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WORKSHOP ON AGEING TECHNIQUES IN BERGEN, 1962.

At the ICNAF meeting in 1960 it was recommended that a Working Party on age-reading technique should be established with a view to resolve some of the difficulties in age determination. At the ICNAF meeting in 1961 this Working Party was urged in particular, to study (1) Techniques used in age-reading, (2) Interpretations of zone structures in otoliths, and (3) To decide on a uniform set of terms, definitions, and symbols for the study of otoliths. The final report of the Working Party should be presented at the meeting of the Commission in 1963.

These proposals were again considered at the 1962 annual ICNAF meeting in Moscow. There it was recommended that the Workshop should concentrate on the study of objective criteria for the age determination of cod, and methods of validation, with particular reference to the existing discrepancies in the age-reading of cod from Subareas 3 and 4. It was further recommended that the ICES Working Party on whiting age-reading should be invited to submit a report on their work to the Workshop.

After the conclusion of the 1962 annual ICNAF meeting, correspondence between the interested parties started. The main convenor of the Working Party, Dr. Rollefsen, became ill and was not able to participate in the preparations for the meeting. Other difficulties arose when some of the countries, who originally had intended to participate in the Workshop, withdrew for various reasons. It had previously been agreed that the main task of the Workshop was to resolve the present discrepancies in age determination of cod in Subareas 3 and 4. There were four countries most directly concerned, namely Canada, Portugal, Spain and USSR. It became clear rather late in the arrangements that from these countries only one expert, from Canada, would be present although several other people with wide experience of cod age determination problems would be present. The question of postponing the Workshop was raised with the ICNAF Secretariat, the Chairman of the Committee of Research and Statistics and others directly concerned with the outcome of the meeting. It was thought, however, that a postponement of the meeting would not guarantee the attendance of Portugal, Spain and the USSR. at a later date. It was finally decided to hold the meeting on the dates originally chosen. It has been pointed out several times that it was most important to have the age determination problems cleared up as soon as possible because the discrepancies were delaying the use of the data by the ICNAF assessment group. The question was whether the rather small group of people who could finally assemble in Bergen would make a worthwhile contribution to the solution. It was decided that this group, although small, could dissect the problems, identify the sources of confusion and set out the possible explanations, in such a way that those countries not present could be expected to accept the group's findings, or, failing this, that they should be responsible for advancing very good reasons for rejecting them. It was also felt that to bring fresh ideas and wider experience to bear on these problems would be the most fruitful way of resolving them.

On November 19th, 1962, the following participants in the ageing technique Workshop met in Bergen:

Dr. A. C. Kohler, Biological Station, St. Andrews, N.B.Canada.
Dr. J. Messtorff, Institut für Seefischerei, Hamburg, Germany.
Mr. S. Olsen, Havforskningsinstituttet, Bergen, Norway.
Dr. Birger Rasmussen, Havforskningsinstituttet, Bergen, Norway.
Mr. E. Bratberg, Havforskningsinstituttet, Bergen, Norway.
Mr. B. D. Bedford, Fisheries Laboratory, Lowestoft, England.
Mr. G. C. Trout, Fisheries Laboratory, Lowestoft, England.
Mr. D. J. Symonds, Marine Laboratory, Aberdeen, Scotland.
Mr. A. C. Jensen, Biological Laboratory, Woods Hole, Mass., USA.

In addition the following cod otolith technicians were present from the Institute of Marine Research in Bergen: Mr. A. Hansen, Mr. O. Annaniassen, Mr. A. Frøland, and Mrs. I. Sandrup.

The meeting opened at 10:00 a.m. on November 19th. Dr. Rollefsen welcomed the participants to the Workshop. He was sorry to declare that due to illness he could not participate further in the meeting. He would leave the chair to Dr. Birger Rasmussen, who would act in his place. Dr. Rasmussen took the chair and presented the preliminary agenda and timetable prepared for the meeting. He reviewed the problems to be discussed by the Workshop and the details of the meeting.

The following topics were discussed:

I. Otolith structure (G.C. Trout)

1. General and special variations.
2. Physiology of otolith formation.
3. Causal factors affecting normal change in internal otolith structure and zone formation.
4. Abnormal development as a result of tagging or disease.
5. Structural differences in different stocks and their validity.
6. Differences associated with long term changes.

II. Validation practise and the establishing of objective criteria for age reading (A. C. Kohler).

1. Review of exchange program data.
2. Examination of published age and growth data from Subareas 3 and 4.
3. Review of validation studies by Canada in Subarea 4.
4. Training and control of routine otolith reading.
5. Review of value of otolith exchange programs.

III. Standard terminology and notation for otolith age readers (A. C. Jensen).

1. Nomenclature and definitions of otolith structure.
2. Symbols and notations for laboratory use.

IV. Report on whiting age determination (Dr. Messtorff)

The following points and recommendations emerged from the discussion: It is evident that the crux of the problem which gives rise to the discrepancies in age determination from Subareas 3 and 4 lies primarily in the complexity of the structures present in the first and second year's growth of the otoliths.

Part of the reason for this complexity results from (a) a long spawning period during the summer and early autumn, (b) the opaque material laid down during the first and second year (as evidenced by Canada's sampling of the group O and I fish) includes a varying number of hyaline zones (or checks) before the true hyaline zone is formed. (c) On the whole the earlier spawned fish are larger and have larger otoliths and more hyaline checks than the smaller later spawned fish. Juvenile material, illustrating these complex structures, and accessible only to research vessel sampling may not be available to some of the other countries working within the area. This material is available from Canada on loan.

It was stressed that ageing criteria should be based upon a sound and thorough knowledge of the juvenile otolith for each population, and should be kept under constant review. It was dangerous to apply criteria used to age one population to the age reading of another.

The Workshop was aware of the lack of evidence of what factors were involved in the changes seen in otolith structure and in particular those which occur in the first year's growth. Some current physiological and environmental studies were reported, but there is insufficient conclusive evidence available to support any particular theory on growth and differentiation in the otolith. Studies to determine cause and effect are desirable. The group also found that evidence of the effect of tagging, disease, etc. on otolith growth was inconclusive.

Discussion of the published data suggested that discrepancies might also arise from both age reading and sampling procedure, although length data available from ICNAF sources and discussed in this connection, were surprisingly consistent. In order to separate out any other factors, additional to age determination, involved in these discrepancies, the ICNAF Secretariat should request a specific and detailed note by member countries on the sampling procedures in current use. These notes should be published in conjunction with the ICNAF Sampling Yearbook. The Secretariat should finally stipulate the sampling method to be used.

In general, methods of training new staff to read otoliths, the checking of routine age reading and the periods over which checking was thought to be desirable, were relatively uniform in the countries represented at the Workshop. Transparencies of otolith photographs (35 mm) projected during the meeting by Dr. Messtorff confirmed the great value of this type of photograph for training and discussion, since it enables a large number of people to examine the same otolith and to discuss the same structure with certainty.

With regard to otolith exchange programmes, the group felt that the exchange of otoliths from countries not familiar with a particular population was of limited value. When cod otoliths are exchanged, the country supplying the sample should arrange to have them cut (not broken) in the approved position (i.e. at the interuption of the sulcus accusticus on the convex side - Rolleisen's method).

The reading of a sample of selected "difficult" otoliths, submitted by Portugal, and read by the majority of the participants, showed that the original age determinations were not biassed in any particular direction. For this reason it is thought that countries interested in Subareas 3 and 4 should exchange whole samples of otoliths. Canada, Germany and the UK have already agreed to read the whole sample presented to the meeting by Portugal.

A.C. Jensen's paper "A Standard Terminology and Notation for Otolith age readers" was discussed, revised and adopted (a copy of the adopted paper is attached as Appendix A). This terminology and notation should be used by the readers in future otolith exchange programs. In connection with Jensen's annotation on readability of otoliths and the ICNAF General Secretary's letter of Oct. 23rd, 1962, the Secretariat should state on the data sheet the form in which doubtful readings are to be reported.

A draft report on the findings of the whiting age reading group was presented by Dr. Messtorff. After discussion it was suggested by the Workshop that further clarification of some of the photographs and drawings should be made before publication. A copy of the draft report is attached as Appendix B.

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES
Workshop on Ageing Techniques, 1962.

APP. A.

A STANDARD TERMINOLOGY AND NOTATION FOR OTOLITH AGE READERS

by Albert C. Jensen.
Fishery Research Biologist, U.S.Department of the Interior,
Fish and Wildlife Service, Bureau of Commercial Fisheries,
Biological Laboratory, Woods Hole, Massachusetts.

Results of the cod otolith exchange program (Anon.,1959), and the analysis of a questionnaire (Keir, 1960) distributed to biologists engaged in age determination of fishes, indicated some important disagreements between different workers, particularly in the terminology used to report their findings. Because of the fundamental importance of age data to the work of ICNAF the Standing Committee on Research and Statistics recommended at the 1960 Annual Meeting (Anon.,1960) that a working party on ageing techniques be set up to resolve these disagreements, and to draw up a uniform set of terms and symbols.

