Northwest Atlantic Fisheries Organization

Serial No. N2085 NAFO SCR Doc. 92/37

SCIENTIFIC COUNCIL MEETING - JUNE 1992

Age Determination Methods for Nova Scotian Hake

by

L. V. Shcherbich, A. P. Senina, Yu. A. Markov

Atlantic Scientific Research Institute of Marine Fisheries
and Oceanography (AtlantNIRO)
5 Dm. Donskoy Str., 236000, Kaliningrad, Russia

ABSTRACT

The work finishes the 26-year-long scientific discussion between Canadian and Russian scientists on the problem of age-length relation for the age group 1 of Scotian hake (Noskov, 1966; Sauskan, 1966; Senina, 1966; Hitchi, 1965). The Canadian point of view was adopted as an official one (Hunt, 1976, 1979) according to which fish up to 25 cm in-length with moda of 20-23 cm is considered as 1-year-old. We have shown at diurnal level that fish of 20-25 cm, caught in April, was aged as 500-550 days old, and belonged to the last but one spawning, not the last one, as assumed before. Thus, the first age group, presented by Hunt (1978, 1979), is actually divided into 2 year-classes of 1-year-olds and 2-year-olds. Estimates of all annual growth zone radii of otolith, fish mean length-at-age, length-age relation in days, visual sings of annual and additional rings are presented in the article. Results in express-analysis of fish age.

INTRODUCTION

At least 4 hake populations are available in the shelf area of the Northwest Atlantic varied greatly in growth rates. Levels of panmixia between the populations mentioned have not yet been established (Konover, Flitz, Vieira, 1961). In the present paper Nova Scotian hake is taken as one of the most exploited populations which is fished during dozens of years. Interest shown by the scientists to the age of fish is quite natural as accuracy in estimating age composition of catches is of great importance for evaluation of total stock size and total allowable catch, primarily as far as recruitment (1-2-year-old fish) is concerned. But just for these age-groups and their age-length relationships different opinions and discrepancy can be observed (Noskov, 1966? Sauskan, 1966,1967; Senina, 1966; Anderson, Nicky, 1975; Hunt, 1977, 1978, 1979, 1989). Taking into account that the first age-group is the starting point for

the subsequent years we can realize the urgency of the problem.

It should be stressed that 1 and 2-year-olds have rather distinct growth zones which are readable in 90-95% of fish. It was confirmed during mutual otolith interpretation made by the Russian and Canadian scientists in March 1990. At that time we agreed with the interpretation of the otolith centre suggested by the Canadian side. During separate reading degree of concurrence exceeded 90% (Hunt, 1991). Further each side pledged to develop age determination technique using unconventional methods. Then the techniques developed will be compared and agreed conclusion will be made.

Results of our surveys on juvenile hake otolith microstructure and latest literature data are included into the present paper.

First age determination method for the Scotian hake were suggested by Hunt (1976, 1979). The principal result. i.e. relationship "fish age-fish length at a given age" was obtained without analysis of such structures as scales and otoliths. The author used modal analysis of length frequencies obtained during conducting trawling surveys between 1970 and 1976.

Method of modal analysis includes plotting of frequency natural logarithm for each length interval (in this case 1 cm) and approximation of parabolas to the trus mode using the least-square method. The major conditions for the method application are the normal length distribution at a given age for each group, minimum coincidence in subsequent age-groups, modal length of one fish group should not be less in subsequent months and fish mode should not stand out from length row frequency in the next time interval. As a result fish aged 1 can approach to 25 cm in length by March-April (Hunt, 1976, 1979).

In age-length keys constructed using data od annual April-June trawling survey on abundance length of 1-year-olds ranged from 0 to 25 cm with the modal length of 20-23 cm.(Hunt, 1977, 1978; Waldron, 1991).

What forced us to revert to the problem? Some doubts about correctness of the existing age determination method for the

younger age groups (fingerlings, yearlings and 2-year-olds). They are as follows:

1. According to Noskov (1966), Senina (1966), Sauskan (1967) mean length of larvae at hatching is 2.8 mm. At the end of summer and in autumn of the first year fish were 2.5-7.5 cm in length and in February and April-May of the second year of the life cycle they had length between 3.0-10.0 cm and from 5.0 to 18.8 cm, respectively.

