NOT TO BE CITED WITHOUT PRIOR REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N052

NAFO SCR Doc. 80/II/20

SPECIAL MEETING OF SCIENTIFIC COUNCIL - FEBRUARY 1980

Age Validation of Silver Hake, *Merluccius bilinearis*

by

J. J. Hunt
Department of Fisheries and Oceans, Biological Station
St. Andrews, N. B., Canada EOG 2XO

Introduction

Age determination of silver hake has been the subject os several ageing workshops (Hunt 1980) but, while good agreement on otolith interpretation was achieved by participants, there continues to be apparent differences in estimates of age composition submitted by countries sampling commercial catches of this species. These differences have a significant effect on the results of catch analysis and frequently lead to conflicting conclusions on management strategy. In recent years it has been agreed to accept Canadian estimates of age composition for the commercial catch but this arbitrary decision has not resolved validity of age composition.

Discussion of ageing difficulties has identified several aspects of silver hake biology which are reflected in the otolith and might lead to inconsistent interpretation. Formation of a "pelagic zone," frequency of a "spring-summer check" and variation in early growth have been noted in this species and recognized as the main factors in differing interpretations. As well, the method of examining otoliths has been reviewed but results suggest that differences exist as much within as between whole glycerin-stored otoliths and dry sectioned otoliths (Hunt 1980). Results of ageing workshops and other related studies have been summarized by Hunt (1980) in an attempt to standardize technique and interpretation of otoliths.

This study considers age validation of silver hake by examination of otolith morphology and apparent growth characteristics derived from observed shifts in length frequencies.

Materials and Methods

A considerable volume of data is available for silver hake. Canadian and international research cruises have sampled catches over the entire Scotian Shelf and in recent years commercial catches have been sampled through the International Observer Program. Otoliths are available for most of these samples and catch length frequencies were calculated and summarized by month.

Since much of the difference in estimates of age is associated with the first and second year, analysis of length frequencies was confined to the 0-25 cm length range which should include all of age-group one and most of age-group two. Length frequencies were combined by month, sex and year for the period March 1970 to October 1979 and plotted chronologically to show any shift in modes with time. Results are shown in Figure 1 and a summary by month for the 10-year period is presented in Figure 2.

Length frequencies of catches of larval silver hake by month were available and these are summarized in Figure 3 for the length range 0-25 mm.

Beamish (1979), in a study of Pacific hake *(Merluccius productus)*, found considerable variation in estimates of age, based on the interpretation of the surface and cross-section of otoliths. To examine this factor for silver hake, measurements of fish length, otolith length, otolith width and otolith weight were made. Otolith length was defined as the longest extent in the anterior-posterior axis and width as the longest extent in the dorsal-ventral axis and at right angles to the long axis. Measurements were made using a camera lucida attachment with a stereo microscope by superimposing a grid pattern on the otolith. Dimensions were recorded in eyepiece units (EPU) and reduced to millimeters (1 EPU = .06773 mm). Weight was determined for dry otoliths and recorded to the nearest milligram.

Regression of fish length on otolith length yielded a linear relationship as shown in Figure 4. Plots of fish length and otolith width and otolith weight suggested a curvilinear relationship and curves were fitted by eye to the data (Figures 5 and 6). Otolith length and otolith weight appeared to follow an approximate cubic relationship and a line was fitted by eye (Figure 7).

Otolith edge characteristics were classified into four groups - narrow hyaline, wide hyaline, narrow opaque and wide opague - and are summarized by month in Table 1. These data are shown in Figure 8 in which the two hyaline and two opaque classes are combined.

Results and Discussion

A total of 41,589 silver hake were measured to determine length frequencies for the length range 0-25 cm for March to December. Earlier work (Hunt 1980) had shown little difference in mean length between males and females less than 25 cm and it was assumed that combined length frequencies would have equal application to both sexes.

Examination of Figure 1 shows a series of 34 monthly length frequencies representing length distributions for March through December. Sample size varied from 50 to 12,389 specimens but in most cases can be considered of adequate size to be representative of the population length frequency. Samples for April-August 1978 were derived from commercial catches while all others represent research catches which are assumed to sample the entire length range through use of codend liners. While the monthly series are discontinuous for most years, progression of modes is still evident in moving from spring through summer and into fall. Two apparent modes are represented in most of the frequencies and the increase in mean length with time of these modes appears consistent for all years, although the observed mean shows some variation between years.