Dir. Gunnar Rollefsen was appointed Convenor of the working party that met in Bergen 19 - 24 November, 1962. During the meeting the working party discussed a preliminary listing of terms, definitions, and abbreviations prepared by the author. The present paper represents the consensus of the members of the working party and is prepared for use in the laboratories of ICNAF members, in otolith exchange reports, and in the preparation of papers dealing with otolith studies.

The terms have been kept as simple as possible. Preference has been given to terms that have precedence in the literature or have a valid historical basis. Quite often the oldest term is the best term.

Terms that deal with validity of methods (e.g., year-marks), and terms for which the dictionary definition has been replaced by a common usage definition e.g., annulus) are not considered here. The proposed terms are intended to be descriptive and of a restricted nature. Also they are terms that will have a similar meaning when translated from English, the official language of ICNAF, into the various languages of the ICNAF members.

Otolith Marks

Term	Synonyms	Definition
Zones	Annuli, rings year marks, bands, winter rings, summer rings, growth rings	Bands of concentric hyaline or opaque material seen in otoliths and counted for age determination.
Check	Check mark, check ring, false ring, secondary ring, secondary zone, split	Hyaline matter not counted in age determination. Checks are sometimes indistinct, discontinuous or, in the judgement of the reader, do not meet the criteria established for identification as a year mark.

Term	Synonyms	Definition
Nucleus	Focus, center, origin, kernel	The central area of the otolith bounde by the first check or zone. (In most laboratories the center of the otolith is not fully understood, thus many biologists have not yet developed a firm definition for this term).
Opaque edge	Summer edge, fast-growth edge, dense edge	The otolith periphery composed primarily of opaque material.
Hyaline edge	Winter edge, slow-growth edge, translucent edge	The otolith periphery composed primarily of hyaline material.
Spawning zones	Spawning marks, spawning rings	Hyaline and opaque zones formed in the otolith from the onset of sexual maturity. In general, both hyaline and opaque zones of spawners are uniform in size and form, and the opaque zones are distinctively narrower than those formed during the immature period of the fish's life. The hyaline spawning zones are clear and usually free of opaque material; in many species (e.g. cod) they are frequently broader than the subsequent opaque zones.

Readibility of Otoliths

A system of number notations is proposed to grade the readibility of the otoliths. Such notations will also serve as a guide to the reliability of the ages determined for each otolith. The numbers will permit use of these notations in IBM and similar machine systems.

Notation and term	Definition
0 -- Good	The zones are plainly visible with general good definition between hyaline and opaque zones. Any check readily identifiable as such. The reader has a good degree of confidence in resulting age determination.
1 -- Fair	The zones are visible but not well defined. There are many checks present. The reader has fair degree of confidence in resulting age determination. In many otoliths the zones may form distinct patterns that make reliable age determinations feasible.
2 -- Poor	The zones are vaguely marked. Otoliths with zones so poorly defined as to be undecipherable, or where the age is merely estimated, are placed in this category.

Abbreviations and Symbols

It is desirable to keep abbreviations and symbols to a minimum and as simple as possible. Any lengthy comments on the appearance of the otolith and its markings, or on the degree of confidence of the determined age, are best made in an appropriate remarks' column on the form used to record the results of the otolith reading.

Asterisks, plus and minus signs, or other addenda to the age notation, serve only to clutter the data. When comparing the results of duplicate otolith readings, the reader's first concern is, "Do the ages agree?" After this, the question may be asked, "Why did the duplicate readings agree (or disagree)?" Symbols and remarks will serve to answer the second question, but they should not clutter the sheet such that, after the otolith has been studied and an age assigned, the data sheet must be studied to find the notation of age.

Type of edge growth.

Determining the type of growth (hyaline or opaque) seen at the edge of the otolith can, at times, be difficult and sometimes depends upon the subjective judgement of the reader. Final determination of the type of edge growth is influenced by the manner in which the otolith is cut or broken for reading and usually the beginning of the new growth is best seen at the narrow tip of the long axis of the otolith. These factors must be taken into consideration by the reader when he records his observation of the type of edge growth. Since the type of edge growth is used to translate age determinations from zone counts, recognition of the edge type is essential to the otolith reading process. To help in this recording, the following abbreviations are proposed:

Hn	- narrow hyaline zone at edge	(1)
Hw	- wide hyaline zone at edge	(2)
On	- narrow opaque zone at edge	(3)
Ow	- wide opaque zone at edge	(4)

For card punch systems (IBM, Keysort, etc.), the numerical notation may be substituted for the abbreviation, but care should be exercised to avoid confusing the edge code number with the age or zone-count number.

Checks

$C_{3,4}$ - check in third and fourth opaque zone

Spawning zones

12 (4s) - total of 12 zones of type counted, 4 of which are spawning zones

Age notation

9	- clearly, nine completed zones of the type counted
9(10)	- probably nine, possibly ten completed zones
(8)9(10)	- probably nine but possibly eight or ten completed zones
12(?)	- best estimate of count from ambiguously marked otolith

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APP. B

AGE DETERMINATION IN THE WHITING (MERLANGIUS MERLANGUS (L).) BY MEANS OF THE OTOLITHS

by
R. Gambell and J. Messtorff

Introduction

In recent years interest in the whiting stocks of the North Sea and adjacent waters has increased considerably. This is due in part to the greater demand for the fish in certain countries (e.g. Scotland), and also because of the concern felt in some quarters about the possible effects on the whiting stocks of certain fisheries employing small mesh nets. This interest has heightened the need for a better understanding of the general biology of the whiting, and especially of aspects bearing particularly on population studies, including age and size composition of the stocks and possible stock separation and identification.

Age determinations have therefore been of great importance in the investigations into the whiting populations which have been carried out by workers in a number of European countries. In 1959 a programme of exchanges involving material, methods and readings was initiated between the whiting workers, and this programme was formally recognised and encouraged by ICES, in 1960, in setting up a working group to study age determination methods and to reach agreement on the results of age readings for whiting.

The members of the working group were:

R. Gambell(Scotland), convener
L. Hannerz (Sweden)
J. P. Hillis (Republic of Ireland)
H. Knudsen (Denmark)
J. Messtorff (German Federal Republic)
M. Roessingh (Netherlands)
D.W.R. Rout (England)
D. Sahrhage (German Federal Republic)

Meetings were held between members of this working group, in addition to the exchanges of material and results, and this paper deals with the conclusions reached as a result of these activities.

Methods of Age Determination

The ages of fish can be estimated, ideally, from the annual growth rings on the scales, the growth zones in the otolith or other skeletal structure, or by Petersen's (1895) method. For the whiting however, only the otolith provides a practical and reasonably reliable basis for age determination of older fish. The scales from young whiting are readable, but they become increasingly difficult in fish older than about four years of age. Petersen's method is difficult after the first year of life in most areas off north-western Europe, probably because of the long spawning season of whiting. This causes each year-class to have an extended length range, and consequently results in consecutive year-classes overlapping very considerably on a length scale. It is therefore not very reliable (Graham, 1928). Vertebrae, spines and some bones of the head all show seasonal growth zones which can be interpreted to give the age of the fish, but as with the scales, they become increasingly difficult with age, and also suffer from the disadvantage of being difficult to collect in some cases.

This leaves the otolith, which gives an estimate of the age of the whiting over the whole life span of the fish. It is capable of interpretation for most fish from all the areas studied, and this paper provides the standards for interpretation arrived at by the working group.

The Structure of the Whiting Otolith

The otolith of the whiting has been described by Bowers (1954) from fish in the waters around the Isle of Man. This description applies equally well to the otoliths from the North Sea and adjacent areas. The important features of the structure of the otolith from the age determination point of view are the alternating opaque and hyaline zones, one of each zone being laid down at the edge of the otolith each year. There is no final proof that this is the case but observations of the edge of the otolith throughout the year provide strong evidence that it is so. Fig. 1 illustrates the type of edge found on the otoliths of northern North Sea whiting for each month of 1961. The data were obtained from monthly market samples, each containing 150 fish of all ages from one year old upwards, and all sizes from 25 cm and over. They demonstrate quite clearly the alternation of the two edge types, the opaque zone being formed in the summer and the hyaline zone in the winter.

