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Age and Growth Studies of Silver Hake (*Merluccius bilinearis*) in the Northwest Atlantic

by

J. J. Hunt
Fisheries and Oceans Canada, Marine Fish Division
St. Andrews, N. B., Canada

Introduction

An intensive fishery for silver hake in the Northwest Atlantic since 1962 has yielded high annual catches ranging up to 300,000 tons and averaging about 100,000 tons in the Scotian Shelf area. Stocks have been managed by catch limitation since 1974 with separate quotas for Canadian and American continental shelf areas assuming discrete populations. Mesh size restrictions, geographic limitation of fishing activity, and by-catch quotas probably accounted for the small (36,000 tons) catch in 1977.

Biological sampling of commercial catches, as well as research surveys for length frequency and age distribution, have provided considerable data for this species. Historically, age structure of the population has been based on otolith interpretation but recent comparison of age estimates (Anderson and Nichy, 1975) indicated a definite lack of agreement between readers. Since 1975, a number of ageing workshops, as well as other biological studies, have been completed (Hunt, 1976, 1977, 1978) and this report attempts to summarize results of this research and provide a comprehensive guideline for determining age and associated growth parameters of silver hake in the Northwest Atlantic. Sections dealing with collection and type of samples, general biology and distribution, age determination, growth, and a reference collection of otolith photographs are included.

Collection of Biological Samples

Biological samples generally consist of a length frequency of at least 100 fish selected at random from the catch from which a detail sample is retained by stratifying one or two fish per centimeter by sex. Length should be recorded to at least the nearest centimeter and should be measured from the tip of the snout to the center or fork of the tail. Differential growth between sexes (see Growth section) necessitates separation of length frequencies into male and female components. Catch data should include location, date, gear and mesh type, and any other information which might be available.

Samples retained for detail analysis are examined for length (nearest mm, if possible), weight (nearest gm), sex (male, female) and maturity stage. Maturity is assigned on the basis of eight stages which include immature (I), ripening 1 (II), ripening 2 (III), ripe (IV), spawning (V), spent (VI), recovering (VII) and resting (VIII), and apply to both sexes.

Otoliths, scales, vertebra, or other potential structures for determining age, are removed at the time of detail sampling. Scales are generally taken from the area ventral to the lateral line and within the radius of the pectoral fin. They are stored dry and either mounted on glass slides or used to make plastic impressions. Care should be taken to ensure correct identification of fish from which scales were removed.

Vertebra are generally removed from the

dry in envelopes. Two or more vertebra are taken from the same fish for comparative examination and estimation of age.

Otoliths are extracted by making a transverse cut through the skull just posterior to the eye. Exact location of the cut varies with fish size and care should be exercised to avoid breaking the thin rostrum. Otoliths are easily seen and quite large relative to fish size. After removal, otoliths should be cleaned in water and either stored wet or dry, depending on the planned method of ageing. Dry storage is usually in paper envelopes on which relevant sample data has been recorded. Wet storage is in a 50-60% glycerine solution to which thymol has been added as a preservative. Small vials with numbered tags are frequently used to hold the otoliths until examination.

Separation of two similar species, offshore and silver hake (M. albidus and M. bilinearis) at the time of collection has proven difficult. Mombeck (1971) compared some characteristics of the two species and keys presented in Leim and Scott (1966) allow separation based on gill raker counts and lateral line scales. They report less than 12 gill rakers on the first arch and more than 130 scales on the lateral line for M. albidus and more than 14 gill rakers and less than 130 scales for M. bilinearis. Observation suggests that M. albidus have a purple sheen posterior to the operculum while M. bilinearis appear to be gold in color, when in fresh condition. As well, offshore hake appear to reach a larger size and Mercluccius sp. over 50 cm should be closely examined to ensure correct identification.

Otolith morphology is distinctly different between species, at least for fish over 25 cm. Otoliths of M. albidus become much more broad and the rostrum is less pronounced relative to M. bilineraris. General shape by species and length group is shown in Figure 1 but it is apparent that this characteristic becomes less reliable for fish under 25 cm.

General Biology and Distribution

Silver hake are encountered along the continental shelf area of the NW Atlantic from Newfoundland to South Carolina, including the Gulf of St. Lawrence and Bay of Fundy. Two generalized stocks or populations appear to be separated by the northern extent of Georges Bank. Scott (1976) reviewed the summer distribution of silver hake on the Scotian Shelf based on survey data and found it to be wide-spread with specific areas of aggregation apparently related to temperature. He suggested 6-8°C as the preferred bottom water temperature. Hunt (1978) also examined survey data and found similar distribution patterns with some variation from 1970-1976. Some segregation by size was evident with smaller (<25 cm) fish generally closer to shore. Winter distribution appeared to be more concentrated with areas of aggregation influenced by water temperature.

Distribution off the coast of USA appears to follow the edge of the continental shelf and extends from Georges Bank to about 37° latitude. Some concentration in the Gulf of Maine area has also been observed. Historically, commercial catches of silver hake in the NW Atlantic have been greatest in the first two quarters of the year, suggesting concentration suitable for intensive fishing at that time of year.

As previously mentioned, maturity of silver hake is classified into eight stages based on gonad development. Stages 3-8 indicate either pre-, active or post-spawning conditions and apply to mature fish, while stages 1 and 2 apply to immature individuals. Seasonal rate of development has not been studied and it is possible that fish classified as immature early in the year may mature and spawn for the first time late in the season. Length is generally considered to be a determining factor in achieving maturity and this relationship is usually represented by a sigmoid curve. Percent mature by length-group data from Doubleday and Hunt (1977) were used to construct such a curve for silver hake. This relationship is shown in Figure 2 based on August lengths obtained from survey results (6500 fish) from 1971-76 on the Scotian Shelf. Males and females were considered separately and lines fitted by eye suggest 50% maturity at a length of 23.9 cm and 26.6 cm, respectively. The smallest length at which a mature condition was observed was 18 cm while 34 cm was the largest observed immature fish, although fish at these lengths may be abnormal.

Spawning of silver hake takes place in summer and appears to be strongly influenced by water temperature. On the Scotian Shelf, fish in spawning condition may be observed from June through September although peak spawning is generally in mid- or late-July (Sarnits and Sauskin, 1967; Noskov, 1976) on Sable Island Bank. Spawning occurs somewhat earlier on Georges Bank and further south, and peaks in early or mid-June. Annual variation in both the peak and range of spawning period appears to be significant and may have considerable influence on juvenile growth potential. Eggs of silver hake are pelagic and are generally found close to major spawning locations. Knowledge of time and distribution of eggs is somewhat limited but they have been recorded by Noskov et al. (1978), and by Kohler (unpublished) in August and September.

Age Determination

Estimation of age for silver hake is presently based, almost exclusively, on interpretation of otoliths for the presence of hyaline and opaque zones which are assumed to represent winter and summer growth periods. Storage, preparation and examination of otoliths follow two different formats. One method consists of storing otoliths in a glycerine solution until examined for age. These otoliths are viewed in either glycerine or alcohol using reflected light at a magnification of 10-20 diameters. Hyaline zones appear translucent and in general the quality of otoliths is very good, although some masking of early growth in large fish may occur.

Otoliths stored dry become opaque and are unreadable as whole otoliths without preparation. These otoliths are presently sectioned using a macrotome and the resultant section or surface used to estimate age. Otoliths are mounted on a small paper tag using paraffin wax and require careful orientation to ensure cutting through the sulcus and at right angles to the long axis. The mounted otolith is held secure in the chuck of the macrotome and either cut in half or sectioned. A saw such as the Buehler Isomet low speed saw (Model 11-1180) with diamond grit blades has been found suitable for this purpose. One blade is used to halve the otolith while two or more with appropriate separators are used to obtain sections. Sections less than 0.5 mm thick have been determined to give the best results, but they are very fragile and care must be used to ensure they are not broken. Sections are examined using reflected light on a black background at 30-50 diameters and are frequently covered with alcohol to reduce glare. Some success in mounting sections on black plexiglass trays using a solvent such as 1, 2 - dichloroethane has been achieved and this technique will reduce handling and breakage. Hyaline zones appear translucent under reflected light and early growth is usually clear.

When otoliths have been stored dry and sectioning is not convenient or possible, some alternatives may be considered. Simple breaking of the otolith through the sulcus and polishing of the halves may yield a surface suitable for ageing. Staining (see below) may further enhance the appearance of zones. Whole otoliths may be partially cleared using several methods. Relatively fresh otoliths (< 1 month) may return to a "wet" condition by placing them in glycerine for 48-96 hours. Older samples require more preparation which consists of placing them in one of several possible solutions. Saturated saline (Na Cl) and 1-2% nitric acid or ammonia solutions have been found effective. Immersion in the saline solution for at least 48 hours and transfer to 50% glycerine provides fair results, as does immersion in acid or alkaline solutions for about 5 minutes prior to reading. However, all of the post-sampling processes give only fair results, particularly for older fish, and at present should only be considered when preferred techniques are not possible.

Staining or enhancement of otoliths zones has been attempted using a number of techniques including both chemcial and mechanical treatment. Some improvement in the appearance of hyaline zones from sections has been noted using oil of cloves. Sections are covered with the oil at the time of ageing and allowed to stand for a short time. Whole otoliths which are to be sectioned or broken may be stained with silver nitrate solution. One technique consists of immersing the otolith in dark vials for 1-2 weeks in a solution consisting of 2 gms silver nitrate in 25 ml distilled water and 25 ml ammonium hydroxide. Otoliths are allowed to darken in sunlight for 3-5 days and then sectioned or broken. As previously mentioned, treatment with acidic or alkaline solutions may also be benefitial. Numerous other straining processes, based on the varying chemical composition of hyaline and opaque zones, may be suitable for silver hake but the degree of enchancement does not presently seem to warrant the additional time required for preparation except in special studies. The use of metal ion stains may have some future advantage in detecting zones electronically.