This year growth rates and age for Scotian hake larvae and fingerlings at a length of not more than 3.25 cm were studied (Markov, Sherstyukov in press). Age of juvenile hake 3.0-3.25 cm in length was shown to be 75 days. If this growth rate is assumed to be the same up to the age of 5-9 months. i.e. up to the April surveys, then mean monthly increment will be 1.3 cm. Thus, 5-9year -olds will be 6.5-11.7 cm in length.

These calculated data are close to the observed ones (Noskov, 1966; Sauskan, 1966, 1967; Senina, 1966; Nicky, 1967; Sherstyukov, 1990), to our data and those obtained by Hunt (1976, 1979).

2. According to the results of the annual joint ichthyoplankton and juvenile surveys conducted in autumn and winter 1977-1988 within the framework of the cooperative Canada-USSR fisheries research length composition of the juvenile hake catches ranged from 1.0-to 9.0 cm with modes between 3.0-7.0 cm; mean length was from 2.8 to 7.3 cm (Sherstyukov, 1990).

According to our data fingerlings of 2.0-11 cm in length with modes between 5 and 7 cm were fished in November survey 1990-1991.

3, Each subsequent year-class of the Scotian hake occurred from April to August. The species shows two spawning peaks in July-August. Each female spawns two egg batches with 1 month interval (Sauskan, 1966; Sauskan, Serebryakov, 1968; Alekseev, Demodov, 1991). The start and completion of the spawning period vary from year to year and depend on the water temperature on the spawning grounds. Low temperatures result in slackening of spawning (Sauskan, 1966).

Minimum length of juvenile hake at the age of less than 30 days (October-November) is 1.0 cm. It can be regarded as an

indication that hake spawning period finishes later than it is commonly accepted and in some years it lasts up to October inclusive.

4. Methods used by Hunt to construct the age-length relationship basing modal frequency of the size row are not applicable to fish with prolonged spawning period. First of all it refers to conditions for the method application mentioned above (Hunt, 1976). Due to the extension of the spawning period considerable superposition of fingerlings' and yeralings' lengths will occur and modal length of juveniles from the second batch will be less as compared to that of from the first batch. At least some modal lengths had to be obtained by Hunt (1976) for the first age-group.

Hunt (1976, 1979) singled out 14 types of hyaline and opaque growth zones. However, the methods applied did not allow to get reliable age estimates as growth zone for fish from the first and last batches was not traced and measured after the first winter and first spring of the first year of life.

MATERIALS AND METHODS

The present paper uses age samples of juvenile and adult silver hake collected in April, May, June, July and November 1989 and in January 1990. A total of 670 pairs of otoliths were taken. Fish were sampled by each month from minimum to maximum length. Size composition of the sample ranged from 2.2 to 45.0 cm. Complete biological analysis (length measurement, weighting, stomach index and fat content determinations) were performed. Otoliths for age estimation were taken as well.

Otoliths were examined in reflected light using a MBS-9-type binocular at a magnification of 1 x1 (1mm = 10 units of ocular-micrometer). At sea silver hake otoliths were kept in a 50:50 water/glycerin mixture and examined in a 50:50 alcoholic/glycerin solution. Lateral radii at the blunt edges were measured, i.e. the distance between the centre of the otolith and the end of the each annual growth zone. Combination of the summer opaque zone and additional rings and wide hyaline zone of the slackened winter growth is considered to be an annual growth zone. In

other words it is an annulus. The major features of the annulus are: continuity all over the otolith plane and thickness. Additional rings are always narrower than the annulus within the same growth zone and are often broken.

To study daily growth of juvenile hake 100 pairs of otoliths were used collected in November-April from specimens of 3.7-25.0 cm long. One otolith was ground and then used to count daily growth zones; the other one was used for visual age determination.

Otoliths were mounted on the glass using a supercement-type glue. Then they were ground from both sides, washed with distilled water and kept in hydrochloric acid solution (1%) for 5-10 min (depending on the otolith size). Then otoliths were washed with distilled water and placed into Canadian balsam under the cover glass. The MBI-15V-type binocular microscope was used to analyse otolith microstructure at a magnification of x 800-1000. Length, width and radius were measured to the nearest 1 mm . Total amount of daily increments was calculated. Structure containing linght and dark rings was considered to be a daily increment.