Many of the length frequencies presented here had been examined by Hunt (1978) and resolved into normal components using a logarithmic transformation. Results of this work, with the addition of later data, are summarized in Table 2 to give a time series of calculated modal values. The smallest calculated modes were obtained for October 1978 and 1979 (2.94 cm and 1.70 cm, respectively) based on length frequencies derived from two joint research cruises by Canada and the USSR using a fine mesh "fry trawl." To show the progression of modes, a plot of mean length in Table 2 and elapsed time from January 1970 was made, as shown in Figure 9, and adjacent points connected assuming positive growth grom one interval to the next. This yielded a series of line segments which appeared to adequately describe progression of modes with time or growth in length. Within any 12-month period, two distinct lines were present suggesting two age groups being represented in the 0-25 cm length range. The connected points for mean values, as well as observed values, approximated a straight line and linear regression of month against mean mode resulted in the two lines:

$$\text{length} = 4.4744 + 1.5169 \times \text{month} \quad R^2 = 0.92 \qquad \text{A}$$

and

$$\text{length} = 13.1284 + 0.6469 \times \text{month} \quad R^2 = 0.82 \qquad \text{B}$$

It was assumed that the larger mean lengths within the same month would apply to fish at least one year older and, consequently, twelve was added to the month used in the second regression. September was taken as the time zero and the time coordinates adjusted accordingly. Values for the means in October were thus considered as one and thirteen for the smaller and larger values, respectively. Figure 10 shows the values used and the two lines fitted to the data. Line A has an intercept of approximately 4.5 cm and, with exponential growth expected up to this size, can reasonably be assumed to represent growth of silver hake over the first 12-14 months. Line B represents growth of the next older age group and thus can also be assumed to reflect growth from 12-25 months.

Data for length frequency distributions of larval and metamorphosed silver hake are shown in Figure 3 for the months of August, September and October. Significant numbers of specimens less than 10 mm were caught in all three months from 1976 to 1978 suggesting that spawning occurs over a protracted season in late summer and fall. Mean lengths ranged from 3.9 to 13.2 mm in August and the overall mean of 5.10 mm for the 124,155 fish measured can be equated to an approximate September length.

Regression of fish length (FL) in cm against otolith length (OL) in mm suggested a linear relationship and the line

$$OL = 0.3972\ FL - 0.3443$$

was found to give the best fit based on 864 observations and $R^2 = 0.97$. This implies that growth in length of the otolith is directly proportional to growth in fish length and that significant changes in fish length should be clearly reflected in the otolith. This relationship, as shown in Figure 4, appears valid to at least 50 cm and suggests that otolith growth zones should be consistent with seasonal changes in growth rate associated with deposition of hyaline and opaque material. Hunt (1979) also found a good relationship between otolith length and fish length and included a linear regression of otolith half length (AHL), as measured from the nucleus to the anterior end, with the fitted line

$$AHL = 0.1992\ FL - 0.1175$$

giving the best fit to the data. The derived values from Hunt's (1979) data for the posterior half length (PHL) give the line

$$PHL = 0.4839\ FL - 0.1175$$

which implies that the relative increase in length of the posterior half is more than twice that of the anterior half. Since both dimensions are proportional to fish length, it seems reasonable to expect minor changes in growth, or checks, to be more pronounced in the posterior half of the otolith. This possible dominance of checks in the posterior (pointed) end has been noted by age readers and a recommendation to exercise more caution in interpreting this part of the otolith was made by Hunt (1980) in his summary of ageing workshops.

The scatter diagram of fish length and otolith width and the approximated regression line (Figure 5) suggests an exponential relationship with the relative increase in width decreasing with size. This means that the dimension of growth zones in the dorsal-ventral axis of the otolith is not directly proportional to increase in fish length and that zones may become compressed and overlaid with successive years and consequently this region of the otolith is of questionable use for ageing. The relationship of otolith length and fish length to otolith weight is also non-linear (Figs. 6 and 7). These three relationships considered together suggest that otolith growth is allometric and that they tend to increase in thickness at a faster rate than the increase in length. Allometric growth has several implications on the use of otoliths for age determination. Increasing thickness may obscure the central or early growth patterns of older fish, cause zones to be discontinuous or overlaid in the dorsal-ventral axis and, for old fish, to limit growth and ring formation in the anterior-posterior axis. However, inspection of the length, width and weight relationships suggests that allometric growth does not become significant until the fish reaches 30-35 cm and that the otolith should be an accurate representation of changes in specific growth rate up to at least this length.

Edge characteristic of otoliths should reflect change in season and associated changes in growth rate by deposition of alternating hyaline and opaque material at the periphery. In temperate climates this means an opaque edge or zone in summer followed by a winter hyaline ring, subject to any lag or time delay for changes in the otolith to become evident.

