COMISION INTERNACIONAL DE PESQUERIAS
DEL ATLANTICO SUD-ORIENTAL

COMMISSION INTERNATIONALE DES
PÊCHES DE L'ATLANTIQUE SUD-EST

INTERNATIONAL COMMISSION FOR THE
SOUTHEAST ATLANTIC FISHERIES

ICSEAF OTOLITH INTERPRETATION GUIDE

NO. 2 CAPE HORSE MACKEREL

MADRID 1986

For bibliographic purposes, this publication may be cited as follows:

Otol. interp. Gde Cape horse Mack. int. Commn SE. Atl. Fish. 2:

Orders for copies should be sent to the following address:

International Commission for the Southeast Atlantic Fisheries

Paseo de la Habana, 65, 28036 Madrid, Spain

I.S.B.N.: 84-398-8112-6 - Depósito Legal: B-36.324-1986 - Printed in Spain - Imprenta Juvenil, S.A. - Maracaibo, 11 - 08030 Barcelona

COMISION INTERNACIONAL DE PESQUERIAS DEL ATLANTICO SUD-ORIENTAL

COMMISSION INTERNATIONALE DES PÊCHES DE L'ATLANTIQUE SUD-EST

INTERNATIONAL COMMISSION FOR THE SOUTHEAST ATLANTIC FISHERIES

ICSEAF OTOLITH INTERPRETATION GUIDE

NO. 2 CAPE HORSE MACKEREL

MADRID 1986

The ICSEAF guide for Cape horse mackerel otolith interpretation was prepared by the ICSEAF Working Group on Growth and Age, under the Chairmanship of B. Morales (Spain), with the collaboration of H. Hatanaka (Japan), M. Kerstan (Federal Republic of Germany), M.A. Kinloch (South Africa), P. Kolarov (Bulgaria), M. Lima Dias (Portugal), M.L. Marecos (Portugal), F. Mombeck (Federal Republic of Germany), A.I.L. Payne (South Africa), R. Sacks (ICSEAF Secretariat), and A. Wysokiński (Poland). The guide was edited by A.I.L. Payne and R. Sacks.

CREDITS

Figures 1-3 and 5-9 furnished by the Sea Fisheries Research Institute, Cape Town.

Figure 4 furnished by the Far Seas Fisheries Research Laboratory, Shimizu.

Photograph 1 and Photographs 6-26 furnished by the Sea Fisheries Research Institute, Cape Town.

Photographs 2-5 furnished by the Instituto de Ciencias del Mar, Barcelona.

TABLE OF CONTENTS

1. INTRODUCTION

Cape horse mackerel, **Trachurus trachurus capensis** Castelnau, is, in terms of mass landed, the dominant species in the ICSEAF Convention Area; and, in value, it ranks second only to Cape hakes.

In view of its importance, the species has been subject to intensive stock assessment by all the ICSEAF member countries involved in the fishery. These assessments have been based on the total reported catch, with basic parameters determined by each individual participating country. Of these basic parameters, age is probably the most vital, and therefore age data were recently pooled in an attempt to improve the annual assessments. It immediately became evident that age interpretations varied not only for specimens taken in widely separated areas but also for fish caught in essentially the same geographic location and at the same depth.

Such a finding had already been made for Cape hakes, and an ICSEAF otolith interpretation guide (No. 1 Hake, ICSEAF 1983a) had been produced, immediately resulting in greater standardization of interpretations. While subjectivity had not been entirely eliminated, the differences among the separate data sets had soon been reduced to within acceptable limits, with the result that greater confidence could be attached to such parameters as mortality rate, ages at recruitment and maturity, and growth constants.

It is with this same aim of standardization in mind that the ad hoc working group on age determination of horse mackerel set out to develop a guide for the interpretation of Cape horse mackerel otoliths, and its use is again recommended to age readers working on this species, particularly in its Southeast Atlantic habitat. The basic information for this guide has been taken from recent reports on horse mackerel ageing and from discussions among regular members of the working group as well as among these scientists and workers on other horse mackerel populations.