Heating or baking of otoliths at 285°C for about 5 minutes prior to sectioning or breaking has also been found to enhance the appearance of hyaline zones but again the additional time required relative to degree of improvement does not seem justified for routine examination and age determination.

Established conventions and definitions relating to age of silver hake apply to both whole otoliths, sections and other potential ageing structures. These include birthdate, hyaline and opaque zones, nucleus, checks or false annulli, pelagic zone, spring-summer check, age group, and yearclass. Silver hake spawned in mid- to late-summer are assumed to spend their first winter as juveniles and, by convention, their age is increased by one on January first of each year they survive. This means that fish of 4-6 months chronological age become 1 year old on the first of January and their defined age continues to be 6-8 months greater than actual age for the duration of survival.

Hyaline zones are translucent and, using reflected light with a black background, appear dark in both sections and whole otoliths. Opaque zones do not transmit light and consequently appear white under reflected light. The optical appearance of zones is reversed when using transmitted light. As with most temperate water species, hyaline zones are assumed to be laid down in periods of slow growth generally associated with winter conditions. The chemical structure of otolith increments is related to growth rate and accounts for the variation in optical density of fast and slow growth periods (see Blacker, 1974). Under ideal conditions, with well defined periods of fast and slow growth, one season or year should be represented in the otolith by a distinct hyaline and opaque zone. Invariably, this situation does not occur in nature and short periods of fast growth during winter or, more frequently, slow growth in summer may be reflected in the otolith by secondary opaque or hyaline zones. These zones are termed checks or false annulli and appear to occur at random in the otolith, although a characteristic check may be present in one zone which can be related to some significant environmental stress and time period affecting a large proportion of the stock. Two such checks have been identified in silver hake and these are termed the spring-summer check (SSC) and pelagic zone (PZ). The SSC is a hyaline zone frequently found between the first and second annulus and may be very pronounced in some cases. This zone is thought to represent growth during late spring when 1-year-old fish (9-12 months) move from juvenile concentrations to mix with the adult stock with a resultant change in diet and increased competition with larger fish. It may also represent growth over the first spawning season when the potential for post-spawning growth is high and can result in a well-defined opaque zone prior to formation of winter hyaline in the otolith. Age readers should anticipate the SSC and can frequently identify it by the relative radius of the first, SSC, second, third and subsequent hyaline zones.

The pelagic zone is also characteristic of silver hake and is thought to form prior to the first winter hyaline at about 3-5 months. Juvenile hake are generally pelagic up to this age and then migrate, under the influence of temperature and food availability, to the bottom where they tend to follow a demersal existence. This change in environment is assumed to be reflected by formation of a hyaline zone. The rel·tive diameter of the PZ may range from very small (co-incident with the nucleus) to quite large (co-incident with winter hyaline) and in these extreme cases, it cannot be distinguished as a separate zone. However, in most cases, the PZ is present as a well-defined hyaline zone which may be more clear than the subsequent winter hyaline. The diameter of this zone appears to be related to geographic area and tends to decrease in size moving from north to south.

At present, hyaline zones assessed to represent winter growth are counted as annulli and age group is thus defined as the number of completed hyaline zones excluding the nucleus and can include the 0 age group. Yearclass is defined as the year sampled minus the age group. For example, a fish aged as 3 years and caught in 1977 would be assigned to the 1974 yearclass.

Time of formation of hyaline and opaque zones has not been documented other than to establish a general correlation of hyaline with winter and opaque with summer growth. As a guide, hyaline zones are thought to form from late fall (October) to late spring (May) with opaque zones laid down in May through October. Annual variation as well as differences between juveniles and adults can result in anomolous otoliths which, for example, may have no apparent hyaline edge in February. This type of otolith could arise when advantageous environmental conditions occur affecting some proportion of the stock and allowing a prolonged "summer" growth season. In the case of juveniles which have a higher growth potential, the effect of less favourable environmental conditions may be increased or require shorter exposure before becoming apparent in the otolith. Assigning an age to otoliths of this type frequently requires assumption about edge characteristic, particularly for samples collected in January or February when a hyaline edge would be counted as an annulus. Conversely, otoliths with a well-defined hyaline edge early in the fall must be carefully examined to exclude counting this zone as an annulus. In general, otoliths of fish caught on the Scotian Shelf tend to exhibit edge types consistent with season, while those from areas further to the south show more variation and are less uniform in relation to season.

Geographic variation in the relative dimension of the pelagic zone, first and second hyaline zones, and edge type have been identified as contributing factors in differing estimates of age. While some characteristics of these factors with respect to area have been observed, both intra-area and annual variation continue to limit specific classification. The pelagic zone and edge type have been discussed above. The relative size of the first annulus or hyaline zone appears to be related to area and is influenced by spawning time and environmental conditions. In general, this zone is distinct from the pelagic zone and of large diameter for fish caught off Nova Scotia, but tends to be small and similar to the pelagic zone for fish caught on Georges Bank or farther south. The second annulus is characteristically large and distinct for most silver hake regardless of area and it is frequently used as a reference to identify other annulli. Hyaline zones subsequent to the second are generally clear and increments appear to be uniform. Checks are less frequently encountered, although some tendency for spliting has been noticed.

Variation in the region of the otolith used to count zones has been identified as a possible source of different estimates of age. The entire otolith should be observed, but tendency for zones to split in the anterior (narrow) end suggest that more weight should be given to the appearance of zones in the posterior (rounded) end when counting annulli. A similar situation in sections implies preferred use of the ventral (rounded) aspect.

As indicated above, variation in the relative dimension of the pelagic zone, first annulus and the SSC both within and between areas creates problems in interpreting juvenile growth. The combinations of these zones are shown in Figure 3 where dimensions are classified as S-small, M-average, L-large and A-absent or co-incident with another zone. Possible interpretation of the various types is indicated and these are assessed as 1-correct age and interpretation, 2-correct age but incorrect interpretation. While all of the types are possible, some occur more frequently within geographic areas and these are identified by X-Scotian Shelf, Y-Gulf of maine, and Z-Georges Bank and south. Relative dimensions of the zones based on otolith measurement data of Hunt and Stuart (1978) for Scotian Shelf fish are shown below:

Zone	Mean (mm)		Standard Deviation	
	Radius	Diameter	Radius	Diameter
Pelagic	2.2	4.2	1.67	2.92
1	3.3	7.1	1.47	2.39
SSC	4.8	11.2	3.04	6.52
2	5.0	11.7	1.38	2.16
3	6.0	14.2	1.35	2.08
4	6.7	16.1	1.42	2.26

The value for the pelagic zone is probably over-estimated because of masking in whole otoliths of central zones, and the standard deviation of the SSC measurement suggests some incorrect classification.

Exchange of ageing material between readers is a continuing part of silver hake age determination. These samples should consist of both the whole glycerine-stored otolith and a section (or polished half) and include all relevant catch data, fish size and sex, and photographs. To facilitate discussion of interpretations, a code suggested by Hunt (1977) should be followed as shown below:

(i) Hyaline zones - winter growth

- VNH - very narrow hyaline, winter edge just visible
- NH - narrow hyaline, winter growth starting
- H - hyaline, winter edge well formed
- WH - wide hyaline, winter edge almost complete

(ii) Opaque zones - summer growth

- VNO - very narrow opaque, summer growth just visible
- NO - narrow opaque, summer growth starting
- O - opaque, summer growth well formed
- WO - wide opaque, summer growth almost complete

(iii) Classification of hyaline zones

PZ - pelagic zone

SPL - split zone

C - check or false annulus

SSC - spring-summer check

$\underline{\quad}$ - strong or clear zone (under line)

$\overline{\quad}$ - weak or diffuse zone (over line)

(iv) 6(5) - preferred age 6, possible age 5

2? - indicated age inconsistent with other data (e.g. length)

A typical code for an age 4 fish might be:

$\overline{\mathrm{PZ}}$, $\underline{1}$, SSC, $\underline{2}$, SPL3, 4, NO

<u>Age Validation</u>

Establishing the true age of a fish can be accomplished in both direct and indirect ways. Direct methods include multiple reading of the same structure, comparison of different structures and growth related studies such as tagging. Indirect methods consist of comparison of a year-class over a number of years in terms of consistency of age composition, and by analysis of frequency distributions.

Multiple reading of otoliths, either by the same reader or by other readers, does not prove age but rather ensures consistency in interpretation. Discussion or justification of the estimate of age makes it necesssary to relate the interpretation to probable life history and any inconsistencies usually become apparent. Comparison of different structures is based on the premise that changes in growth rate should be reflected in all indicators. A zone which is apparent in otoliths but missing in scales, vertebrae, etc. must be explained on the basis of growth or other physiological factors and can frequently be discounted as an annulus. Comparison reading of otoliths, scales and vertebrae are presently being conducted but are not yet complete.

Tagging of fish and subsequent recapture can yield information on age by establishing minimum possible age (time-at-large) which can be related to otolith zones. If the interval between release and recapture is sufficiently long and if fish measurements were taken at release, then some increment in size can be calculated. The relation between fish length and otolith (or scale) size can then be used to outline growth of the otolith over the time interval and the number or characteristics of zones within this increment related to annulli. Similar results can be obtained by injecting the fish with some chemical, such as tetracycline, which causes a visible mark to be laid down in the otolith identifying size at time of release. Tagging of silver hake has not recently been attempted but could provide some valuable data on stock boundaries and growth related studies. Some unique characteristics in otolith morphology specific to a year-class can frequently be used as a biological tag to identify this age group in subsequent years.