Examination of silver hake otoliths on a monthly basis reveals changes in the edge type as shown in Table 2 and summarized in Figure 8. Approximately 100 otoliths were classified for each month from March through November and the percentage with hyaline and opaque edges calculated. Considering those with an opaque edge, the percentage increase from about 10% in March to almost 100% in August followed by a drop to 40% in September and again increasing in November. Hyaline edges show a similar pattern but peak in February-March. There are, however, two anomalies in the relative proportion of edge types. A slight increase from the expected percentage of hyaline edge types in May possibly represents the "spring-summer check" described by Hunt (1980). The sharp increase in hyaline edges from August to September followed by a decrease may represent a check associated with the normal July-September spawning period and resumption of growth following spawning. It would also appear that a time delay of 1-2 months is necessary for a change in growth to become evident in the otolith. In general, otolith edge types seem to follow the expected 12-month cycle with hyaline being dominant in the winter-spring period.

Conclusions

Length frequency distributions of silver hake in the 0-25 cm range appear to follow a well defined progression towards larger sizes within a 12-month period. Two lines connecting successive modal values within a 1-year period can be used to represent growth of what seem to be two adjacent age groups and, based on observed values, these can be assumed to be age groups one and two. The resultant estimates of mean length at age are consistent with those based on otolith interpretation and tend to validate their use and estimates of age as described by Hunt (1980).

Analysis of otolith morphology also supports the use of otoliths for estimating silver hake ages. Results suggest that the anterior half of the otolith is probably the most reliable index of growth for this species and should be used for age determination. The dorsal-ventral axis and the posterior half of the otolith appear to be less reliable and cannot be used with the same degree of confidence for estimating age. Edge characteristics of otoliths are also consistent with the expected seasonal cycle from hyaline to opaque in winter and summer. An apparent hyaline check evident in

September followed by additional opaque material could result in this ring being called an annulus.

Results of this study tend to support the conclusions and recommendations made by Hunt (1980) and confirm that silver hake reach a length of up to 30 cm by age 2 or 25-26 months after being spawned.

References

Hunt, J.J. 1980. Age and growth studies of silver hake in the Northwest Atlantic. ICNAF Res. Bull. 15 (in press).

Hunt, J.J. 1979. Back-calculation of length at age from otoliths of silver hake of the Scotian Shelf. ICNAF Sel. Papers No. 5.

Beamish, R.J. 1979. Differences in the age of Pacific hake using whole and sectioned otoliths. J. Fish. Res. Board Can. 36(2).

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

Table 1. Edge characteristics of silver hake otoliths by month
(1-narrow hyaline, 2-wide hyaline, 3-narrow opaque, 4-wide opaque)

Edge Length	3		4			5		6			7			8			9				10		11			
	2	3	1	2	3	2	3	2	3	4	2	3	4	2	3	4	1	2	3	4	1	4	1	2	3	4
10	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-
	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	2
12	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5	2
	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	2	5	-	6
14	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	5	7
	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	1	1	-	2
16	-	-	-	-	-	-	1	-	1	-	-	2	1	-	1	-	-	-	-	-	-	-	1	-	1	2
	2	-	-	-	-	-	-	-	2	1	1	1	2	-	1	1	1	-	1	-	-	1	1	-	-	1
18	-	1	-	1	1	-	1	-	2	-	1	5	1	-	1	1	1	-	1	-	1	1	-	-	1	-
	4	1	-	-	-	-	5	-	-	-	-	3	3	-	-	3	5	-	1	-	-	2	-	-	-	1
20	1	-	-	1	2	-	7	-	3	-	-	1	1	-	1	3	6	-	-	-	1	2	1	-	-	-
	6	-	-	-	3	-	2	-	5	-	-	5	-	1	-	3	3	-	2	-	1	2	-	-	-	-
22	3	-	-	2	2	-	1	-	2	-	-	1	-	-	2	2	5	-	1	-	3	3	-	-	-	2
	12	-	-	4	4	-	4	-	5	-	-	3	2	-	1	6	3	-	-	-	6	2	-	-	-	-
24	7	-	-	2	3	1	3	-	5	-	-	4	1	-	-	6	2	-	-	-	5	3	-	-	-	2
	7	-	-	1	3	-	4	-	6	-	-	8	1	-	1	5	1	-	-	-	4	-	-	-	-	-
26	9	-	-	1	4	1	4	1	5	-	1	2	1	-	-	4	3	1	1	1	4	4	1	-	-	1
	3	-	-	6	5	-	4	1	5	-	-	1	-	-	-	7	5	1	1	1	3	6	-	-	-	6
28	4	-	-	2	4	2	2	1	3	-	-	3	-	-	-	5	4	-	-	-	2	6	1	-	1	3
	5	-	-	1	4	1	4	3	8	-	-	1	-	-	-	1	-	-	-	1	4	4	2	-	-	4
30	5	-	-	4	3	2	2	3	1	-	-	4	1	-	1	3	2	1	-	-	3	3	1	-	-	3
	3	-	-	5	1	4	3	1	5	-	-	4	-	-	2	2	-	-	-	1	2	5	2	-	-	3
32	3	-	-	1	7	3	1	1	4	-	-	5	-	-	3	-	1	-	1	1	4	1	-	-	1	1
	-	-	1	2	2	3	1	-	2	-	-	3	-	-	1	-	1	-	1	2	1	2	1	-	-	-
34	1	-	1	3	2	2	1	1	2	-	1	4	-	-	3	-	2	-	2	-	-	-	-	-	-	2
	-	-	-	-	1	2	1	3	1	-	-	4	-	-	1	1	3	-	1	2	2	-	-	1	-	1
36	1	-	-	-	1	4	-	3	2	-	-	4	-	-	1	-	1	1	-	1	-	1	-	-	-	2
	2	-	-	1	1	2	1	-	1	-	-	1	-	-	2	1	-	-	-	-	-	-	-	-	-	-
38	-	-	-	1	-	-	1	2	1	-	-	4	-	-	1	-	-	-	1	-	1	-	-	-	-	-
	1	-	-	1	1	1	2	-	1	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	1
40	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-	1
40+	4	-	-	1	-	7	3	1	2	-	-	2	-	-	4	7	1	-	-	9	-	-	-	-	-	-
Total	86	10	2	40	54	38	58	21	74	1	4	76	16	1	29	66	51	4	15	26	48	48	19	3	21	53