Otolith preparation and daily zone count are very labour-consuming processes, which do not allow to perform mass otolith reading. Therefore the next stage of our work is to compare daily and visual pictures of the otolith growth. The main attention will be paid to the description and quantitative estimation of the first annual growth zone for the fish of the same year-class spawned at the onset and at the end of the spawning period. The quantitative estimation of age growth zone includes mean, maximum and minimum side radii of the age-groups and corresponding fish lengths in cm. Results of such measurements can be used for the Scotian hake age express-analysis (Table 1).

RESULTS

One-year-olds. Daily growth. The procedure of otolith daily growth zone count has some peculiarities. In small fish 1.0-2.0 cm in length daily increments are counted along lateral, ventral and dorsal radii. Unevenness of otolith increment as a recording structure, is observed in fishes 2-2.5 cm in length.

It appeared, that the daily increment number along ventral and dorsal radii is 20-25% less than along lateral one. Thus, for a specimen 18 cm in length the number of increments along the ventral and dorsal radii amounts to 310 days, and along the lateral one - 420 days. It is necessary to take into account, that grounding otolith edges is inevitably resulted in daily increment partial loss, amounted to 10-15% of the age observed. Therefore the absolute age index of fish appeares to exceed the observed one.

Daily increment count for fishes 21-25 cm in length, caught in the beginning of January 1990, shows that they are of 500-650 days old. Thus, all of those fishes belong to the 1988 year-class and was born in April-July. Fishes 15-18 cm in length, caught in April 1990 were 350-420 days old, belonged to 1989 year-class and was born in March-May.

Fishes 19-27 cm in length, caught in April 1990 were 450-650 days old. The smallest fishes were born in 1989, and fishes 20-27 cm in length belonged to 1988 year-class and was borne at the end of the spawning season. Age at length for juvenile fish from 4.0-5.0 cm to 25 cm in length is estimated according to the following regression:

$$N = 19.6 + 23.3 \cdot l,$$

where N - fish age in days

l - fish length in cm.

Peculiarities of first annulus laying. One of the major aspect of age determination methods is the substantiation of first annualus location, as annual growth zones are counted off it. Our data on the time of annulus laying correspondes to the observations by Hunt (1976, 1979). Hunt (1979) showed that in adult fish annulus was laying from the end of the fall (October) through the end of the spring (May). In the juvenile fishes this period is shorter. Our observation showed that winter rings in juvenile fish appeared from January through April (Fig. 1).

Let us follow the annualus laying in fishes of the same year-class, which appeared in the beginning and the end of the spawning season, based on the results of juvenile fish survey during November-January 1989/90. At the end of November the

juvenile fish caught was from 2.2 to 11.4 cm in length. Their age was 52 and 251 days, respectively. Thus the new year-class appearred from April through October 1989 , based on our data. Fig. 2 shows otolith of fish 3.7 cm in length caught in November. In the center of otolith there is a significant transparent hyaline zone, surrounded with a "fingerling ring", formed in many fishes at habitat layer change (movement from the surface layer to the depth). The total otolith radius amounted to 9 units. In fish 11.4 cm in length (Fig. 3) otolith radius equaled to 23 units, with 6 additional rings in the center. The first two additional rings were located at the distance of 8 and 12 units o.m. Note, that in juvenile fish up to 7.0 cm in length two addition rings were observed, located at the average distance of 8 and 14 units o.m. Location of other additional rings, amounted to 8-10 withing the first annual zone, are hardly followed, hence the error of the average value is out of confidence limit. Obviously, those rings were formed during juvenile fish movement from the surface layer into the deep one, occurred repeatedly.

In January hyaline growth zone of juvenile hake otolith was considerably thicker than additional rings-annulus (Fig. 1). Fig. 1 shows the otolith of fish 15.1 cm in length (maximum size of 1-year-old fish, occurred in the period), distance to annualus is 25 units o.m., distance to the otolith edge is 27 units o.m. During juvenile survey in 5-16 January 1981 minimum fish size amounted to 5.0-9.0 cm (Sherstyukov, 1990).

In April the first age group consisted of fish 16-18 cm in length. A broad summer increment zone up to 5-10 units o.m. was observed in otoliths. Visually the first annual growth zone in juvenile hake more often consisted of a hyaline center, surrounded with a "fingerling ring", located at average distance of 8 units o.m.; additional rings and annulus., located at 12-25 units o.m. Hunt described the latter as the first pelagic ring.