Time of Zone Formation

From Fig. 1 it can be seen that in the northern North Sea the hyaline zone begins to appear on the edge of the otolith in September. During the following months it becomes broader, until by December-January the formation of the winter (hyaline) zone seems to be completed. The opaque zone starts in April, and continues on the edge of the otolith for the next four months. These timings appear to hold over the entire North Sea area, as Messtorff (1959) has shown, although there may be slight variations from one year to the next. Generally, the variations range over no more than one month either way. Within these timings there is a relationship between the start of zone formation and the size and age of whiting. Immature fish start earlier than mature fish; for example, immature whiting at the end of their first or second year of life often have opaque edges to the otolith by March. Among mature fish also, the younger ones begin earlier than the older ones. When assessing the age of a whiting from the bands of growth in the otolith considerations such as these of the time of zone formation, and possible slight variations from the normal, must be borne in mind in the interpretation. To avoid difficulties which may arise, for instance, when comparing age readings by different workers, the standard birth date for whiting of April 1st was adopted by the working group members for the interpretation of age-groups (Gambell et al., 1960).

Comparison of the more usual times of zone formation in the North Sea with those of whiting from the French Atlantic coast (Desbrosses, 1948), and the Isle of Man waters (Bowers, 1954), shows that the North Sea fish start to form both their zones rather earlier than do the other two. In the French Atlantic area the opaque growth starts in May, and in the Isle of Man area it appears in June. The hyaline zone in both these areas starts in January.

Further evidence that the growth zones are annual structures is provided by the catches of the good whiting broods of 1952 and 1955 in the North Sea over a number of years, as shown in the following table.

Annual percentage age composition of whiting caught by Scottish research vessels in the northern North Sea.

Sampling year	1956	1957	1958	1959	1960
No. of hyaline zones in otolith	%	%	%	%	%
1	27	5	8	51	32
2	18	54	12	23	43
3	11	19	50	3	21
4	28	5	14	16	1
5	13	14	3	2	3
6	2	3	11	1	+
7+	1	+	2	4	+

These data show that there were peaks in the distributions corresponding to whiting with four hyaline zones in their otoliths in 1956, five hyaline zones in 1957 and six in 1958. It is reasonable to assume that these peaks can be attributed to the same brood each year, in which case an extra hyaline zone must have been added to the otoliths each year. This good brood corresponds with the 1952 year-class. Similarly, a peak in the distributions for whiting with two hyaline zones in 1957, three in 1958, four in 1959 and five in 1960 can be attributed to a single good year-class, that of 1955. This again suggests that a hyaline zone is added annually to the otolith.

Techniques of Otolith Reading

With some whiting otoliths the hyaline and translucent zones can be seen clearly in the whole otolith. By viewing the otolith in transmitted light, or in reflected light against a dark background, the alternating bands can be distinguished. This method of reading is not satisfactory for all otoliths however, since with increasing age the otoliths become thicker, and the growth zones are obscured. It is then necessary to view the otolith in section, and there are two main methods employed.

The quickest technique, and the one most generally used by members of the working group,is to break the otolith across transversely, and to mount the half otolith in plasticine, or a similar soft bed of material. The broken surface, which may be ground smooth to make it easier to read, is brushed with a clearing agent such as xylol or terpineol, and viewed under a binocular microscope by transmitted light. The extreme surface is shaded from the laterally directed light beam, and by altering the degree of shading, the growth zones can be made to stand out in sharp contrast to one another. This arrangement is illustrated in Fig. 2. By this method the translucent zones appear as bright bands and the opaque zones as dark ones. The otolith photographs shown in this paper were taken using this technique.

The second method of viewing the transversely broken otolith is by direct light against a black background. The otolith is submerged in xylol or alcohol in a black dish as in Fig 3, and using this method the translucent zones appear dark and the opaque zones bright. Shading the broken surface to various degrees again increases the contrast between the light and dark bands. The photographs of otoliths published by Messtorff (1959) were taken by this method.

Interpretation of Zones in Whiting Otolith

As a basis for the standardisation of age readings from the otolith, material from whiting in the northern North Sea was selected. Otoliths from fish in this area are probably the least difficult to read of all those studied, the hyaline zones being generally quite compact bands, with a few or no false rings to confuse the picture.

What might be called the 'standard' northern North Sea type of otolith is illustrated in Fig. 4. This shows an otolith with four fairly compact hyaline zones, corresponding to four winters' growth. The fourth hyaline zone is right on the edge of the otolith. This can be compared with an otolith showing a well formed opaque edge, for example, Fig. 5, taken from a fish caught in August. The most easily read sector of the otolith in the majority of fish is indicated in Fig. 4. This particular otolith also shows a hyaline central zone, or 'nucleus', which is not always found in the North Sea otolith. Fig. 5 is an example of the opaque type of centre.

Very often there is a tendency for the second hyaline zone to appear as a double structure, almost as though it was composed of two unusually thin hyaline bands separated by a very thin opaque band. An example of this type of otolith is shown in Fig. 6, where the double appearance also occurs in the third winter zone. That this sort of double band is in fact one winter's growth can be seen in the example given by the fact that the two bands of the second winter unite on the opposite side of the otolith. The spacing of the hyaline bands is also an indication that the true winter zones are double, as annual hyaline zones as thin and closely packed as these are not a feature of the whiting otolith. Further confirmation of the double zone as a single winter's growth is given in Fig. 7, where the formation of such a zone is shown taking place on the edge of the otolith. This otolith was undoubtedly from a fish in its second winter of life, both from its size (male, 23 cm) and from its scales, which showed two clear winter zones.

Fig. 7 also illustrates the narrower type of hyaline band found in the whiting otolith, which can be contrasted with the broader form in Fig. 4, and the components of the double bands in Fig. 6. This otolith also exhibits the opaque nucleus type found in the North Sea.

Bowers' Zone

Difficulties in interpretation of the zones of the otolith are caused not only by the formation of double bands, but also by hyaline bands which are not annual growth structures. One of these false bands is shown in Fig. 8. In the central part of this otolith there is a thin hyaline zone inside the first true winter zone. Such a formation has been described by Bowers (1954) as being laid down around the central core of the Isle of Man whiting otolith in August. It appears to be present in North Sea whiting when they take up the bottom-living habit, in about July or August of their first summer of life. It may be that the "Bowers' zone" is connected with this change from the pelagic to the demersal habitat, together with the associated change in feeding.

Broad First Hyaline Zone Type

Some North Sea otoliths present the appearance shown in Fig. 9, where the first annual hyaline zone is much larger than normal, and the centre of the otolith is composed of a confused mass of hyaline and opaque bands. In the example given, it is considered that there is not a true annual hyaline zone in this central area, and that the otolith was from a whiting in its second winter.

A possible explanation for this phenomenon lies in the very crenulated appearance of the otolith of a whiting during its first year of life (Fig. 10). When the otolith is broken across, the break may occur at any position on the crenulations. If the break happens to fall across two projections on opposite sides of the first hyaline zone, then this zone will appear rather larger than usual in cross-section.

Otoliths which show crenulations in the first hyaline zone are illustrated in Figs. 11 and 12, where the indentations in this zone can be clearly seen. The otolith in Fig. 12 also shows a double second hyaline zone.

Spacing of Zones

Some otoliths are difficult to read because there are many hyaline zones which cannot be easily followed round the entire otolith. In places it may even seem as if they run into one another, and the whole picture is quite confused. An example of this is shown in Fig. 13. The two inside hyaline zones are close together and the outer zones tend to be double. It may be thought that the two inside bands are really the two parts of a double zone also, but they are not interpreted in this way as each of these bands has the appearance of a normal hyaline zone, despite the relatively close positioning of the two zones.

An example of an otolith with two hyaline bands in the centre which are not regarded as separate years' growth zones is shown in Fig. 14. Here the outer of the two central hyaline bands is very thin and unlike a normal annual zone. The spacing of the bands also indicates that it is not a true zone. Generally, the distance between the first and second annual hyaline bands is greater than that between any other two adjacent zones. From the second annual hyaline zone outwards the spacing is regular with the alternating opaque and translucent bands gradually becoming narrower towards the edge of the otolith (Fig. 15). This is not true for the otolith in Fig. 14 unless the first two hyaline bands are interpreted as a single zone or the second band is regarded as a false band. The two inside hyaline bands of the otolith in Fig. 13 can be interpreted as separate annual zones without upsetting the usual spacing pattern, and so these two otoliths are interpreted differently from one another.

Otoliths from Other Areas.

The methods of interpretation outlined for otoliths from the northern North Sea apply equally well to otoliths from whiting caught in other areas. Some differences in the appearance of the otoliths from these areas can be mentioned however. As has been said already, the northern North Sea type of otolith is probably the clearest and most straightforward of all those examined. In other areas the hyaline bands are not always such compact structures as those illustrated from the northern North Sea, but tend to be made up of many fine hyaline lines which can be distinguished from one another in the annual band. This results in the alternating opaque and hyaline zones being less sharply differentiated when the otolith is seen in transverse section.. This diffuse otolith type is found in the Clyde, Irish Sea and Skagerak areas, and is illustrated in Fig. 16. The otoliths from southern North Sea whiting are not so diffuse as this, but even so, are less clear than the northern North Sea type.