TABLE 2. MODAL LENGTHS OF SILVER HAKE, 1970-79

YEAR	MONTH	A	B	C
1970	MARCH	-	12.68	24.90
	JUNE	-	13.83	-
	JULY	-	19.33	-
1971	MARCH	-	-	26.57
	JULY	-	18.91	28.64
1972	MARCH	-	14.69	24.72
	JULY	-	19.39	27.44
	OCTOBER	9.04	23.83	29.98
1973	JULY	-	20.24	28.29
	OCTOBER	-	23.08	30.17
	OCTOBER	-	21.97	29.55
	DECEMBER	-	23.44	-
1974	MARCH	-	-	24.23
	JUNE	-	16.95	28.05
	JULY	-	19.77	27.56
	JULY	-	20.13	28.23
	OCTOBER	8.41	25.40	31.70
1975	MARCH	-	12.73	25.79
	JULY	-	21.32	29.41
	OCTOBER	-	24.46	31.80
1976	JULY	-	21.16	28.99
1977	JULY	-	19.82	-
1978	APRIL	-	16.46	24.54
	MAY	-	18.09	-
	JUNE	-	16.88	-
	JULY	-	19.15	26.01
	JULY	-	17.43	25.18
	AUGUST	-	19.85	26.32
	OCTOBER	2.94	-	-
1979	MARCH	-	13.60	23.46
	JULY	-	19.09	-
	OCTOBER	1.70	21.06	-
	OCTOBER	-	24.01	-
COMB	DECEMBER	-	23.44	-
	MARCH	-	13.43	24.95
	APRIL	-	16.46	24.54
	MAY	-	18.09	-
	JUNE	-	15.89	-
	JULY	-	19.65	27.80
	AUGUST	-	-	26.32
	OCTOBER	5.52	23.40	30.64