Indirect methods of validation do not consider individual fish but relate age composition based on otolith interpretation to other estimates for evidence of consistency. One method is to compare age composition over a number of years and, by following one year-class, to assess the probability of incorrect aging. Using a technique such as cohort analysis, in which catch by age group is related to fishing mortality yielding estimates of population numbers by age group, unrealistic changes in population structure or mortality may be traced to incorrect ageing. However, only gross changes will be apparent and the method is further limited by requirement for accurate estimates of fishing mortality and other input parameters.

Analysis of length frequencies for evidence of normal components assumes that the distribution of lengths within a yearclass is normal and that the degree of overlap between adjacent age groups is small. Silver hake grow rapidly as juveniles and appear to be well suited to frequency analysis. Many methods are available for isolating components and most require transformation of the frequency. One method used by Hunt (1978) consists of transforming the frequency to natural logarithms and then fitting parabolas by least squares to apparent modes. This method uses a logarithmic transformation since the transformed equation of a normal distribution is reduced to a parabola of the form

$$\ln Y = A + BX + CX^2$$

where

mean $= \mu = -B/2C$

standard deviation $= \quad = -1/2C$

proportion $= K = -\pi/C \,.\, \mathrm{EXP}\,(A - B^2/4C)$

The method requires visual inspection of the tranformed frequency distribution to select lower and upper intervals of length to which the parabola is fit. Assuming younger age groups to be the most discrete, modes are resolved from left to right and the residual frequency remaining after the contribution of each calculated mode is removed and examined for additional age groups. An example of this method using known values is shown in Figure 4 and results indicate a good degree of accuracy. The derived values of mean, standard deviation and proportion for catch frequencies can be compared to values from age-length keys and significant differences may be attributed to either incorrect ageing or other potential causes.

In summary, age detrmination of silver hake, based on interpretation of otoliths or other criterion, is subject to several conventions or definitions of anticipated otolith types. Geographic variation introduces more difficulty and limits any general statement concerning estimates of age. However, this variation appears to be confined to juvenile growth while adult (> 2) growth is reflected in the otolith by relatively clear and uniform increments subject to usual checks or splits. Further clarification of juvenile growth and otolith types awaits additional data on spawning variation, stock separation, year class variation, etc.

Growth

Attempts to describe growth of sivler hake are obviously influenced by interpretation of otoliths or other methods of estimating age. Given the present degree of uncertainty about juvenile growth or size at age, the accuracy and validity of growth curves based on these data are limited to general conclusions within specific geographic areas.

Two recent studies of silver hake length at age have provided estimates of growth rate on the Scotian Shelf. Hunt (1978) examined length frequencies from research survey cruise data by a technique of modal analysis. Estimated modal lengths were plotted on a time scale and points joined to give a series of curves assuming a growth rate based on the von Bertalanffy model. Significant differences between males and females larger than 24 cm were found and the resultant averaged growth curves are shown in Figure 5. Calculated values of asymptotic length for males (36.01 cm) agrees with observed lengths in the fishery but that for females (37.88) appears to be lower than maximum observed length (60+ cm), although fish greater than 38 cm do not presently constitute a significant proportion of the population.

Hunt and Stuart (1978) measured the relative dimension of otoliths distribution patterns. To relate results to spawning duration and apparent growth, it is necessary to have duplicate cruise data over a relatively short time interval. Such data are not presently available.

Results of a joint USSR-Canada plankton survey (Noskov et al., 1978) suggest progressively later spawning in moving from west to east on the Scotian Shelf. They found significant numbers of silver hake eggs on Sable Island Bank in late September in addition to larvae ranging from 2-21 mm with a mean length of 6.43 mm. Larvae caught to the east averaged 5.40 mm while those caught to the west (Browns Bank) averaged 10.14 mm. However, the total number caught (1135) was small which suggests the date of the cruise may have been after peak concentrations and that growth and dispersion of earlier spawned larvae permitted avoidance of the sampling gear.

A survey of the Scotian Shelf conducted by Canada in 1976 caught significant numbers of silver hake larvae in mid-August. Largest catches were in the Browns and Sable Island Bank areas and length frequencies are shown in Figure 7 by area. A total of 15943 larvae were caught and measured, 1944 from Browns Bank and 13999 from Sable Island Bank, and mean lengths were 7.19 mm and 5.38 mm, respectively. Modal lengths occured at 6.59, 10.46 and 12.02 mm for Browns Bank and at 4.81, 8.00, and 12.17 mm for Sable Island Bank which suggests later spawning in moving from west to east and agrees with Noskov et al. (1978). His data were collected in late September compared to mid-August for the Canadian survey and this suggests that silver hake spawning can occur from at least early August to mid-September. Such a range in spawning duration would have a significant effect on the size at age 1, particularly, if early growth is rapid.

Otolith Photographs

Otolith photographs of various characteristic types are shown below. The whole glycerine-stored otoliths were selected and all prints are at the same total magnification. Interpretation of the otolith is indicated for each otolith following the code suggested above and summarized in Table 1. Photographs were taken with a Nikon F camera with 85 mm bellows extension and 55 mm Micro Nikkor lens in normal position. Light source consisted of two American Optical microscope lamps 12 cm from the subject and inclined at 45 degrees. Incident light was blue filtered and the camera lens filtered with No. 29 (dark red) Tiffon filter. Exposure was 1 second at F11 using Kodak Panatomic X.

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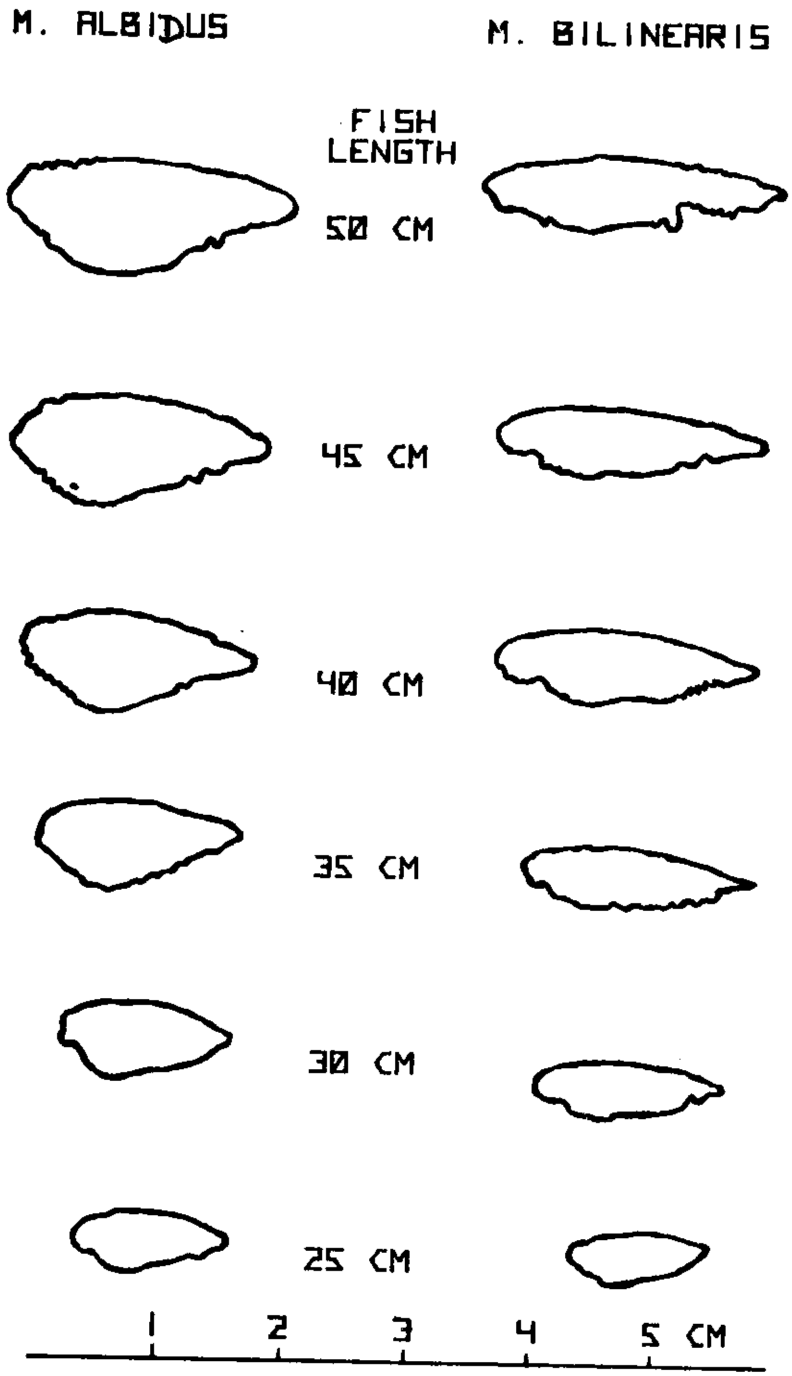