Summary and Conclusions

The whiting otolith is a convenient and reliable structure from which the age of a fish can be estimated. The main methods of reading the otolith, by transmitted or direct light, are described, while the chief difficulties met in the interpretation of the otolith are illustrated. These include the presence of double bands and other zones which are not annual structures. The size and spacing of the growth zones are considered, and it is concluded that by taking into account the general appearance of the otolith, the normal spacing and form of the zones, and the time of zone formation, a reliable age determination is possible for whiting from all sea areas off north-western Europe.

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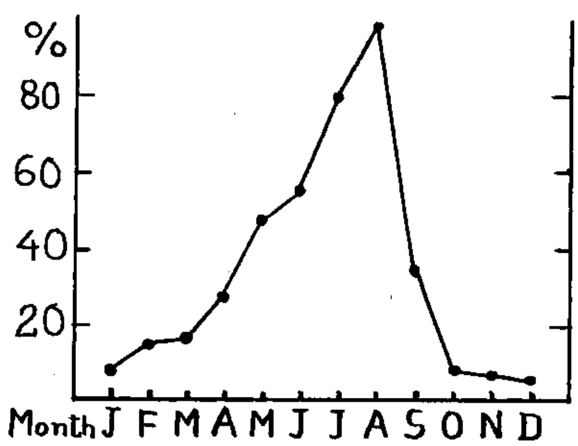


Fig. 1. Percentage of Northern North Sea whiting otoliths showing opaque edges in each month of 1961.

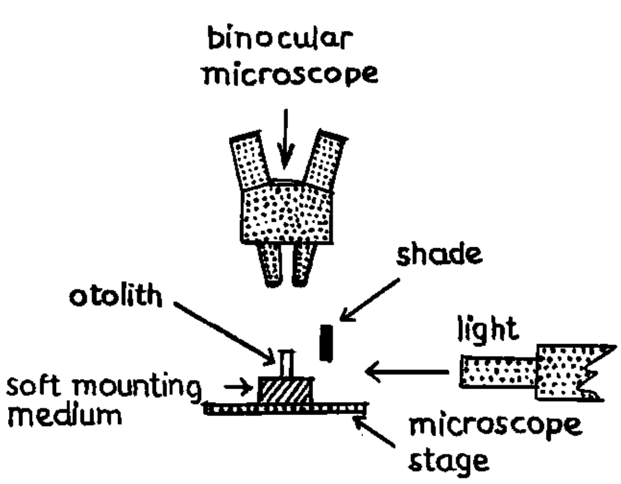


Fig. 2. Method of viewing otolith by transmitted light.

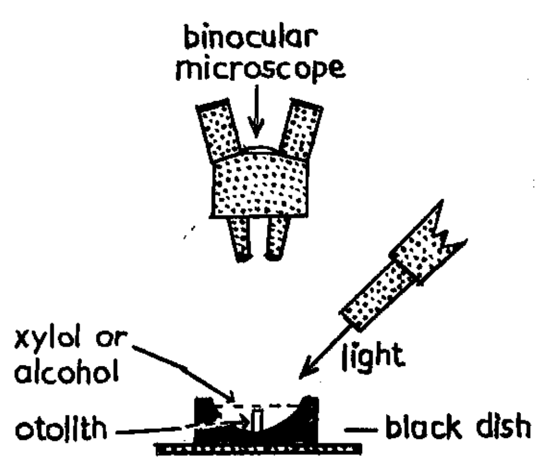


Fig. 3. Method of viewing otolith by direct light.

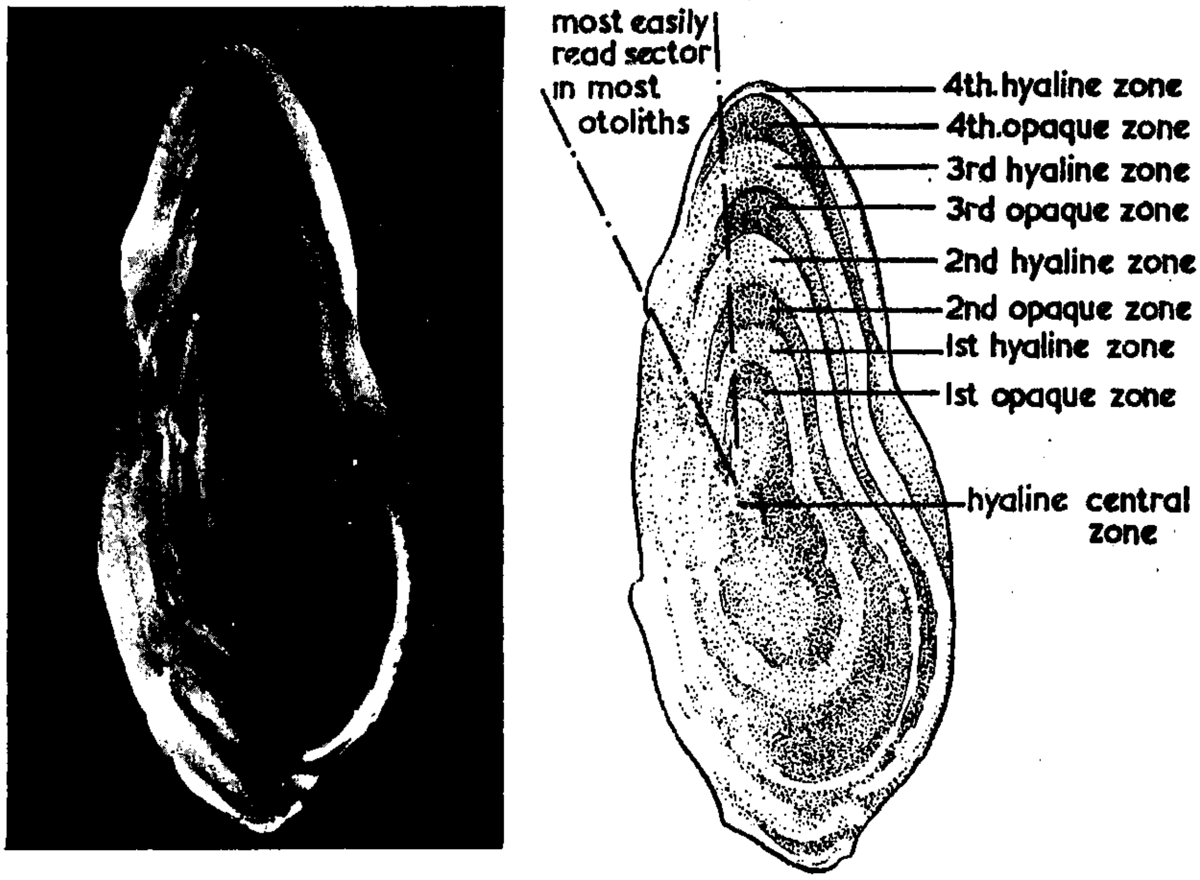


Fig.4. 34cm. 6·5·59
IV·group.

