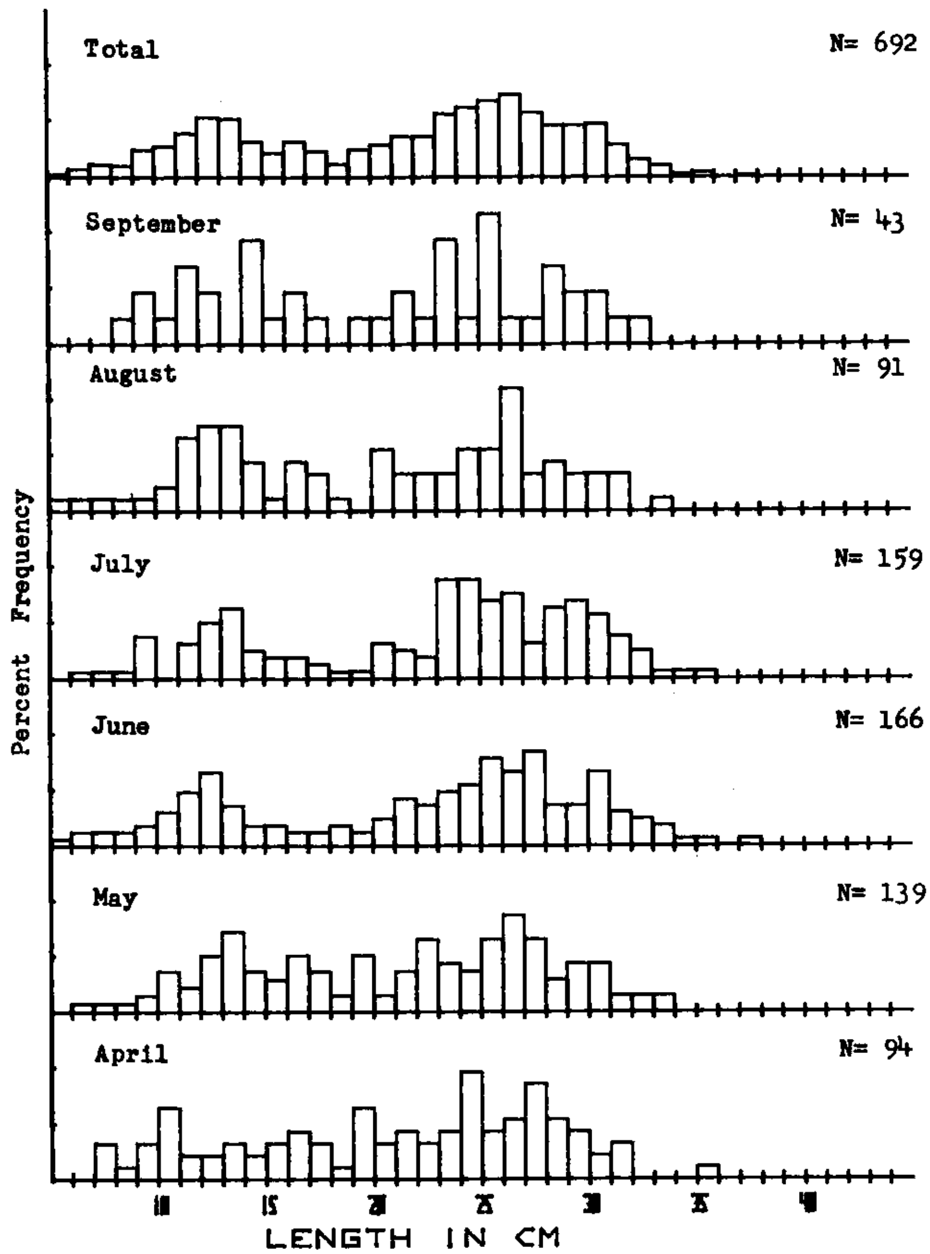

Figure 5a. Frequency distribution of back-calculated lengths
Males

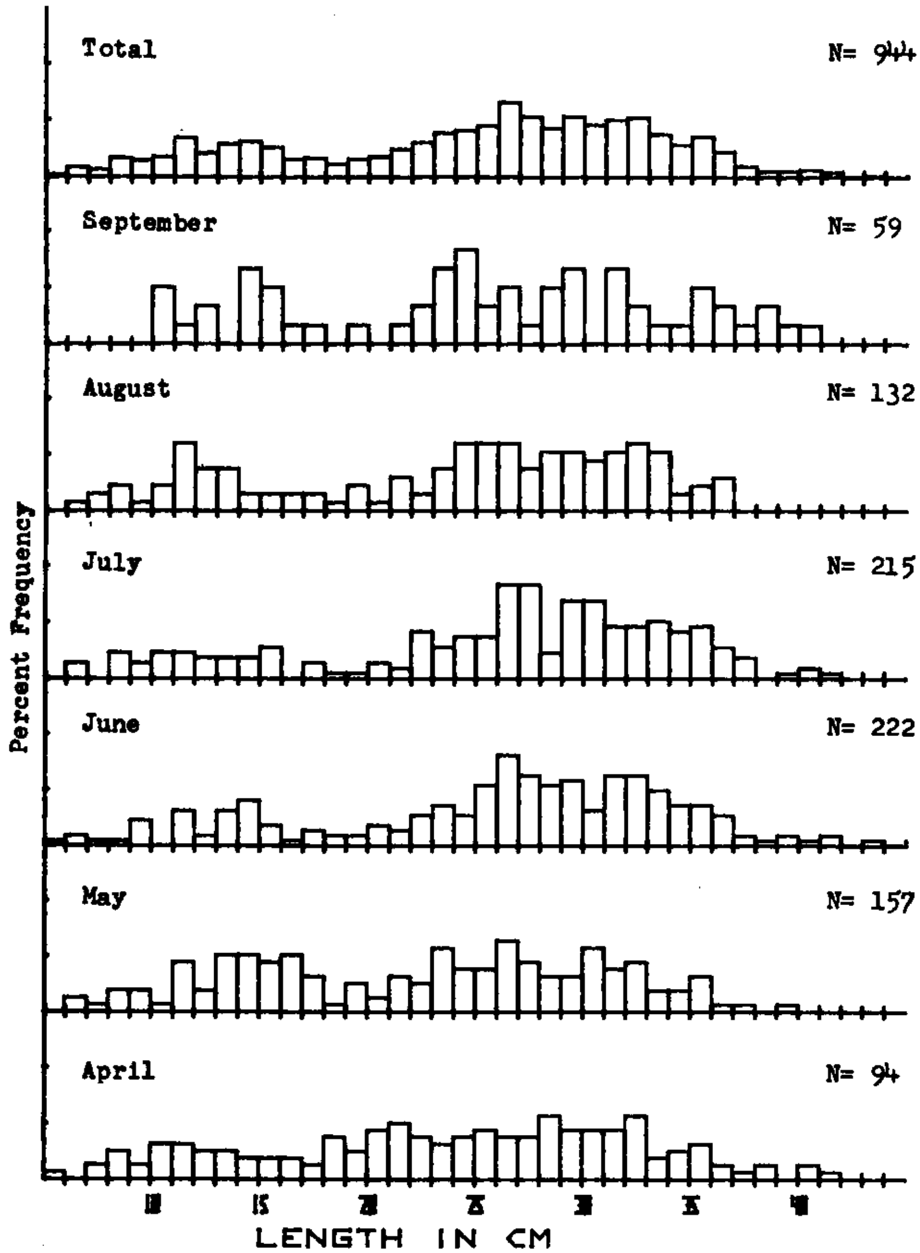