Note that the first annulus in otoliths of fish 15-20 cm in length is visually distinct. Table 1 presents the results of radii measurements of first annual growth zone for juvenile and adult fishes.

Therefore, the first age group, presented by Hunt (1976, 1979), is actually divided into 2 age classes, 1-year-olds and 2-year-olds. It should be pointed out that 1-year-olds almost lack in commercial catches.

Mature fishes. The hake maturation begins at length of 25-28 cm (Sauskan, 1966; Sauskan, Serebryakov, 1968). Analysis of fish seasonal growth, based on otolith data, showed the following: in fall (from November through April) annual rings are layed in otoliths, moreover in older fishes ring are layed later on. Thus in fishes of 6-8 years old winter rings appeared only in April and even in June. In fishes of 3-5 years-old annual rings were layed usually from November through March-April (Fig. 4). Moreover the first three growth zones of hake are broad and correspond to the intensive linear maturing. Later on the growth rate decreased with age. Judging by annual increments of otoliths. adult fish are characterized by considerably lower linear growth rate. Annual growth zones in adult fishes joined together at dorsal and ventral areas of otolith. The number of years could be counted only at the blunt adge and partially at the pointed edge.

For the bulk of fishes at age of 4-5 the otolith center was poorly visible, and for fishes at age 6-8 it is unvisible because otoliths became thick and calcifierous. In such a case it is recommended to refer to average radii of annual growth zones, presented in Table 1. The radius of the first clearly visible annual ring is measured and compared with data from Table 1. For example, Fig. 5 shows a specimen at age of 5 with poorly visible 1 and 2 annual growth zones. Radius a distinct ring is 56 units o.m., so it appears to be the third annual ring (Table 1). Thus the total age of this specimen amount to 5 years.

Age, year-class. Scotian hake is characterized by pronounced seasonal growth pattern. At age determination January is assumed to be the boundary of the year for the next year-class count. (Hunt, 1976, 1979). By January the following typical growth patterns, showing the end of the next year of growth, are formed in otolith as the major registration structure: a ring at the edge; an increment, comparable to the annual growth zone

+++; a ring with a small increment +. Since we determine the age of the entire year-class, not of individual specimen, all those fishes are considered as 0-group till 31 December, and as 1-group from 1 January and etc. Since annual rings laying of Scotian hake lasted till April, it is essential to consider an increment width for 1-4 months at the next year count.

In the second half of summer and fall fish is considered to be fingerlings, and fingerlings overwintered are called 1-year-olds. Accordingly, all specimens born in the recurrent spawning year are considered as fingerlings. In November they would be of age from 1 to 8 months (30-240 days) at length of 2.2 and 11.4 cm. Fish over-winter at age of 5-11 months (100-330 days) (5-15 cm in length) will be considered 1-year-olds.

CONCLUSIONS

1. Unevenness of otolith growth as registration structure became evident in Scotian hake 2.0-2.5 cm in length. Daily growth zones are counted at the blunt edge of otolith.

2. The first annual ring is layed in winter, mainly in January in hake 5-15 cm in length.

The first annual zone radius amonts to 12-25 units o.m., 20.1 units o.m. in average. Average size of subsequent annual growth zones is as following: II - 34.3 units o.m., III - 53.1 units o.m., IV - 62.2 units o.m., V - 69.7 units o.m., VI - 75.2 units o.m., VII - 79.5 units o.m., VIII - 84.0 units o.m.

3. The equation for daily growth of juvenile fish 4-25 cm in length is as following:

$$N = 19.6 + 23.3 \cdot l ,$$

where N - age in days,

l - length in cm.

4. The age of 1-year-olds in April (for the period of standard inventory survey) is estimated as 5-11 months (120-330 days).

5. In older fishes and at age limit (from 5 years old and over), otolith center lost transparency due to thickening and calcification. Radius of the first distinctly visible growth zones are used to determin age. The entire age of specimen is estimated by means of Table 1.

REFERENCES

1. Alekseev F.E., Demidov A.I. 1991. Reproductive biology and functional structure of the Nova Scotian hake area. Annual report, AtlantNIRO, p. 10.