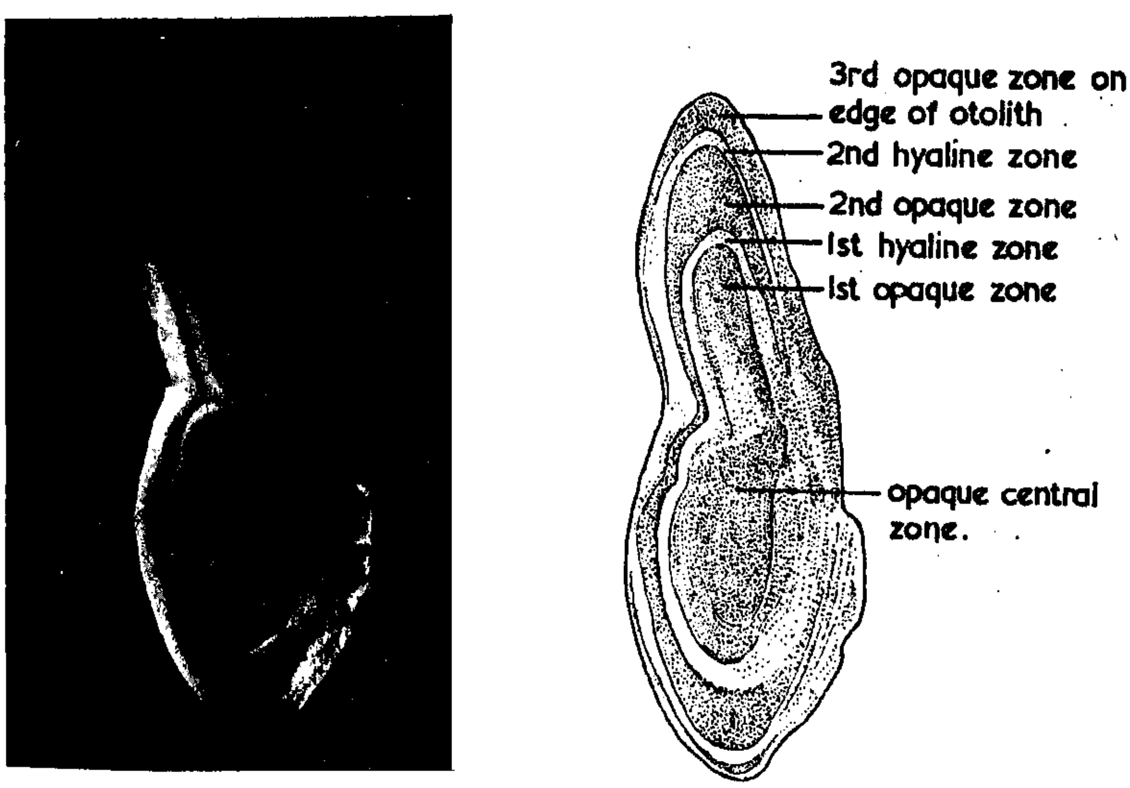


Fig 5 28cm. 2·8·55
II·group

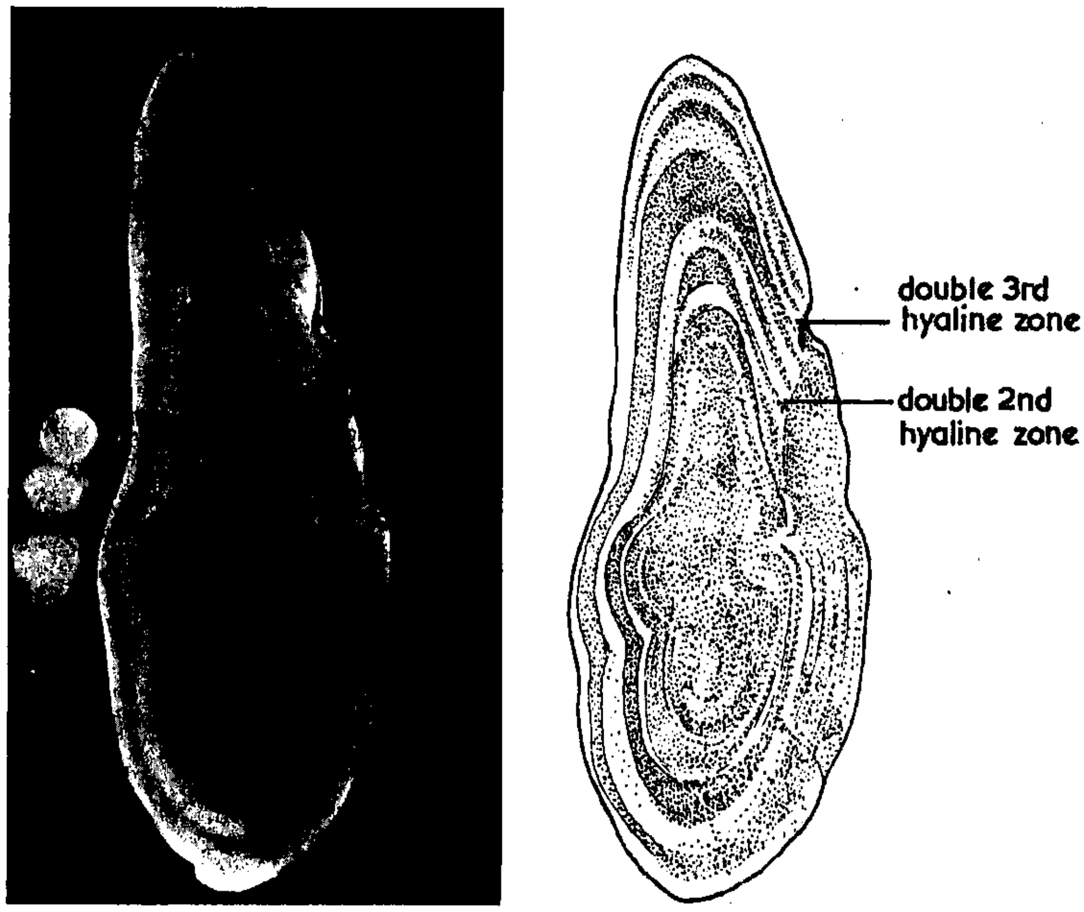


Fig.6. 33cm. 9·2·60
IV- group

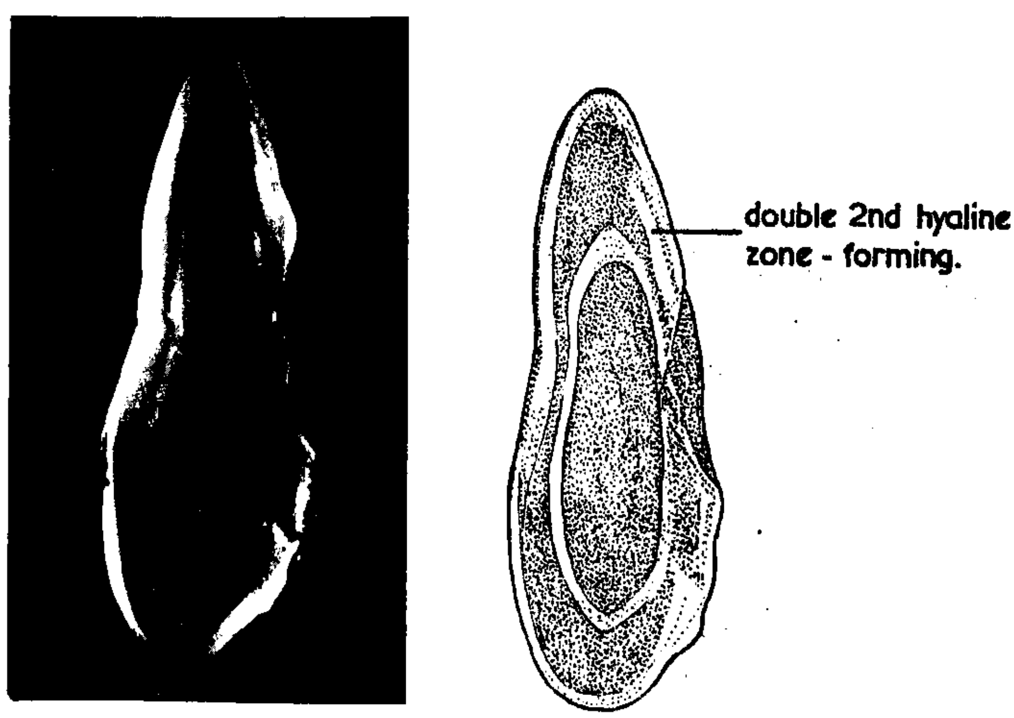


Fig.7. 23cm. 20·3·59
I- group.

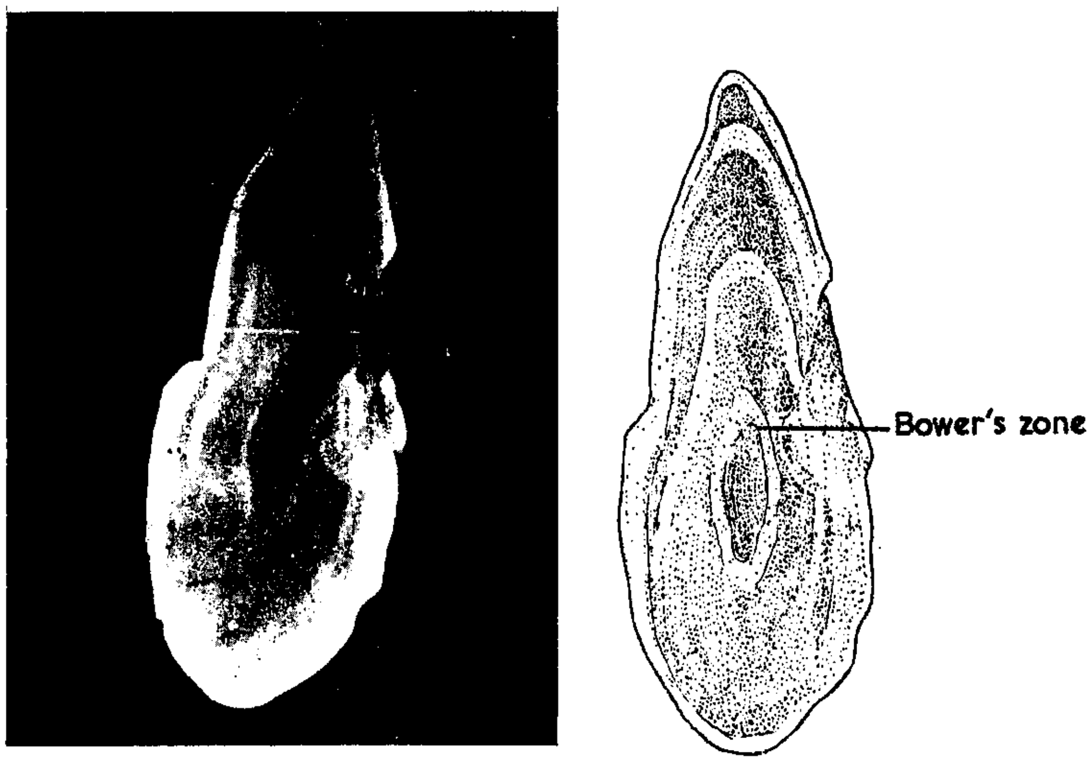


Fig. 8. 32 cm 9·2·60
II-group.