Figure 5b. Frequency distribution of back-calculated lengths Females

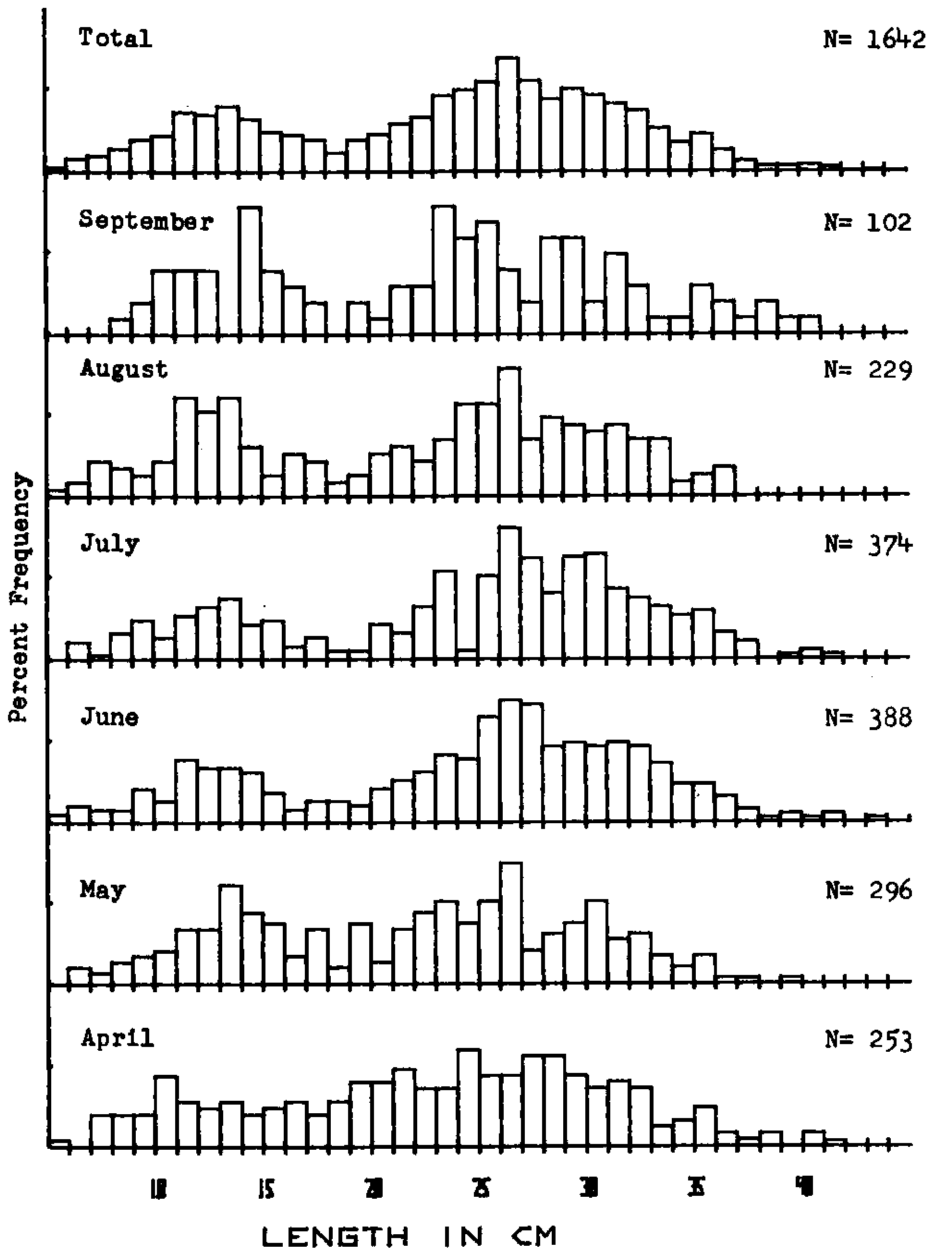

Figure 5c. Back-calculated lengths for