2. Anderson E.D., Nichy F.E. 1975. Comparison between US and USSR silver hake ageing ICNAF Res.Doc.75/13, p. 5.

3. Hunt. 1976. Age, growth and distribution of silver hake (Merluccius bilinearis) on the Scotian shelf from Modal analysis of length frequencies, Department of the Envi ronment, Fisheries and Marine Service, St.Ahdrews, N.B. Canada, p. 12.

4. Hunt. 1977. Report of the silver hake ageing workshop ICNAF, Summ.Doc.13, Ser. 5073, p.5

5. Hunt. 1979. Age and growth studies of silver hake (Merluccius bilinearis) in the Northwest Atlantic, ICNAF, Res.Doc.79/VI/42, p.26.

6. Hunt. 1989. Results of silver hake otolith exchange between Canada and the USSR NAFO, SCR 89/41, Ser. 1591, p. 3.

7. Markov Yu.A., Sherstyukov A.I. in press. Otolith microstructure and silver hake age and growth estimation on the Nova Scotian shelf at the early stages of the life cycle, AtlantNIRO, Kaliningrad, p.11.

8. Nichy F. 1967. Growth patterns on otoliths from young silver hake (Merluccius bilinearis), ICNAF, Res.Doc. 67/109, p.10.

9. Noskov A.S. 1966. Silver hake abundance, catch composition and total mortality on the Scotian Shelf and Georges Bank in 1962-1965. Annual report, AtlantNIRO, Kaliningrad, p. 40.

10. Sauskan V.I. 1966. Biological foundation of the silver hake (Merluccius bilinearis) fishery and systematics for the Atlantic species of the gender. Synopsis of thesis, Kaliningrad, KTI, p. 20.

11. Sauskan et others, 1967. Fishery in the Northwest Atlantic, Kaliningrad, AtlantNIRO, p. 451.

12. Sauskan V.I., Serebyakov V.P. 1968. Silver hake (Merluccius bilinearis) reproduction and development. Questions of ichthyology. Vol. 8, issue 3(50), pp. 500-521.

13. Senina A.P. 1966. Age determination methods for silver hake. Annual report, Kaliningrad, AtlantNIRO, p. 22.

14. Sherstyukov A.I. 1990. The young silver hake growth in the Scotian area, 1977-1988, NAFO, Serial 1702, SCR Doc. 90/02, pp. 1-11.

15. Vieira M., Conover I.T., Fritz R.L. A morphometric study of silver hake. Spec.Sci.Rept. U.S., Fish and Wildlife Serv., 1961, Fish. No. 368. pp. 1-16.

16. Waldron D. 1991. 4 WVX Silver hake catch-at-age for 1989-1990 Using Canadian, Soviet and combined age-length keys, NAFO, SC Working paper 91/11, p. 21.

Table 1

Age-length relation (April), radii of annual growth zones for Scotian hake (length in cm, radii of annual zones in units of ocular-micrometer, 1 mm= 10 units o.m.)

Age (year)	I+	II+	III+	IV+	V+	VI+	VII+	VIII+
Average radius (units o.m.)	20.1	34.3	53.1	62.2	69.7	75.2	79.5	84.0
Maximum radius (units o.m.)	25	50	60	65	75	86.0	89	86
Minimum radius (units o.m.)	12	27	46	53	60	66.0	70	81
Standard deviation (units o.m.)	4.4	4.19	3.2	2.95	2.72	2.53	2.16	4.5
Average length (cm)	10.3	18.0	26.1	30.3	33.7	37.6	40.8	44.1
Number of fish measured (specimens)	670	540	380	260	150	80	35	15