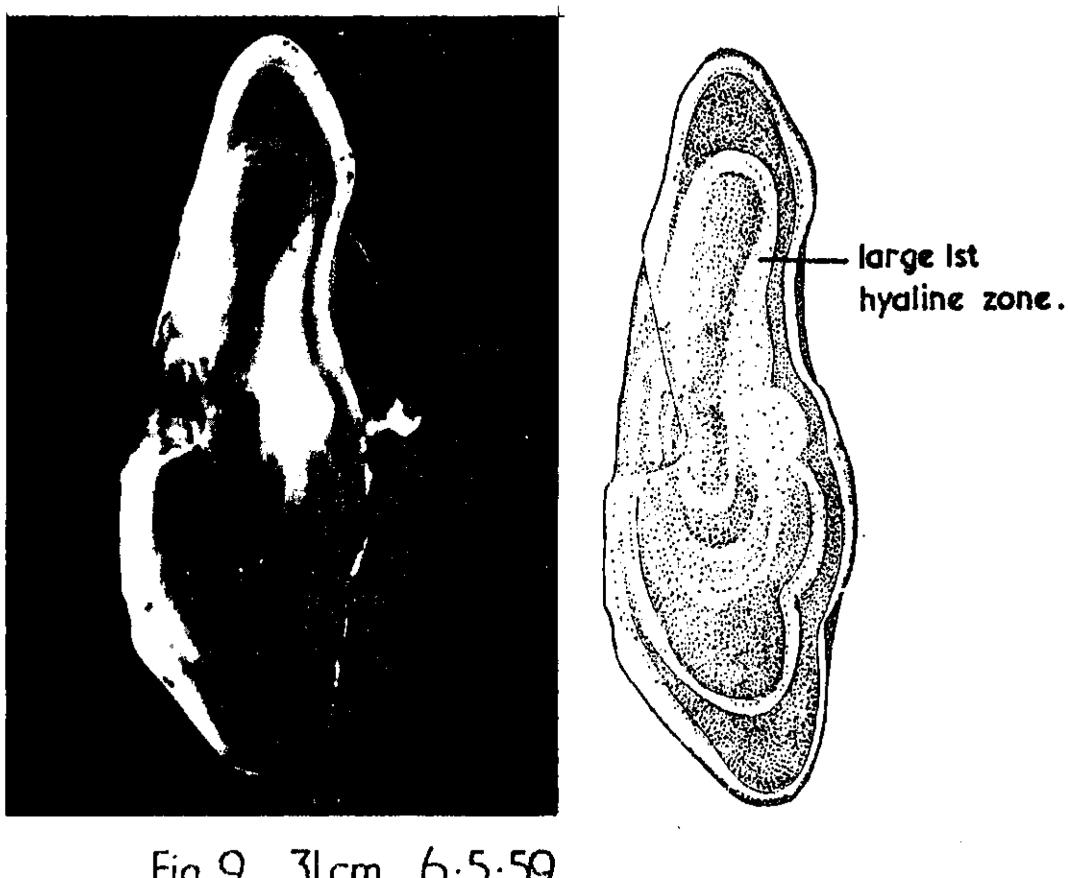


Fig. 9. 31 cm. 6·5·59
II-group.