FIGURE 1. OTOLITH MORPHOLOGY OF OFFSHORE AND SILVER HAKE RELATIVE TO FISH SIZE

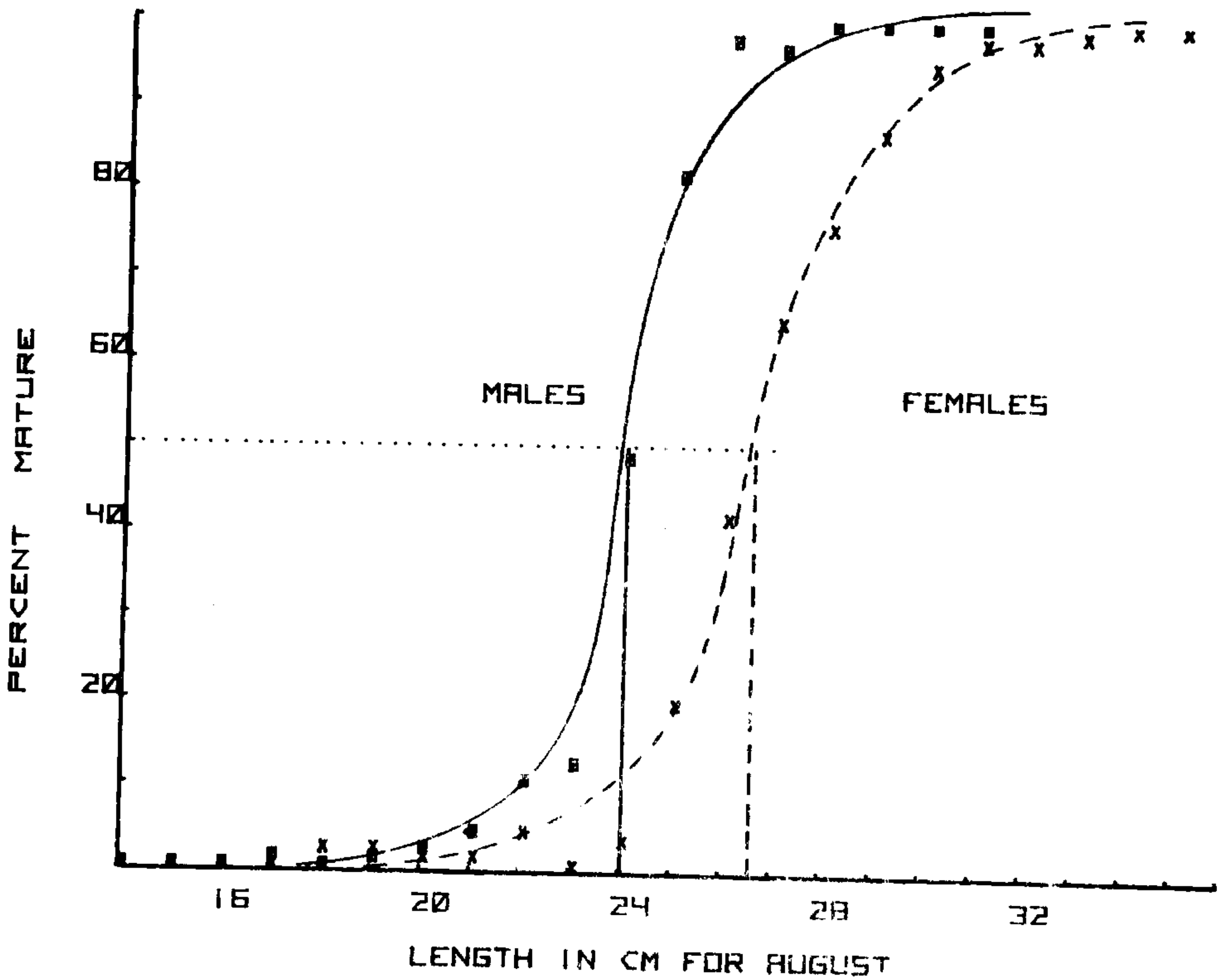
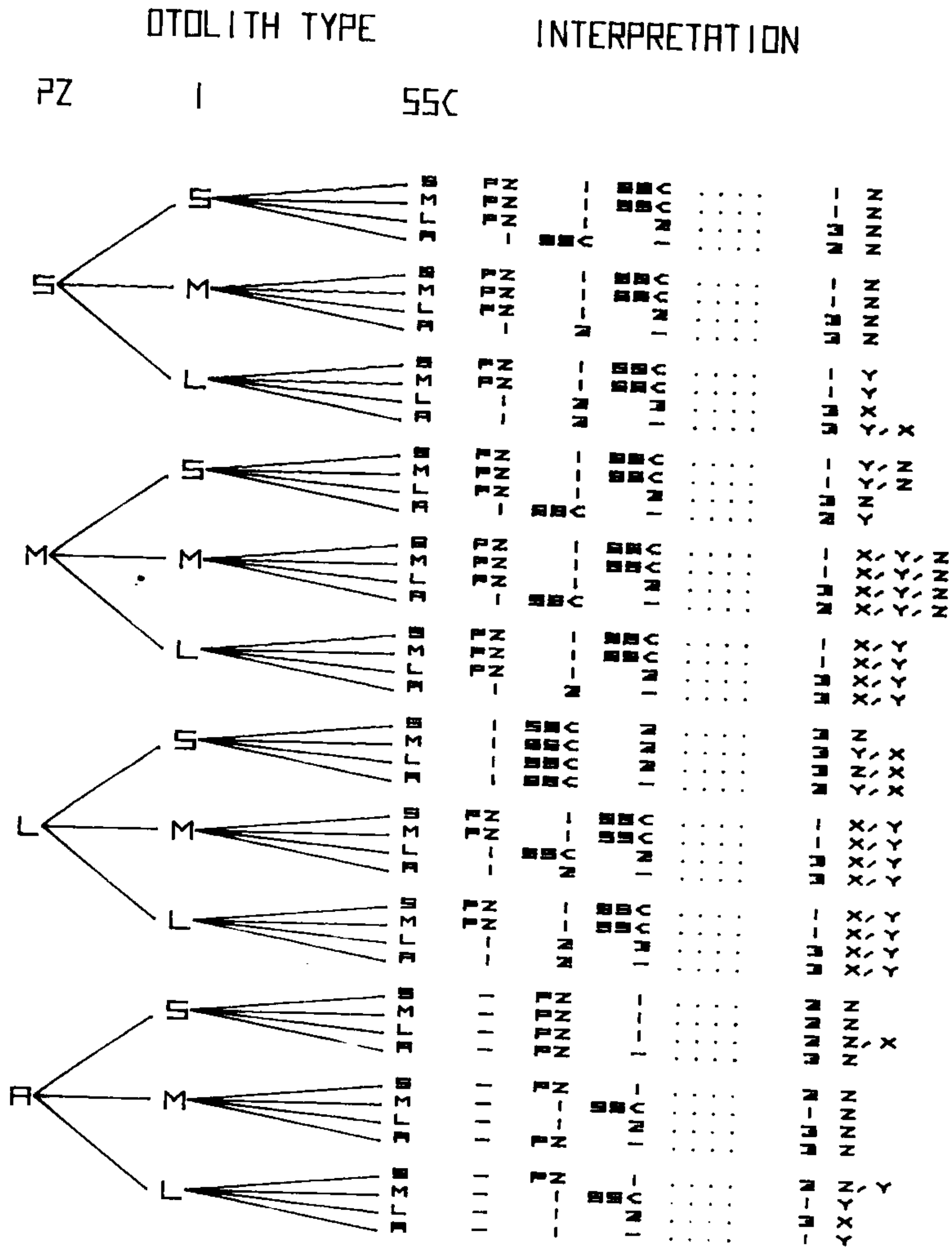