As in the case of hake, the guide incorporates some methodology applicable to other species of horse mackerel and, indeed, to other commercially important fish species. This material was considered to be relevant to the prime objective of the guide, i.e., standardizing Cape horse mackerel age readings; it was also felt to be of value to age readers generally.

2. STANDARD TERMINOLOGY AND NOTATION FOR OTOLITH READERS

Alternating opaque and hyaline zones form the basis for the interpretation of a fish's age. Although in theory this should be a straightforward task, the zones are not laid down uniformly throughout a fish's lifetime. Particularly during the juvenile pelagic phase, more frequent fluctuations in those environmental parameters which affect growth rate result in several rings of opaque and hyaline material being deposited on the otolith in any one year (Photograph 1). Interpretation of the age of the fish therefore becomes reliant on a subjective judgement of which of these rings are annual, and for this reason readings by different workers often vary widely.

To assist in identifying specific otolith features with an aim to facilitating discussion among experts and thereby minimizing discrepancies and errors in interpretation, the terminology and notation on page 2 are recommended:

3. GENERAL CAUSES OF RING FORMATION

Fish otoliths are composed chiefly of inorganic calcium carbonate crystals (aragonite) embedded in an organic matrix (a fibrous protein known as otolin). The organic constituent is the more complex in structure and consists of con-

Photo 1. Example of multiple hyaline rings comprising one hyaline zone; several individual hyaline rings can be discerned within each of the two annual hyaline zones on this otolith

A STANDARD TERMINOLOGY AND NOTATION FOR INTERPRETATION OF CAPE HORSE MACKEREL OTOLITHS*

Recommended term	Notation	Synonyms	Definition and comments
Centre	CN	Focus	Visible or imaginary spot in the centre of the otolith.
Nucleus	N		The central opaque portion of the otolith. It is bounded by the first hyaline zone and is variable in size.
Ring		Mark	A single, concentric opaque or hyaline mark visible around the whole or part of the otolith.
Hyaline zone	H	Hyaline ring Spawning ring Slow growth zone	A single or several closely grouped hyaline (translucent) rings interpreted as the annual hyaline increment; it is laid down on the otolith during a period of slow growth.
Opaque zone	O	Opaque ring Fast growth zone	A single or several grouped opaque (dense) rings interpreted as the annual opaque increment; it is laid down on the otolith during a period of fast growth.
Annual growth zone	Arabic numerals	Annual ring Growth ring Annual band Annulus True ring	A visible opaque and the adjacent hyaline zone collectively interpreted as one year's growth. In otoliths from adult fish, the zones are readily identifiable as single rings. The outermost zone should be distinctly visible over the greater part of the otolith, irrespective of its relative width.
False ring	F	Split ring (SPL) Double ring (DR) Check ring (C) Secondary ring (S) Accessory ring (A)	A ring which should not be interpreted as an annual ring, because it is laid down on the otolith as a result of a random, short-term fluctuation in some environmental parameter briefly affecting growth rate rather than a regular seasonal change in the environment.
Juvenile ring	J		The first hyaline ring surrounding the nucleus laid down before the fish reaches 1 year of age, though not always distinguishable.
Recording of age:			
	6(5)		Preferred age of 6, possibly 5, years.
	2(?)		Indicated age inconsistent with other data (e.g., length) or when interpretation is doubtful.
	3+		More than 3 years of age but no more than 3 1/2 years of age.

*In most cases the terminology and notation correspond to those given by Jensen (1965) as modified by the ICSEAF working group.

centric layers and radial fibres. The inorganic constituent comprises needle-like crystals secreted among the radial proteic fibres and passing through the concentric layers of the organic constituent from the centre of the otolith out to the edge.

Differences in the proportions of the organic and inorganic constituents present result in the alternating concentric hyaline and opaque zones seen on the otolith. Opaque zones form during periods of rapid growth, when proportionally more aragonite is deposited over the surface of the otolith, whereas hyaline zones, in which relatively less aragonite is deposited, form during periods of slower growth which, at least in adults, is usually associated with spawning.