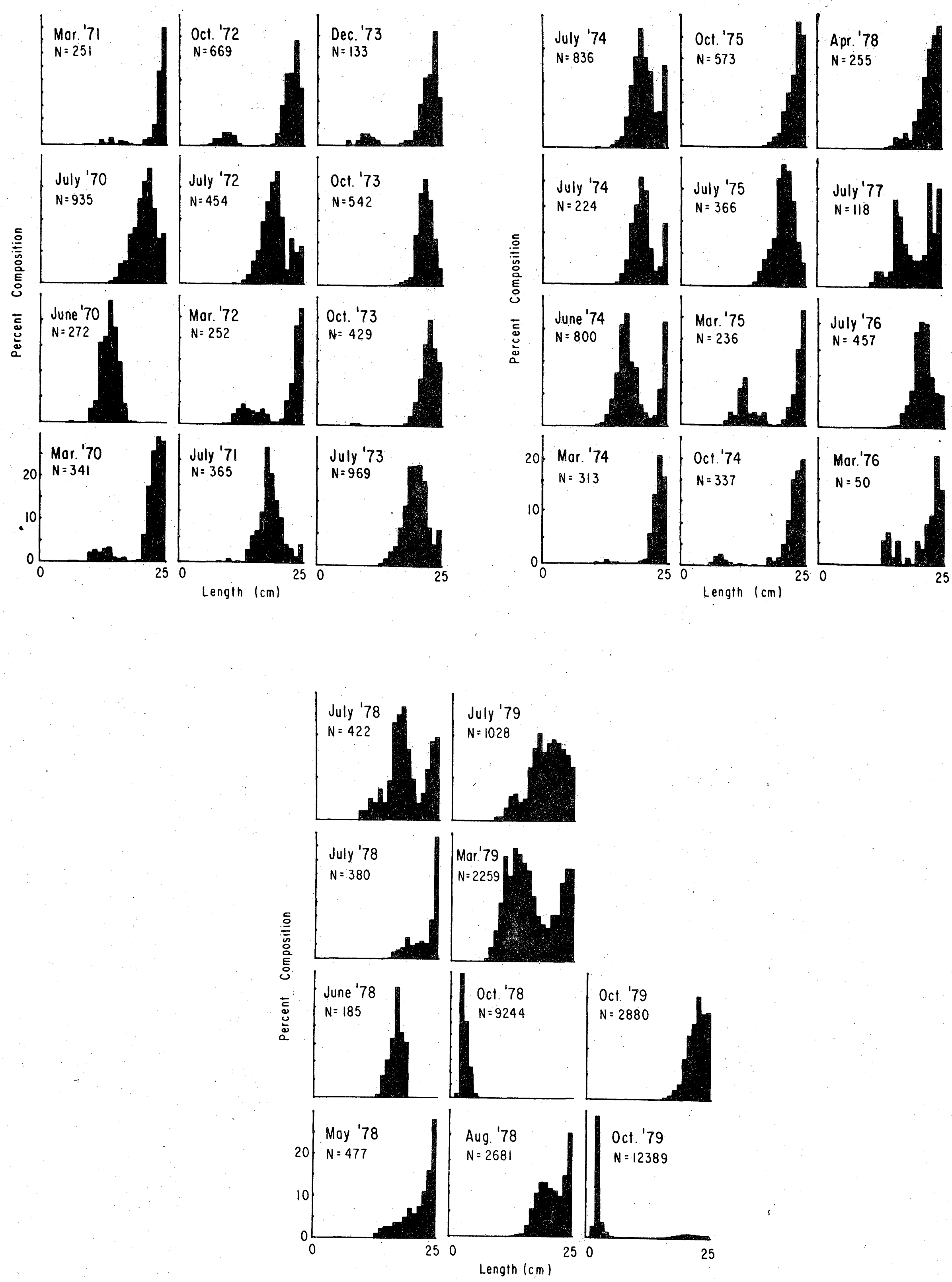

Fig. 1. Length frequencies of silver hake by month, 1970-79.

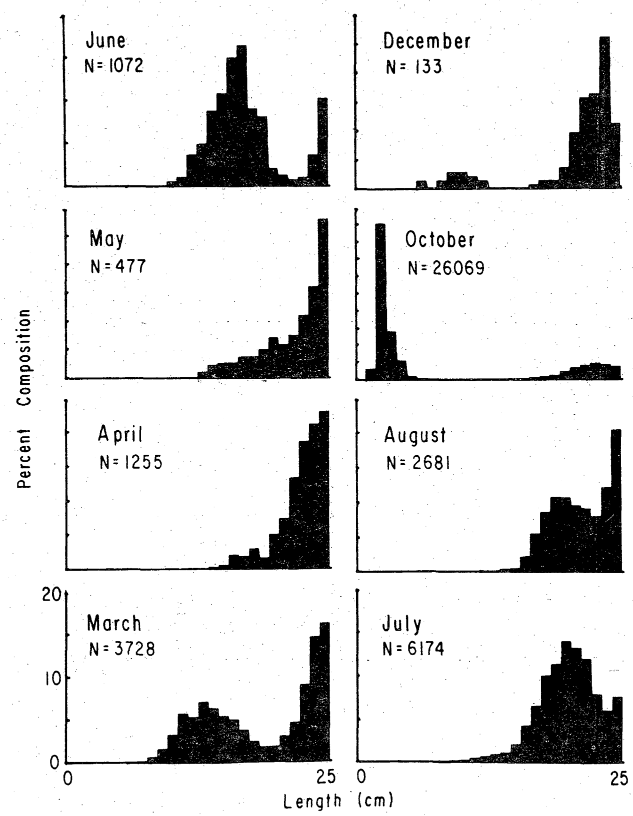

Fig. 2. Length frequencies of silver hake combined by month.