FIGURE 2. MATURITY OGIVE BY SEX IN AUGUST



S – SMALL M – AVERAGE L – LARGE
A – ABSENT OR CO-INCIDENT WITH ANOTHER ZONE

1 – CORRECT AGE AND INTERPRETATION 2 – CORRECT AGE BUT INCORRECT INTERPRETATION 3 – INCORRECT AGE

FIGURE 3. POSSIBLE OTOLITH TYPES AND INTERPRETATIONS

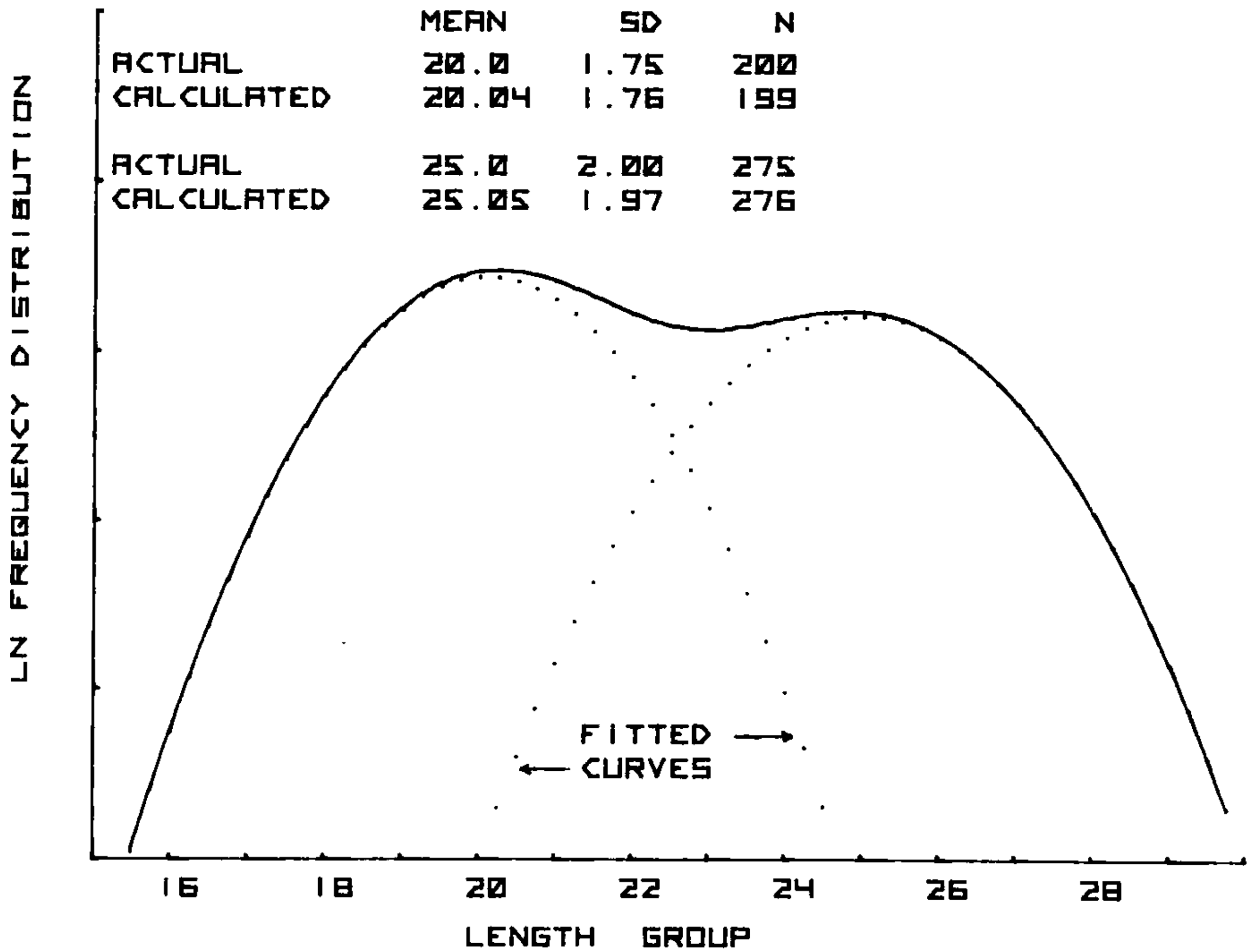


FIGURE 4. COMPARISON OF ACTUAL AND CALCULATED VALUES OF GAUSSIAN COMPONENTS

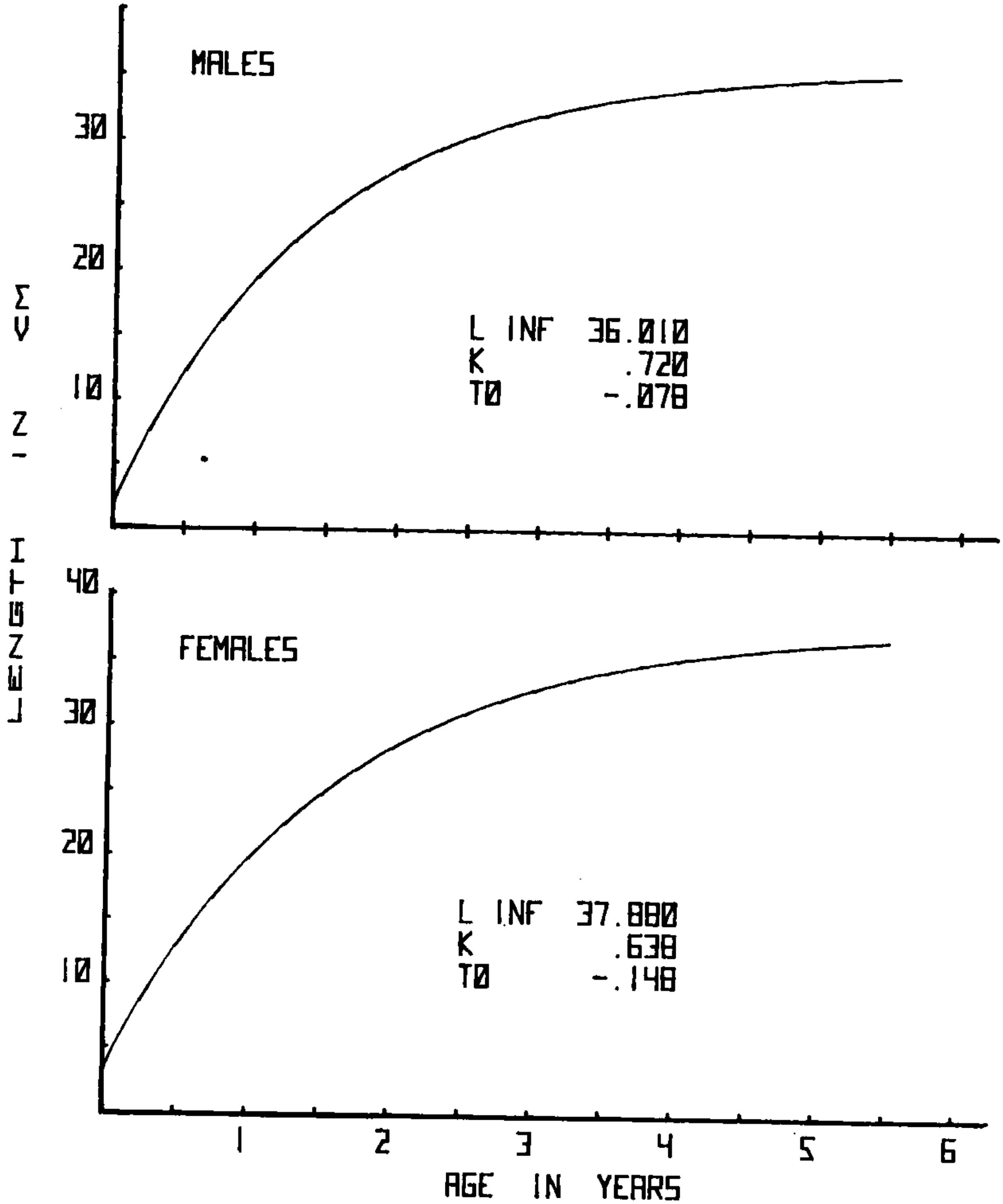


FIGURE 5. VONBERTALANFFY GROWTH CURVES
AFTER HUNT 1978

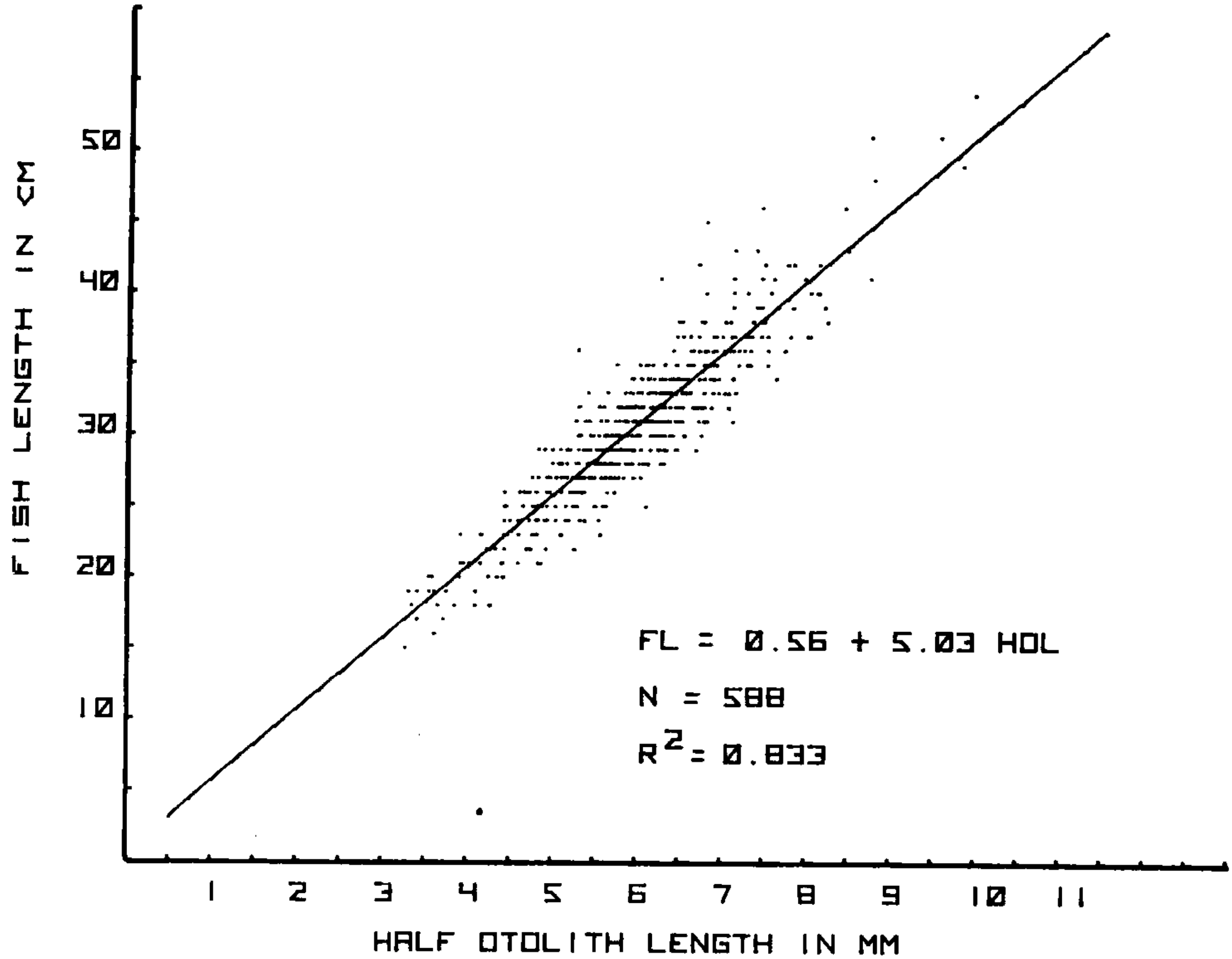


FIGURE 6. REGRESSION OF OTOLITH AND FISH LENGTH

Data on larval growth of silver hake are presently limited to research crusie results which have provided length frequencies and