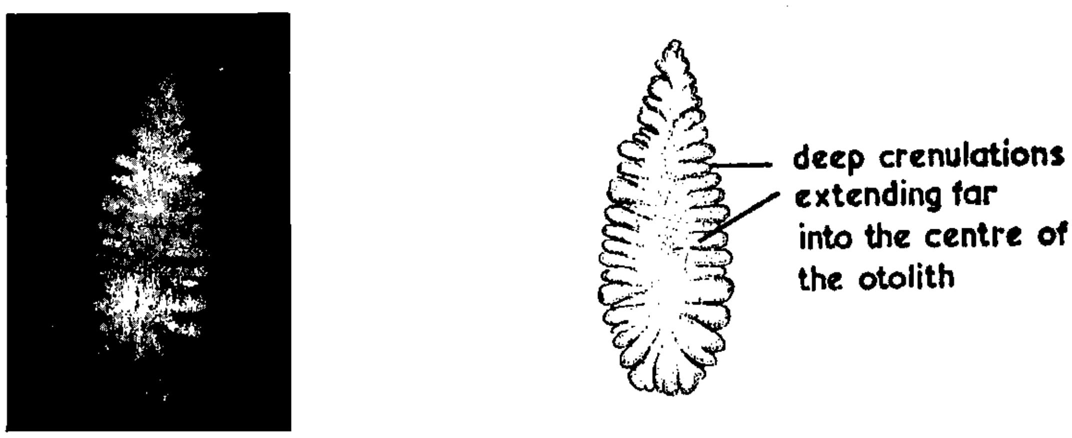


Fig. 10. Whole otolith, o-group.
(by reflected light)
12cm. 2·8·55

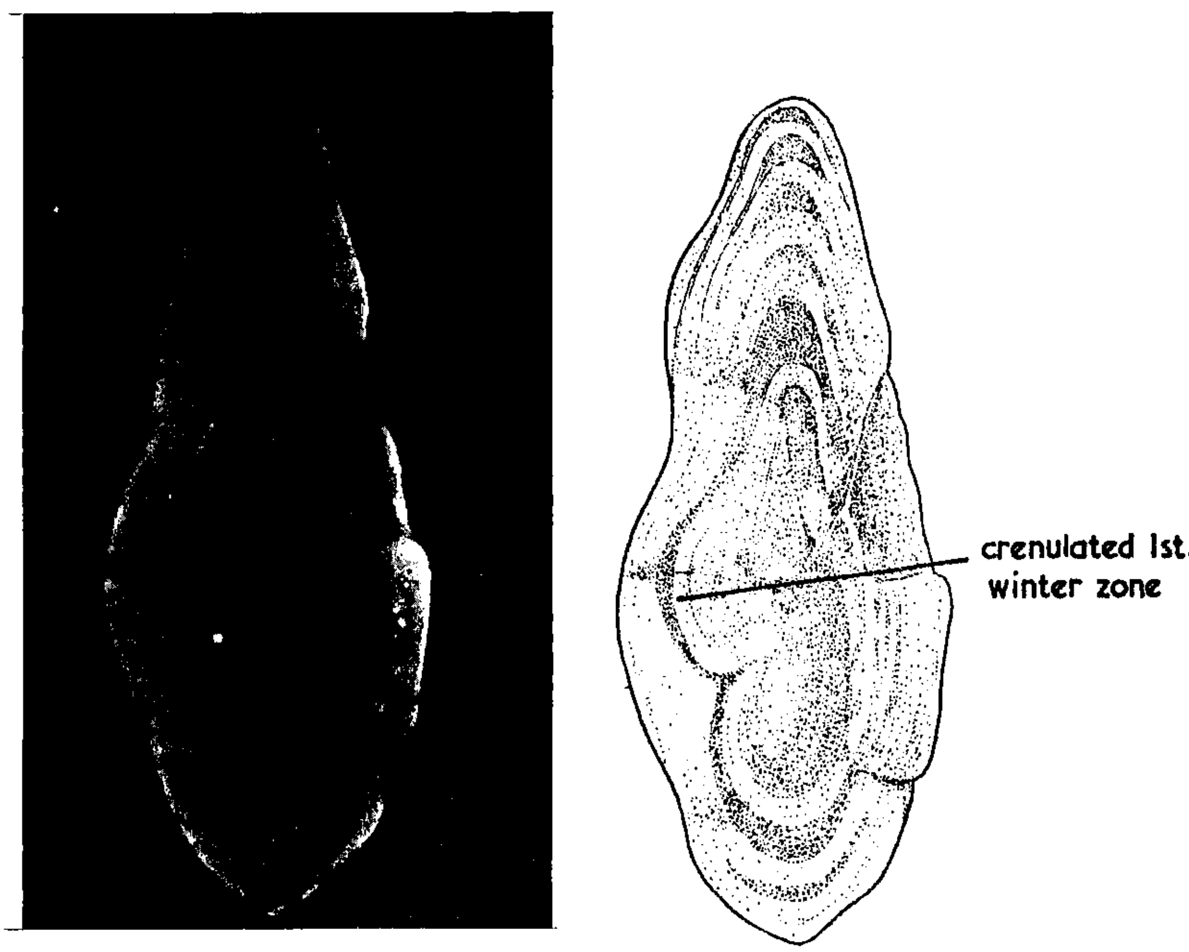


Fig. 11. 34 cm. 9·2·60
IV-group

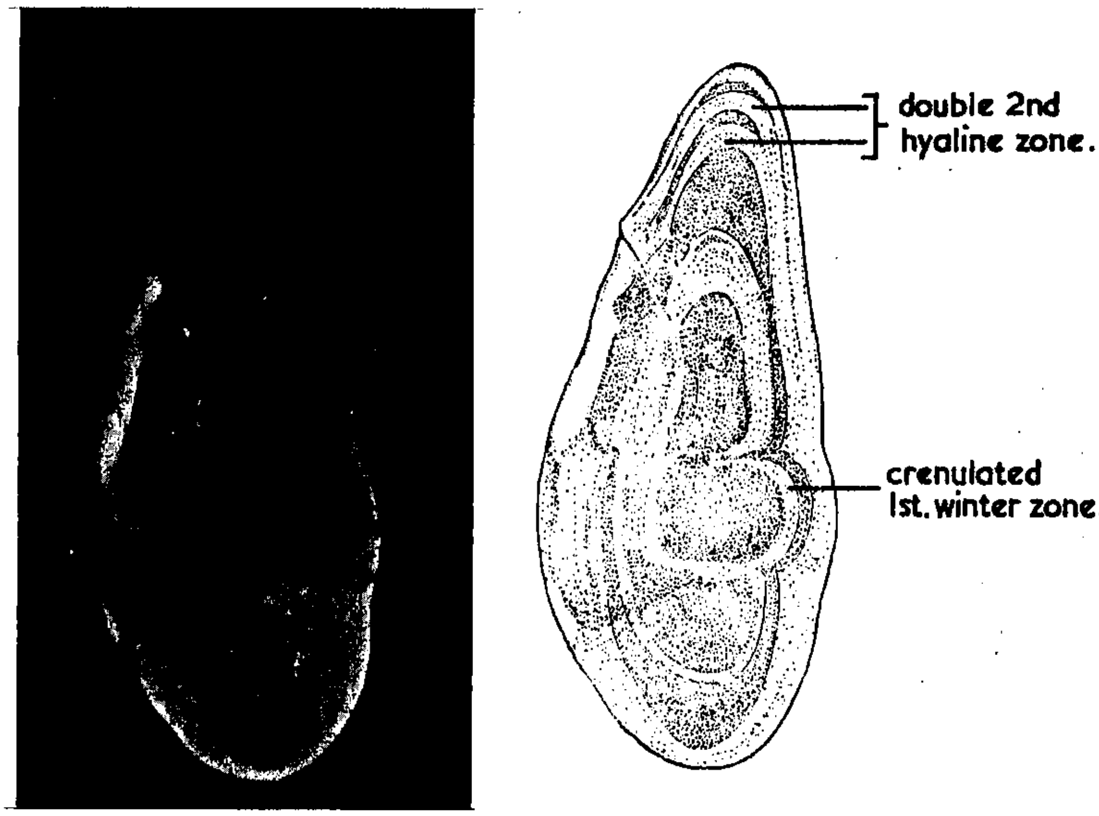


Fig 12. 30 cm. 9·2·60
II-group.

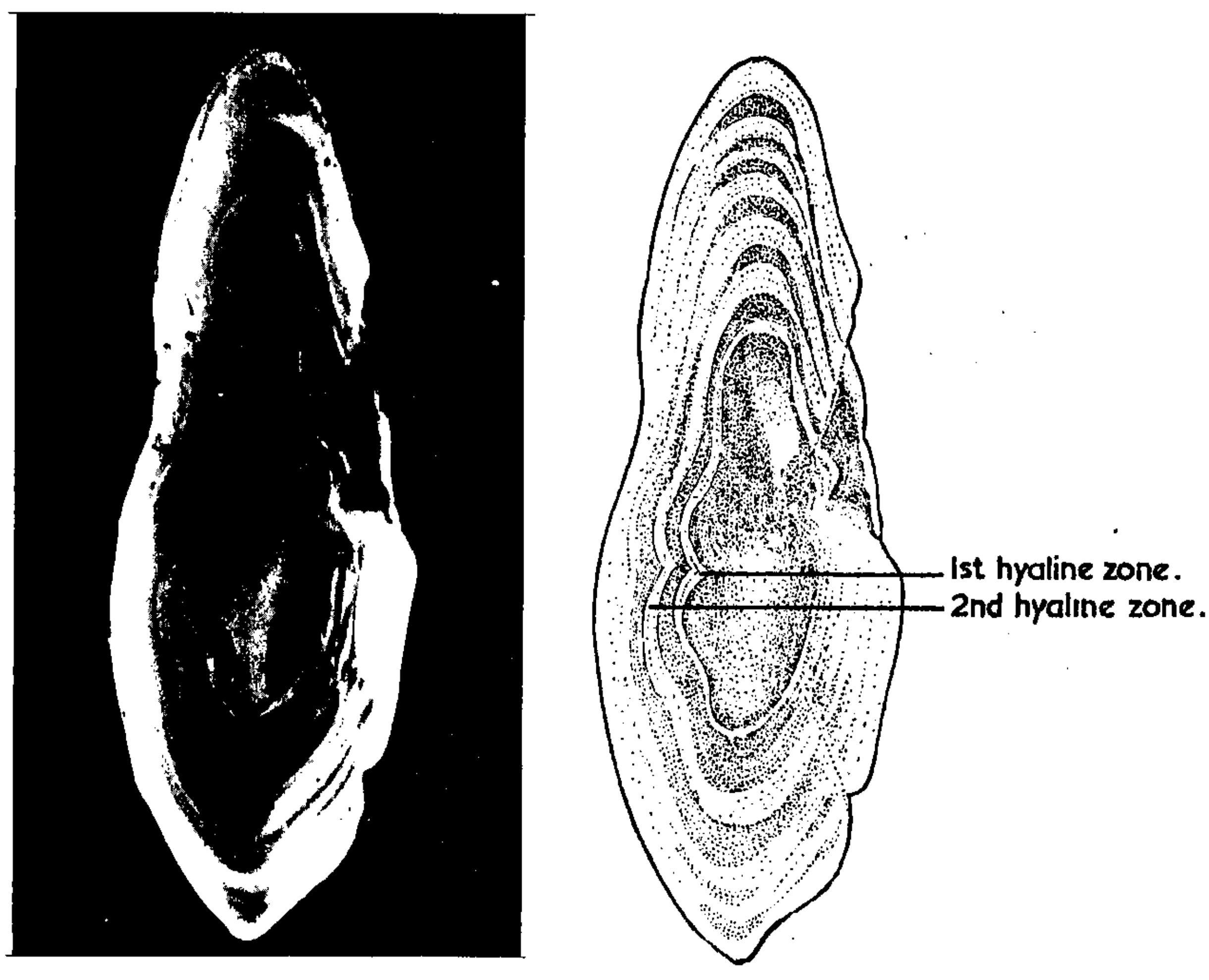
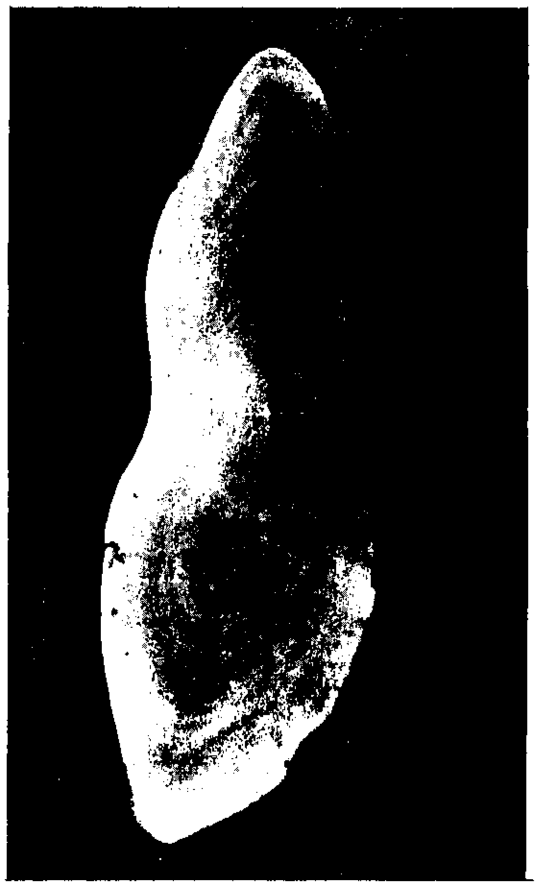


Fig 13. 38cm 6·5·59
V-group.