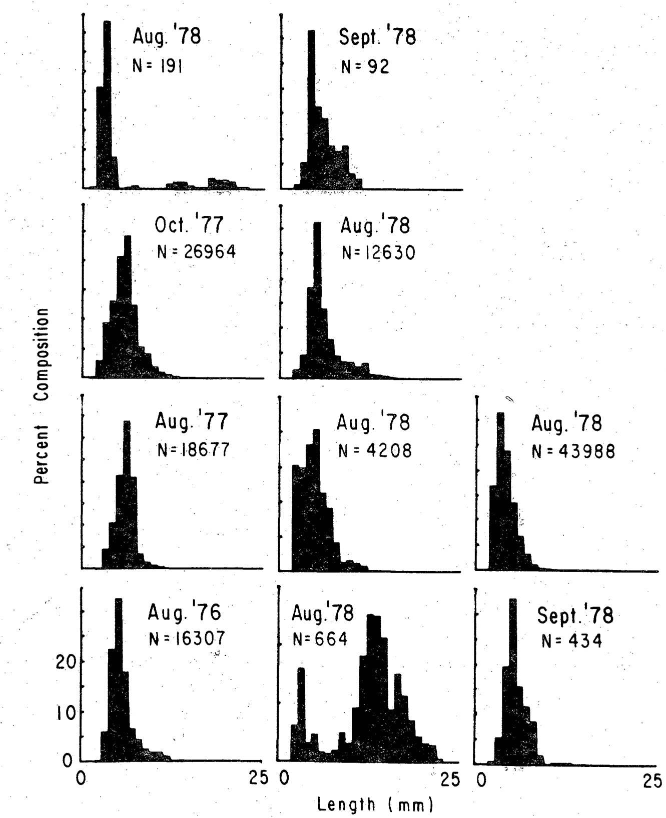

Fig. 3. Length frequencies of larval silver hake by month.

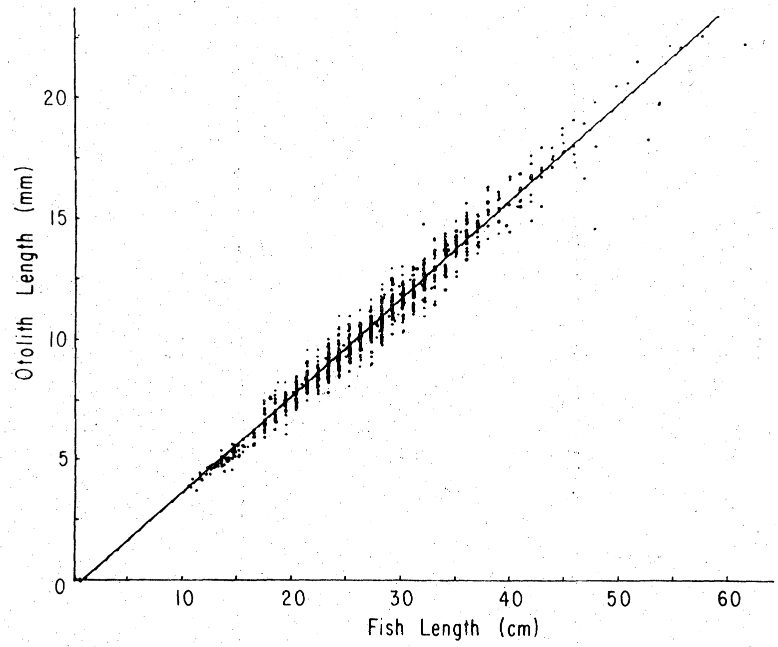

Fig. 4. Regression of otolith length against fish length for silver hake.

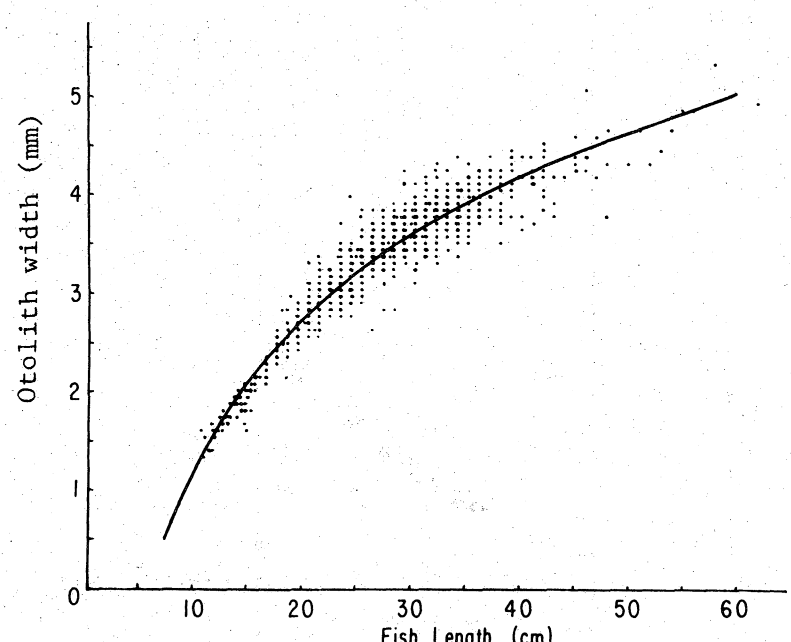

Fig. 5. Scatter diagram of otolith width and fish length for silver hake.