Little is known conclusively at present about the exact causes of ring formation. There would seem to be a genetic factor governing the process, because fish kept at constant temperature and salinity levels continue to lay down annual growth zones in their otoliths. Annual zone formation also appears to be related to spawning, feeding, and environmental conditions. Nevertheless, the entire process is probably carried on according to some innate biological rhythm, as sexually immature fish also deposit annual rings even though they do not spawn. Factors such as abnormal temperature variations, disease, and periods of starvation seem to play a role, affecting the width of annual zones or leading to the formation of false rings (opaque or hyaline) that break the normal growth pattern of the otolith.

The causes of multiple ring formation (deposition of several alternating opaque and hyaline rings during one year, Photograph 1) are not yet fully understood. They are probably related to frequent fluctuations in environmental parameters of an intra-annual nature which are particularly prevalent in the pelagic environment, and hence their predominance on otoliths from juvenile fish. The most important factors are considered to be:

(i) Short-term, irregular changes in hydrological conditions resulting from localized upwelling.

(ii) Fluctuating food availability resulting from changes in upwelling intensity or current penetration. This is probably the most direct cause of the formation of more than one ring (hyaline or opaque) within a year. Thus, the number of opaque rings within any one growth zone would reflect the number of significant changes in upwelling intensity that took place during that year.

However, because the hydrological environment is basically stable and feeding opportunities can be regarded as rather regular throughout the year, the opaque zone tends to be broad. Deposition of several rings within a zone for a given year may, therefore, be a manifestation of short-term variations in feeding during that year.

4. AGE DETERMINATION TECHNIQUES

This section focusses principally on the use of otoliths to determine the age of horse mackerel but also looks at the use of other structures. Thus, it begins with a description of the otolith and goes on to discuss ways of collecting, storing, and viewing otoliths, with advice on techniques for improving readability and interpretation.

4.1 Specific structure and form of Cape horse mackerel otoliths

The general description of the otoliths that follows is based on that appearing in Geldenhuys (1973).

The sagittal otoliths of Cape horse mackerel that are used in ageing undergo rather pronounced changes as the fish mature. The posterior part of the otolith (Figures 1 and 2) is somewhat rounded, while the anterior part, or rostrum, is long and pointed. Dorsally the otolith exhibits both a rather small, pointed antirostrum and an excisura. The dorsal, posterior, and ventral margins are serrate, with grooves perpendicular to the otolith edge dorsally and laterally. A deep groove **(sulcus acusticus)** is located on the medial surface along the anterior-posterior axis, but it is not divided into ostium and cauda. The medial surface of the otolith is convex, and the lateral surface is slightly concave.

The otolith nucleus tends to be opaque (light in reflected light, dark in transmitted light), surrounded by alternating