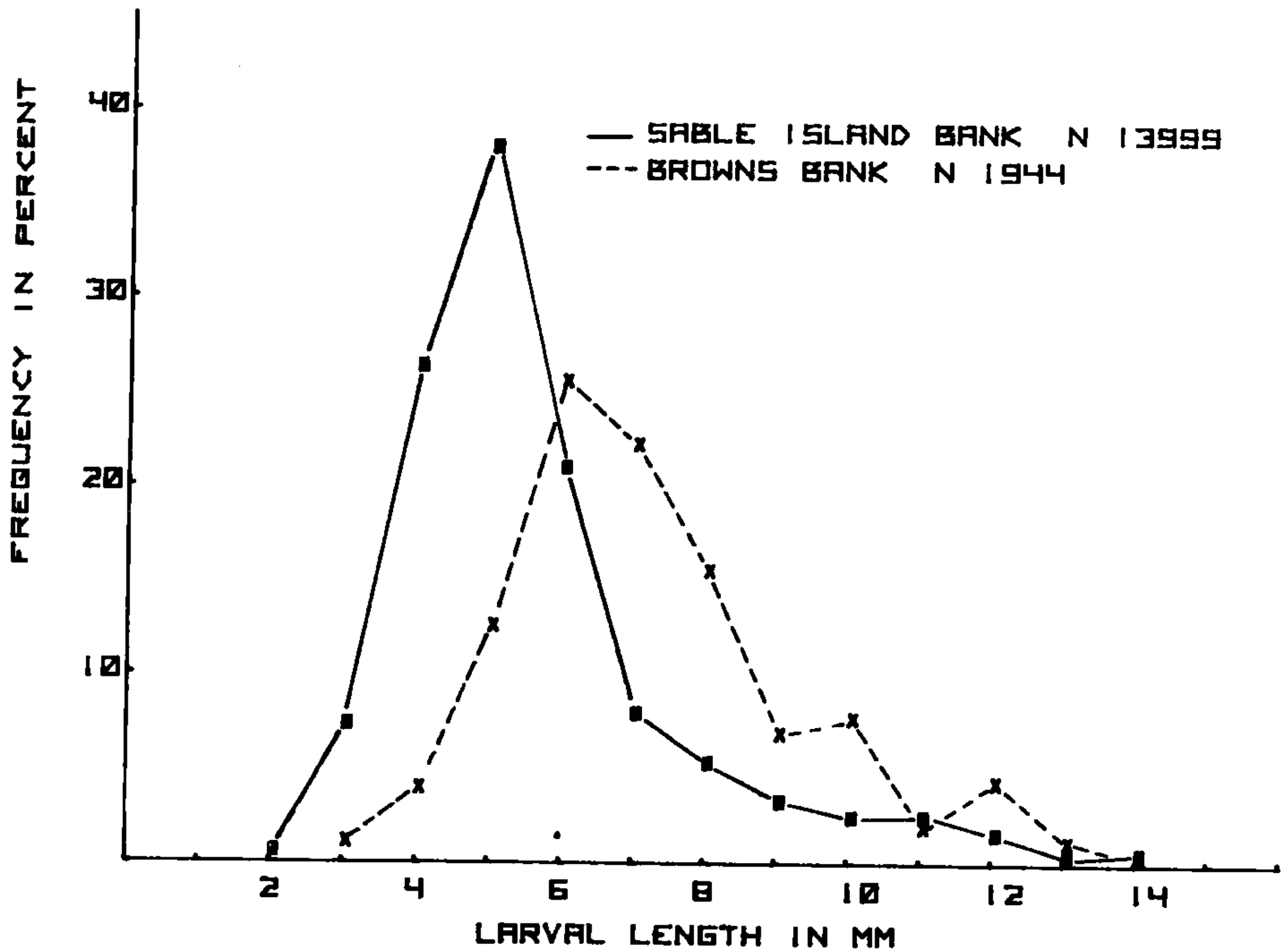
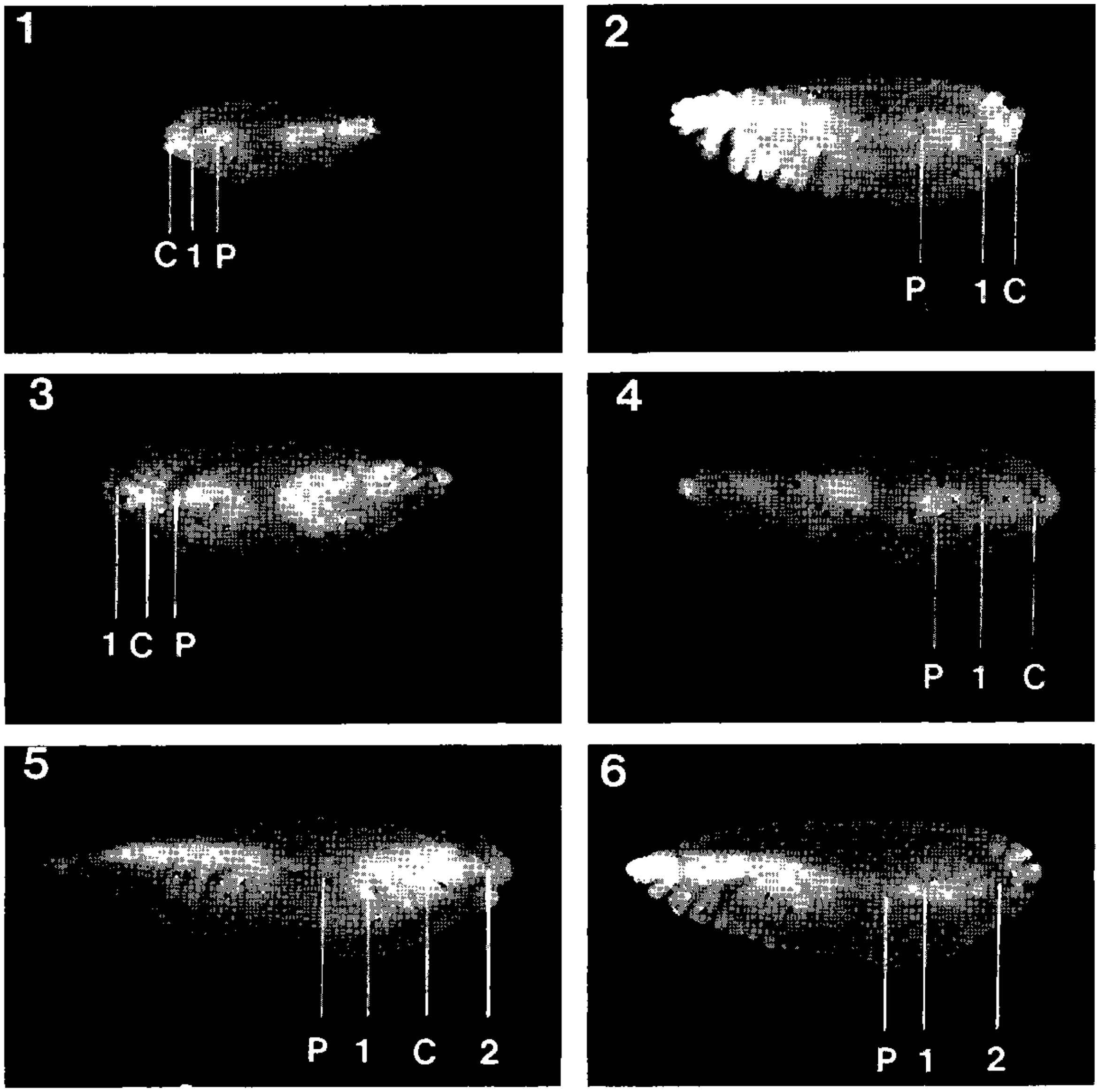
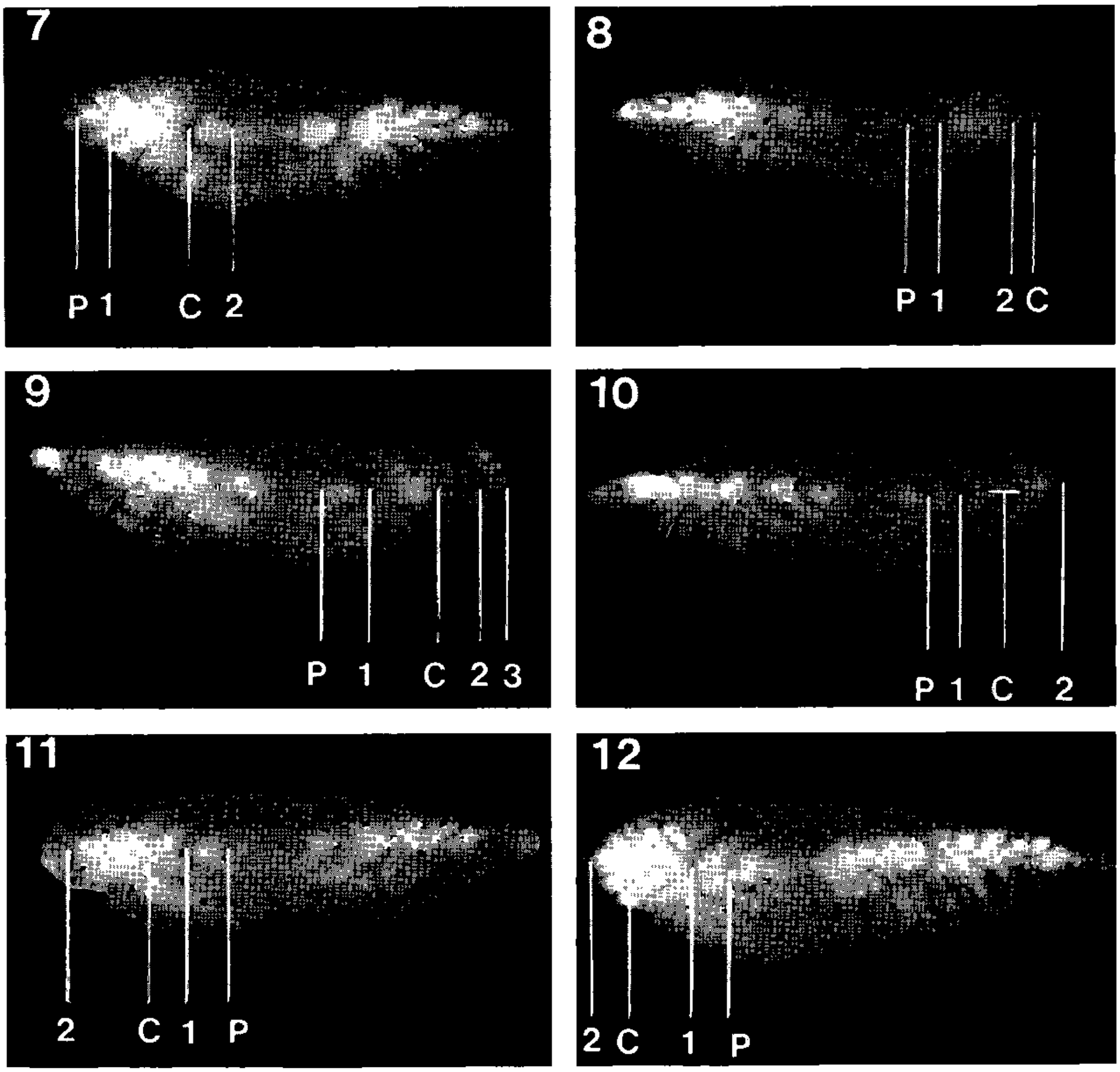