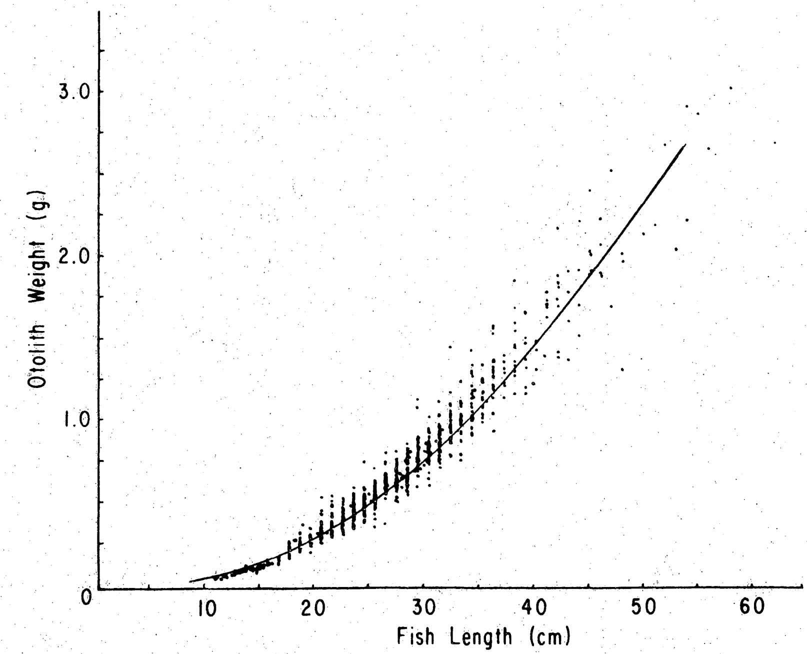

Fig. 6. Scatter diagram of otolith weight and fish length for silver hake.

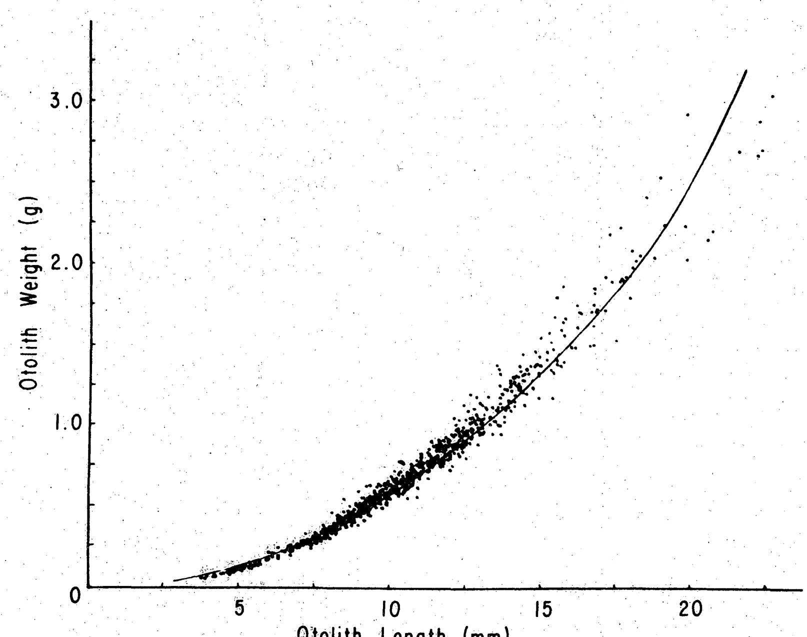

Fig. 7. Scatter diagram of otolith weight and otolith length for silver hake.