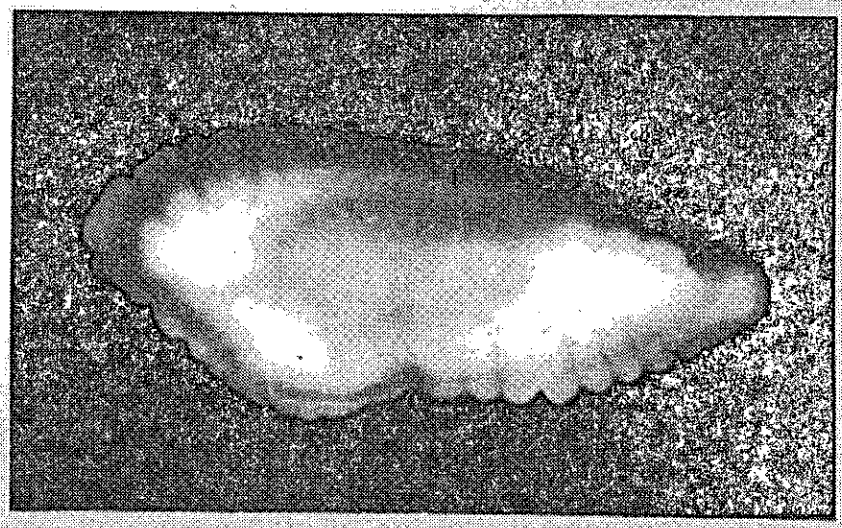

Fig. 1. Silver hake otolith (age 1; 15.1 cm in length). The specimen was caught in January. The first annulus is located at a distance of 25 units of ocular-micrometer.

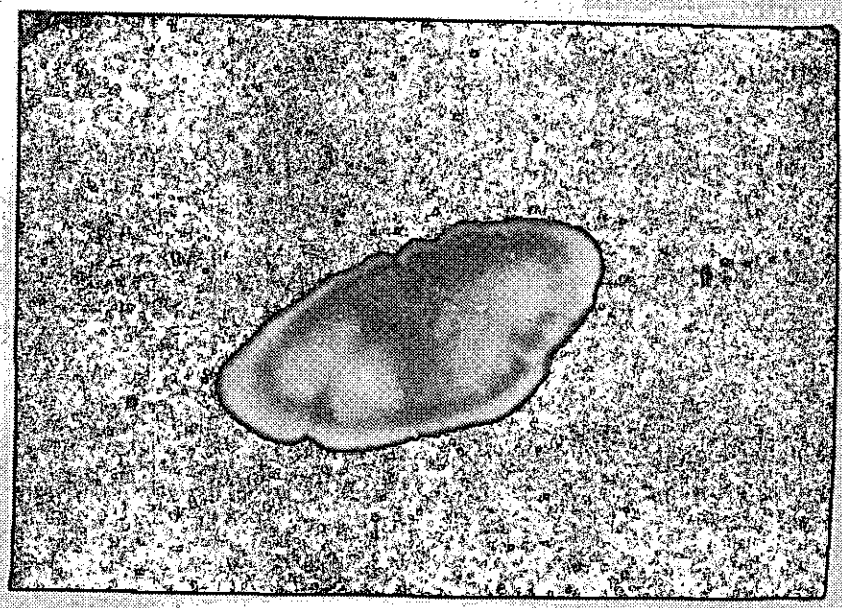

Fig. 2. Silver hake otolith (age 0; 3.7 cm in length). The specimen was caught in November. Fingerling ring is located at a distance of 7 units of ocular-micrometer; the total radius is 9 units of ocular-micrometer.

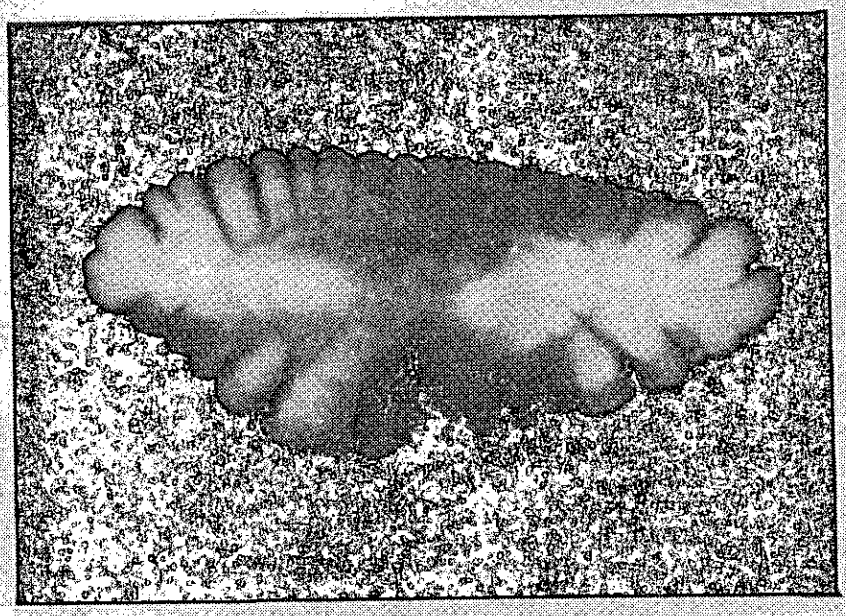

Fig. 3. Silver hake otolith (age 0-; 11.4 cm in length). The specimen was caught in November. The otolith radius is 23 units of ocular-micrometer; 6 additional rings are present.