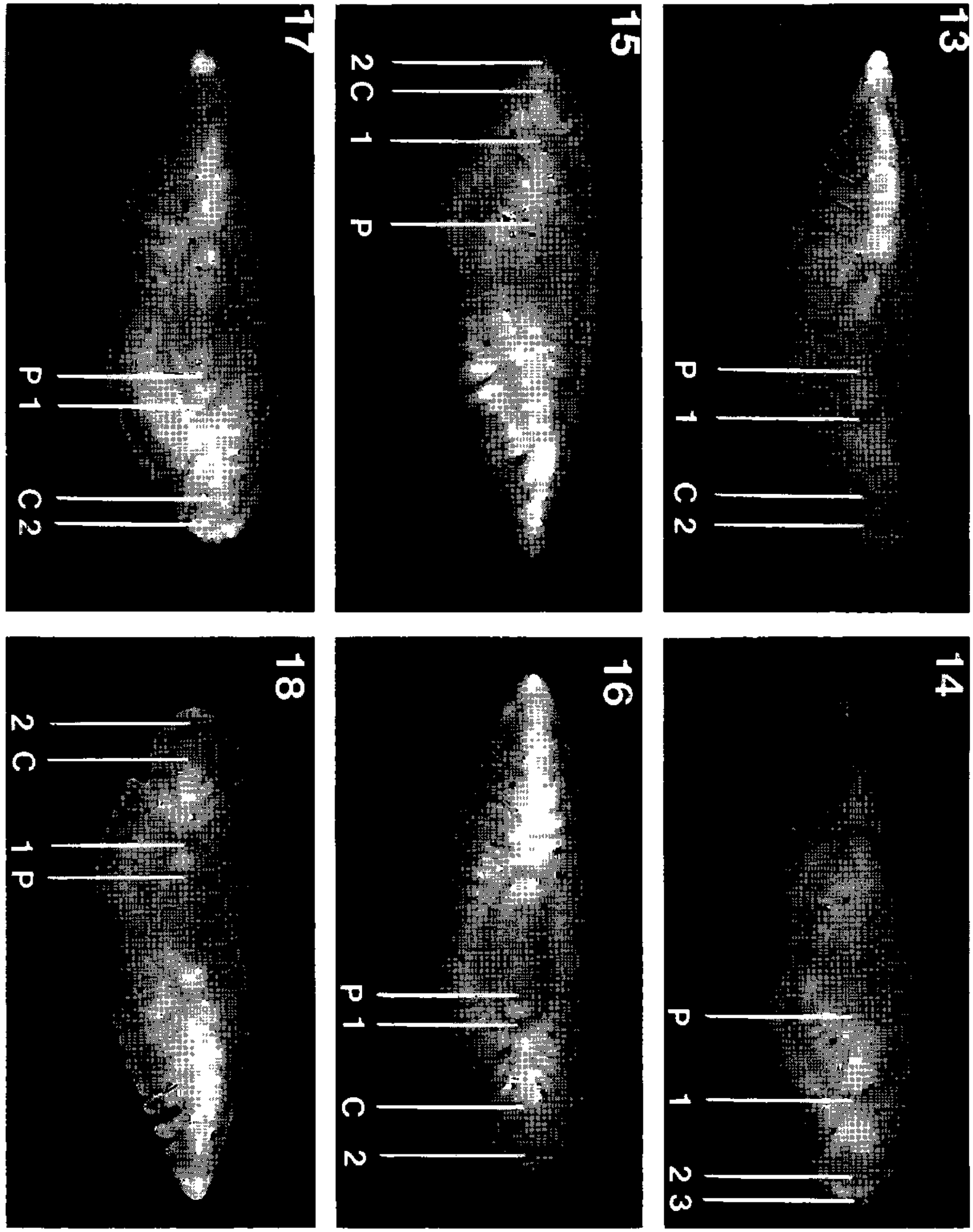
FIGURE 7. SCOTIAN SHELF LARVAL SILVER HAKE 1976

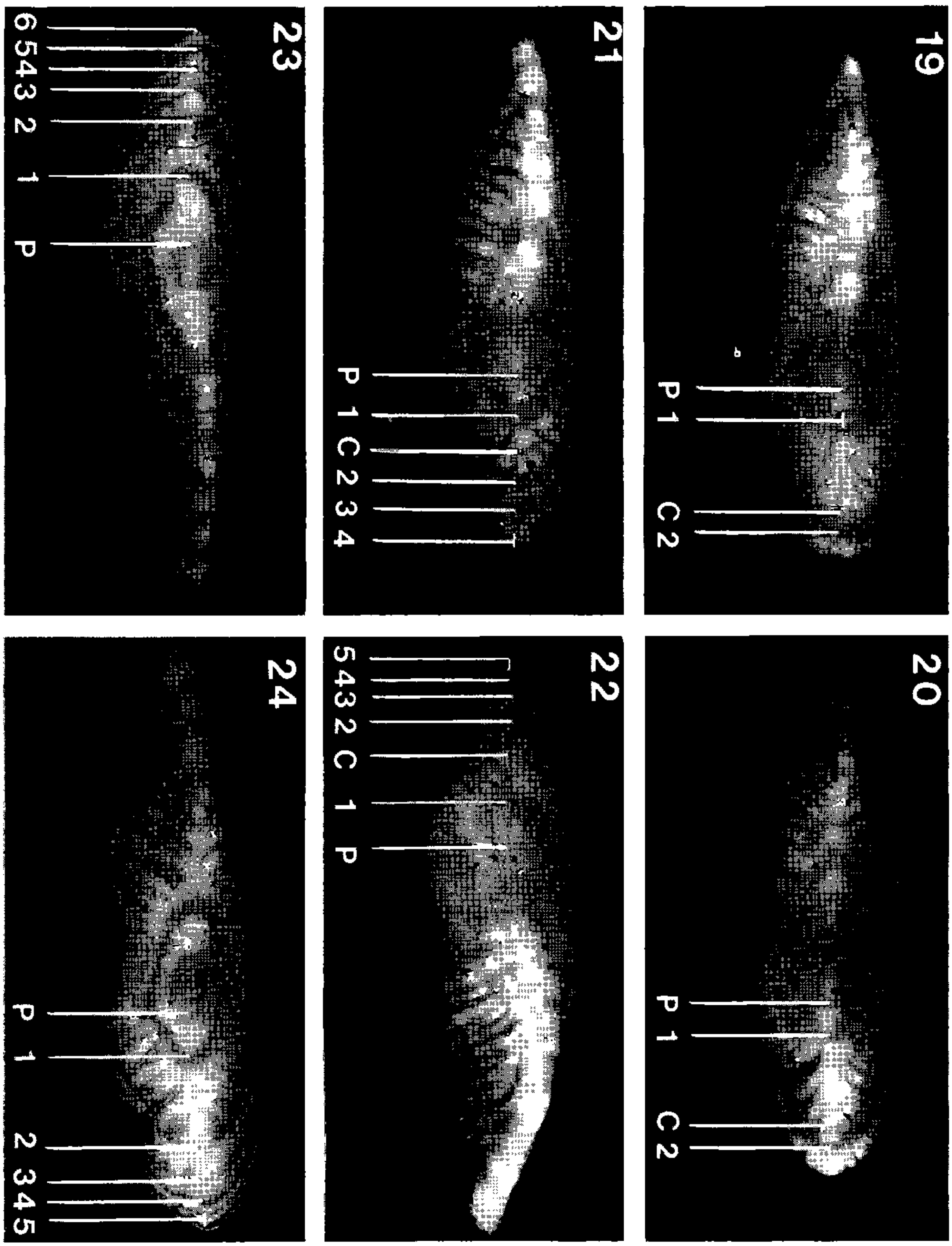
OTOLITH NUMBER	DATE	LENGTH CM	SEX AND MATURITY	INTERPRETATION
1	MARCH	11	0/1	P 1 C
2	JULY	21	2/1	P 1 C
3	JULY	20	1/1	P C 1
4	MARCH	23	2/1	P 1 C
5	JULY	26	1/2	P 1 C 2
6	JULY	22	1/1	P 1 2
7	MARCH	25	1/1	P 1 C 2
8	MARCH	23	2/1	P 1 2 C
9	JULY	27	2/8	P 1 C 2 3
10	JULY	27	1/3	P 1 C 2
11	JULY	25	1/2	P 1 C SPL2
12	JULY	29	2/2	P 1 C 2
13	JULY	32	2/2	P 1 C 2
14	MARCH	32	1/8	P 1 2 3
15	JULY	29	2/3	P 1 C 2
16	JULY	33	2/3	P 1 C 2
17	JULY	33	2/2	P 1 C 2
18	JULY	31	2/2	P 1 C 2
19	JULY	32	2/2	P SPL1 C 2
20	JULY	31	2/3	P 1 C 2
21	MARCH	30	2/7	P 1 C 2 3 SPL4
22	JULY	35	1/2	P 1 C 2 3 4 5
23	JULY	36	2/2	P 1 2 3 4 SPL5 6
24	JULY	35	2/2	P 1 2 3 4 SPL5
25	JULY	37	2/2	P 1 SPL2 SPL3 4
26	JULY	42	2/2	P 1 2 3 C 4
27	JULY	42	2/7	P 1 C 2 3 4 5 6 7 8
28	JULY	42	2/3	P 1 C 2 C SPL3 4 5
29	JULY	44	2/3	P C 1 2 SPL3 4
30	JULY	50	2/4	P 1 2 3 4 5 6