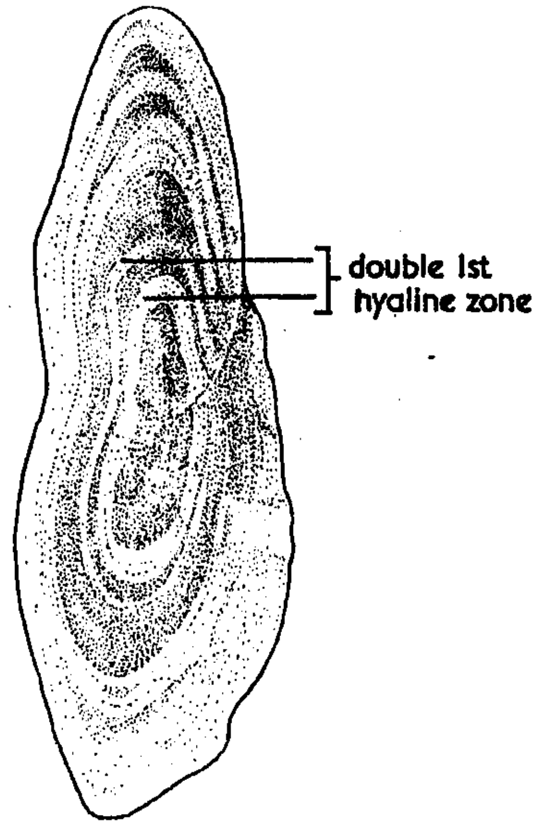
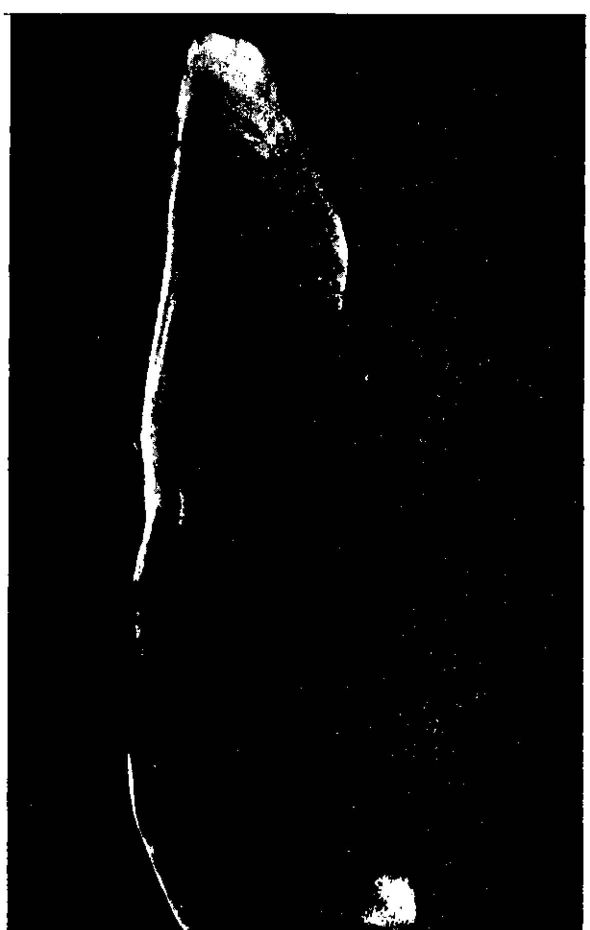


Fig. 14. 31 cm 9·2·60
IV - group.



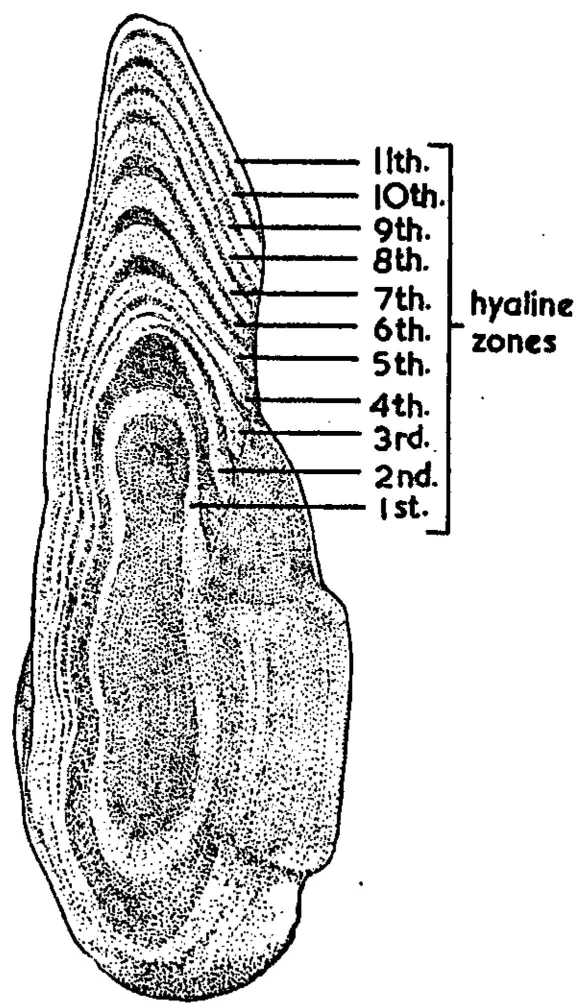


Fig. 15. 39 cm 11·11·59
X - group

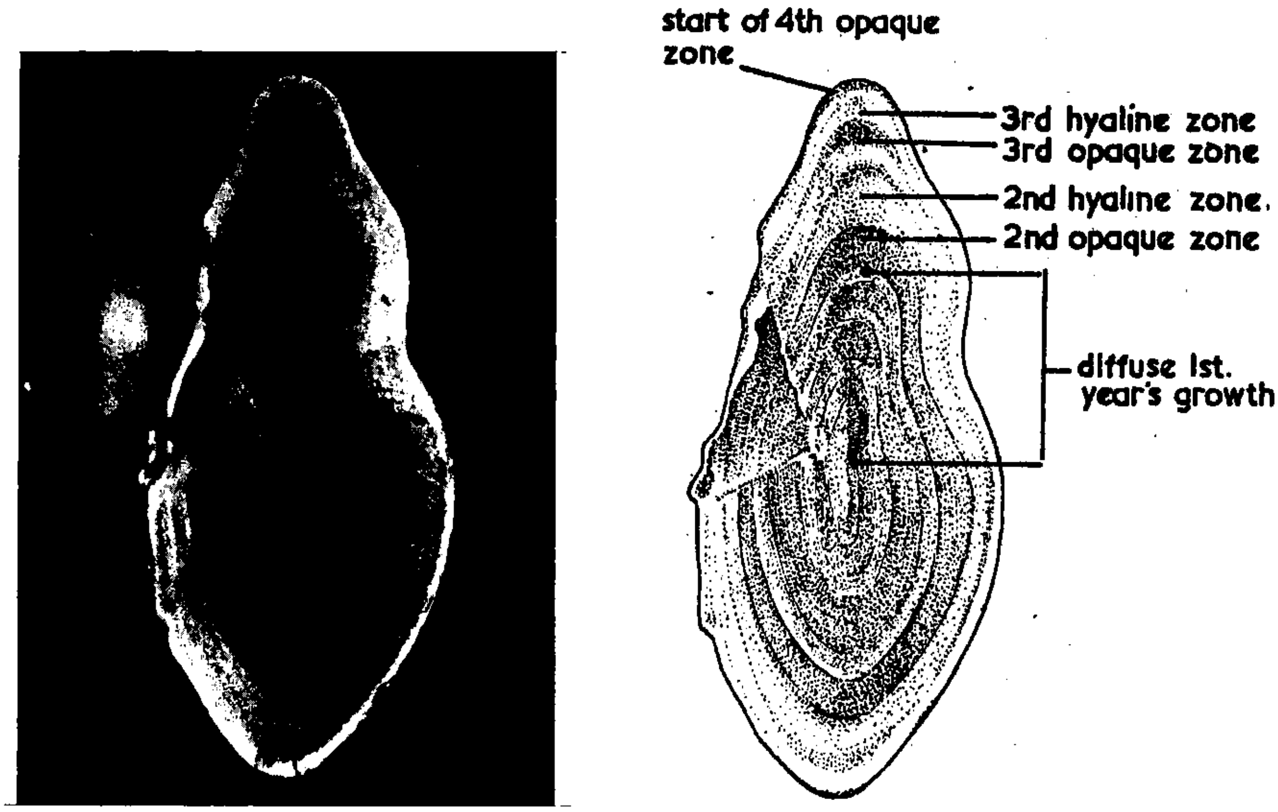


Fig. 16. Clyde otolith. 30 cm. 3·5·60
III - group