males and females combined

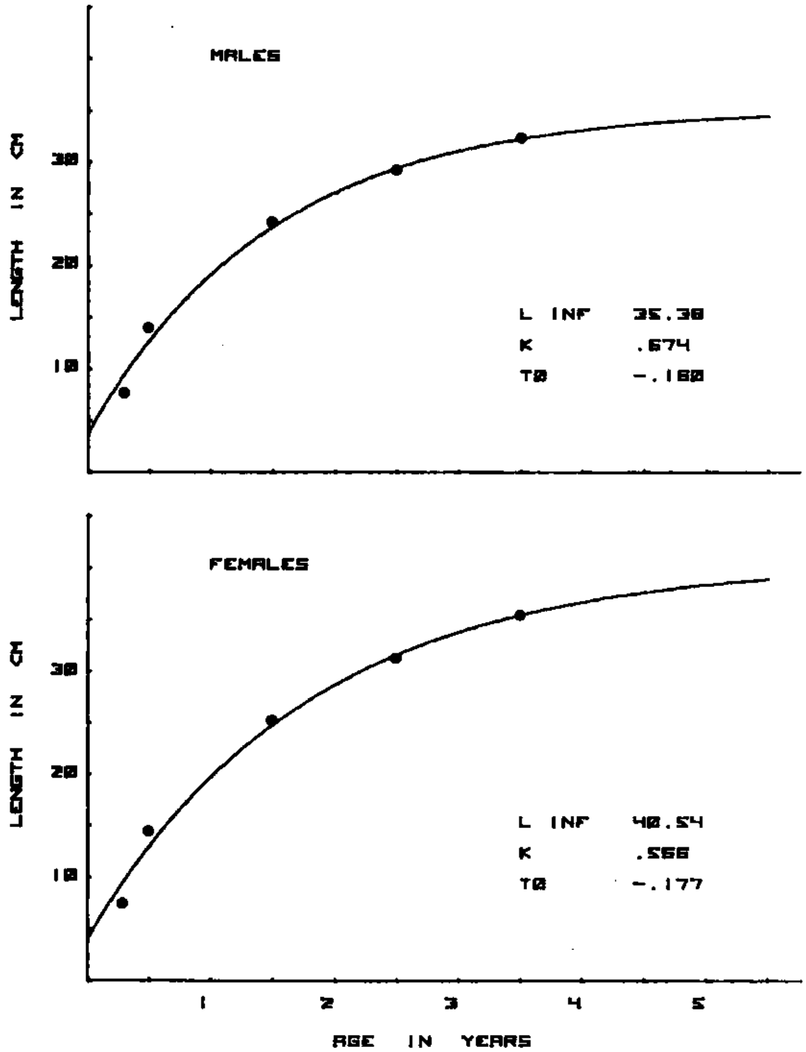

FIGURE 6. BACK-CALCULATED LENGTH AT AGE AND VON BERTALANFFY GROWTH CURVES

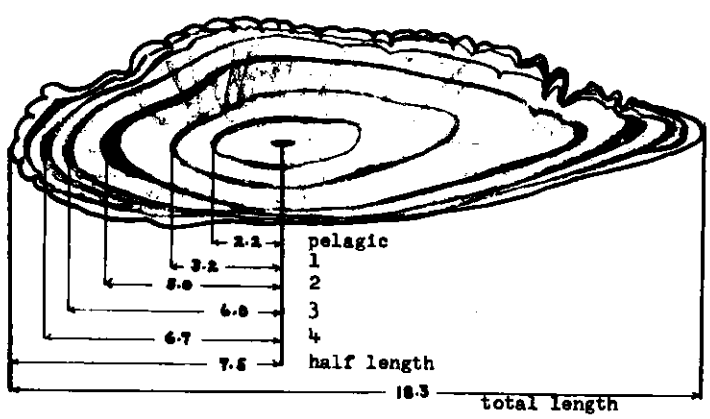

Figure 7. Relative size of hyaline zones based on back-calculated length at age data. Length in mm. Fish length -40cm.