TABLE 1. INTERPRETATION OF OTOLITH PHOTOGRAPHS

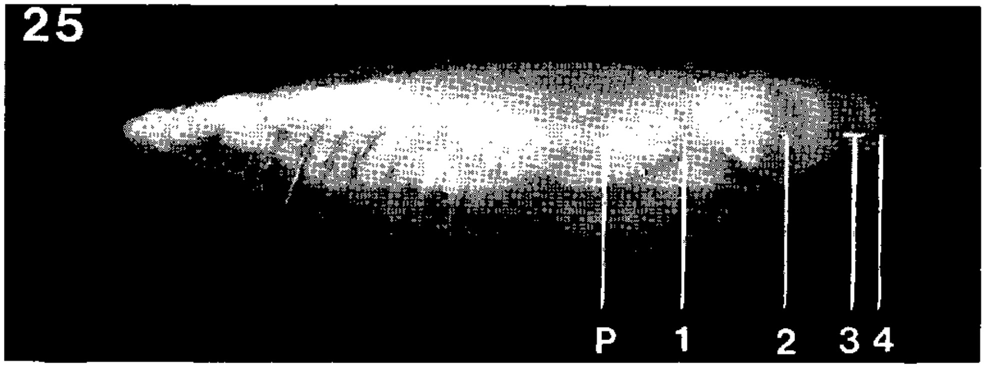

1
C 1 P
2
P 1 C
3
1 C P
4
P 1 C
5
P 1 C 2
6
P 1 2

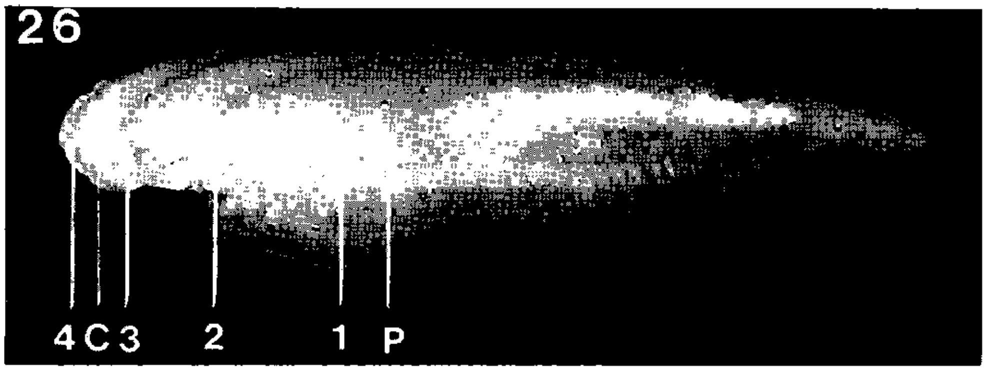

7
P 1 C 2
8
P 1 2 C
9
P 1 C 2 3
10
P 1 C 2
11
2 C 1 P
12
2 C 1 P

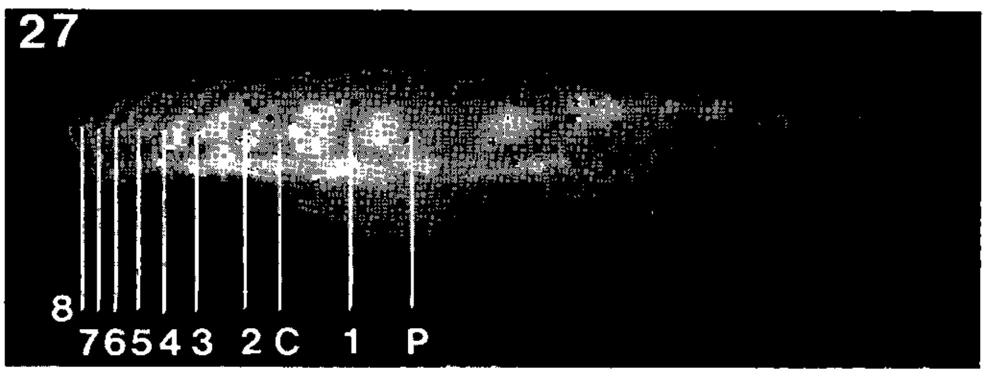

13
14
15
16
17
18

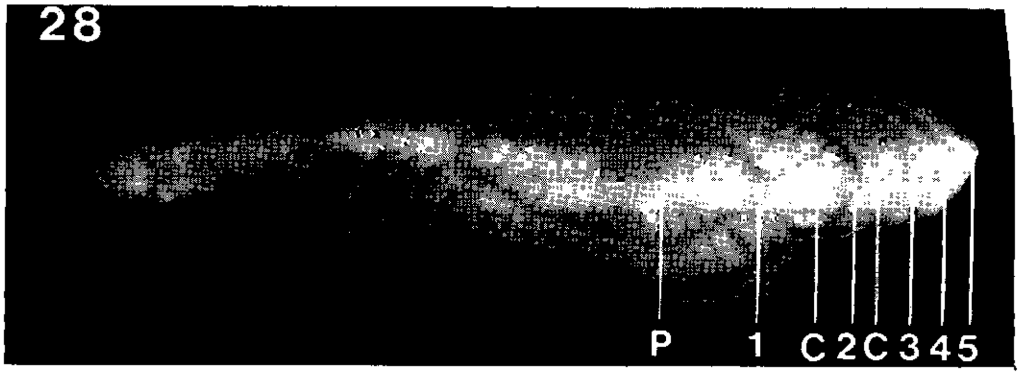


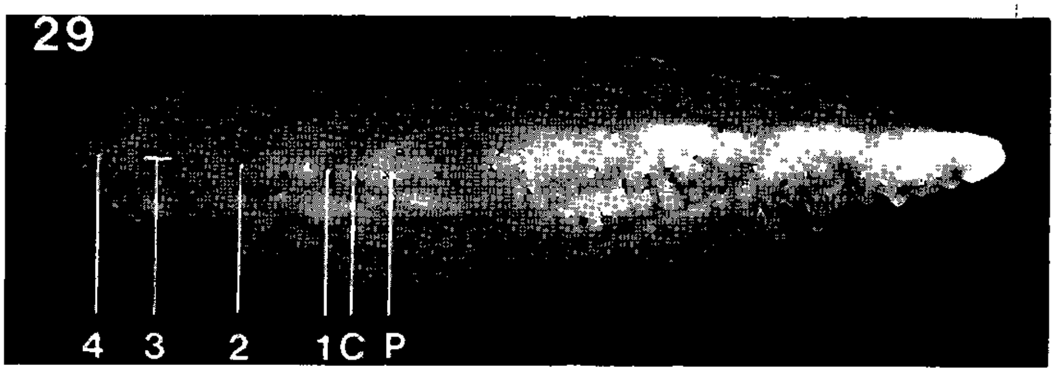
F1

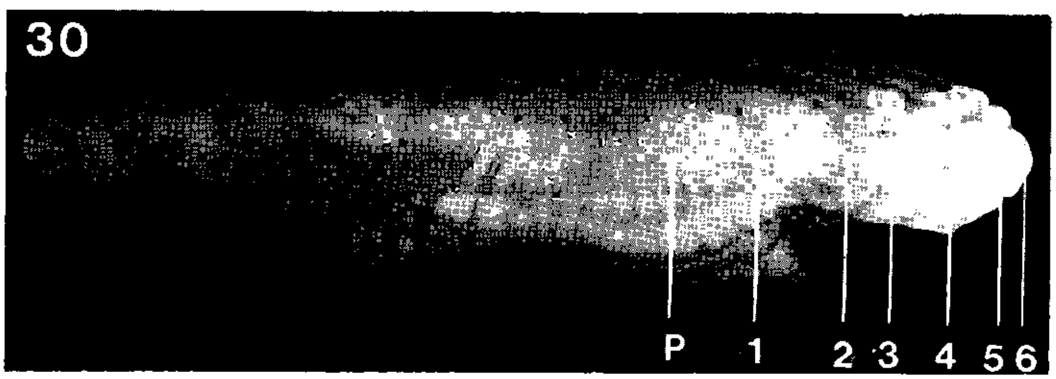

25
P 1 2 3 4


26
4 C 3 2 1 P


27
8
7 6 5 4 3 2 C 1 P


28
P
1
C
2
C
3
4
5


29
4
3
2
1
C
P


30
P
1
2
3
4
5
6