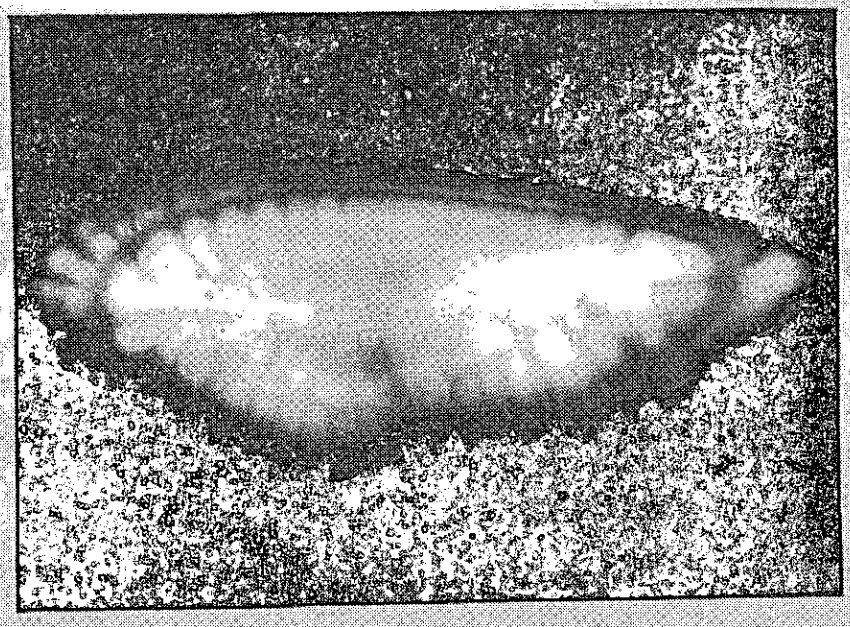

Fig. 4. Silver hake otolith (age 5+; 35.8 cm inlength). The specimen was caught in April. The first of the clearly pronounced rings is located at a distance of 56 units of ocular-micrometer and serves as the third annulus (Table 1). The first and second annuli are poorly seen.

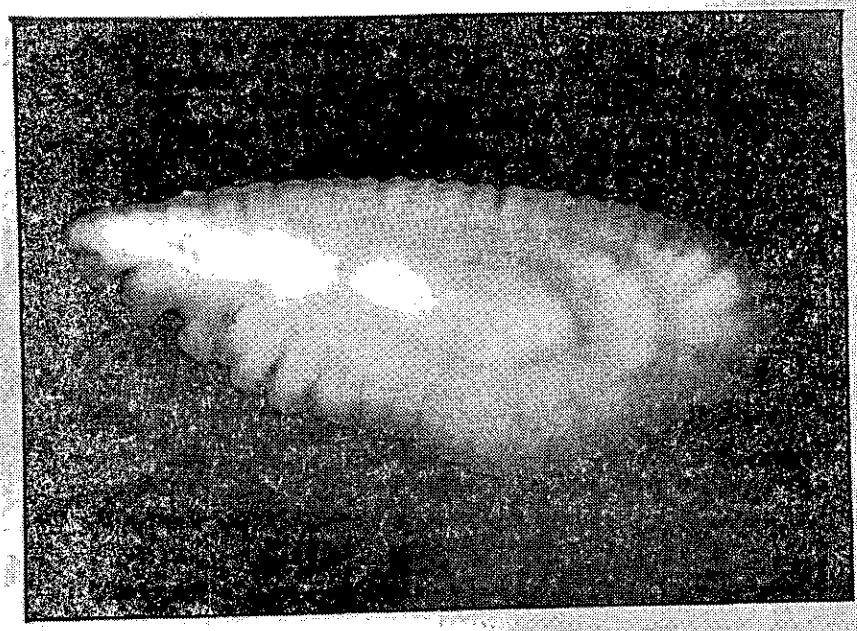

Fig. 5. Silver hake otolith (age 3+; 28.0 in length). The specimen was caught in April. All growth zones are clearly seen; redii are 20, 34 and 52 units of ocular-micrometer, respectively.