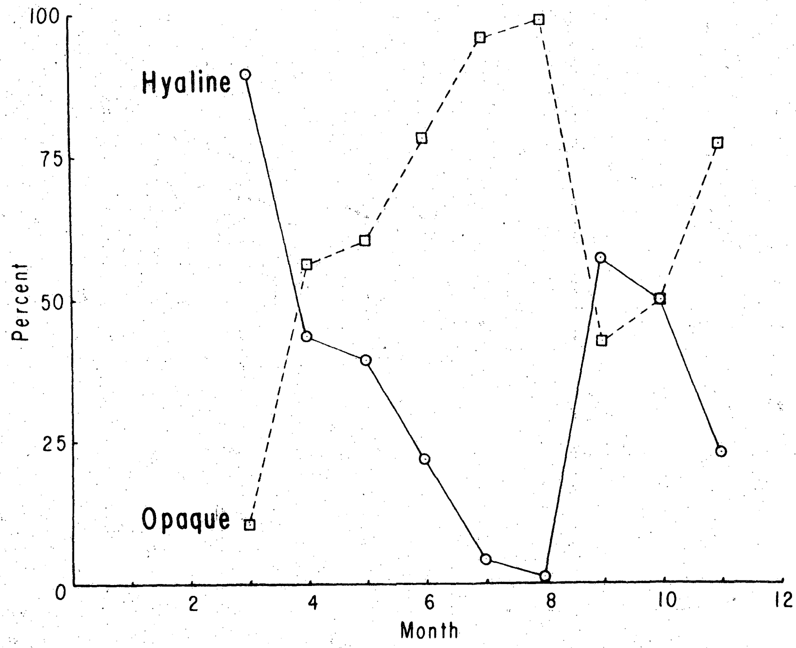

Fig. 8. Edge characteristics of silver hake otoliths by month.

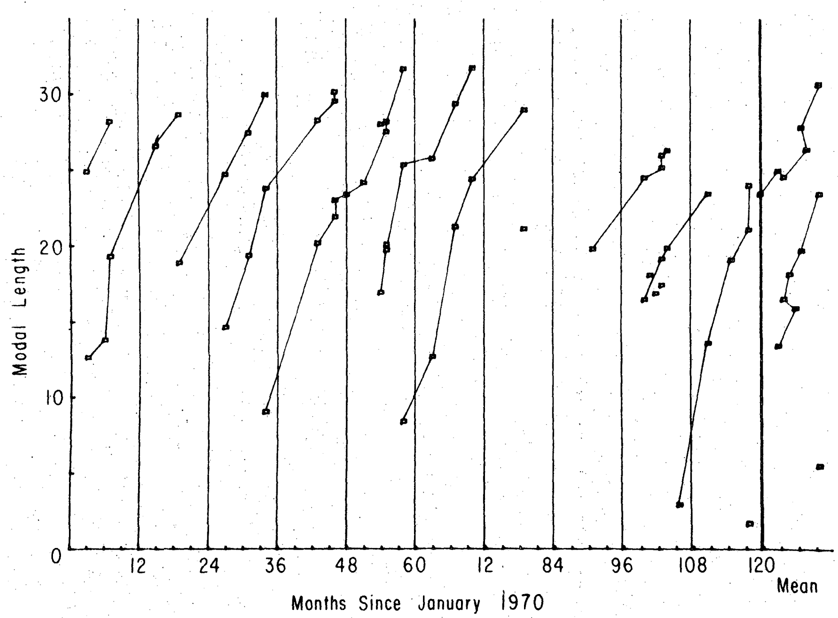

Fig. 9. Modal lengths of silver hake derived from monthly length frequencies plotted against elapsed time from January, 1970.

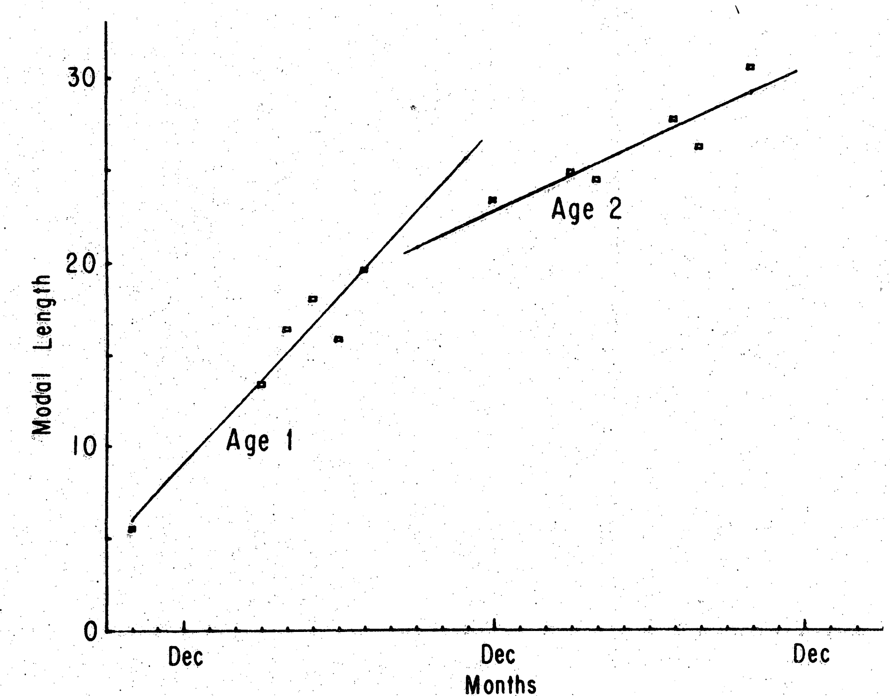

Fig. 10. Regression of modal lengths for age 1 and 2 silver hake.