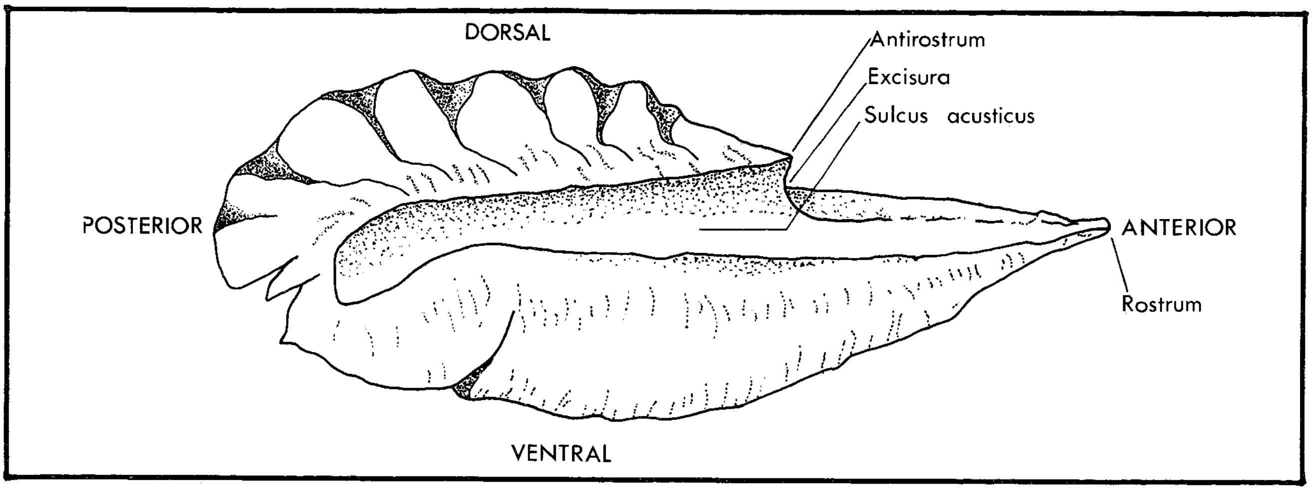


Fig. 1. Medial view of left otolith (internal, convex side up) (from Geldenhuys 1973)

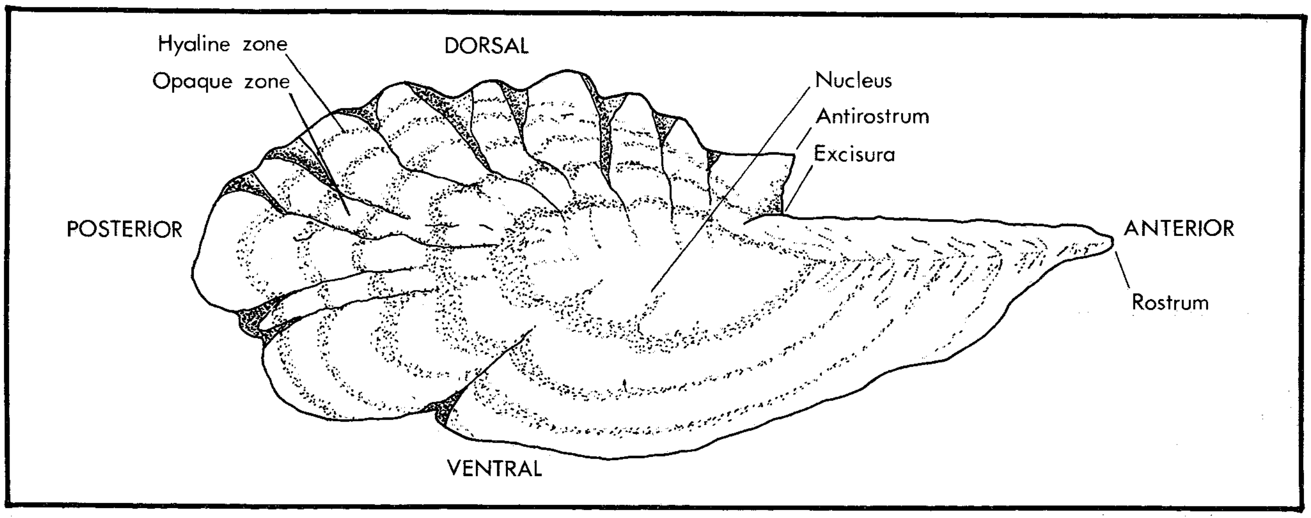


Fig. 2. Lateral view of right otolith (external, concave side up) (from Geldenhuys 1973)

hyaline (translucent) and opaque zones concentric to the outer margin. The zones seem to be most clearly distinguishable on the posterior part of the lateral (external, concave) side and on the rostrum and are generally much harder to identify on the medial (internal, convex) side.

Normally the anterior and posterior parts of the otolith grow faster, that is, otolith growth is faster along its long axis. With age, however, growth slows along both the long and short axes but continues along the lateromedial axis. Otoliths from older fish thus tend to be thick and consequently more difficult to read.

On the other hand, new growth around the edge of the otolith tends to be extremely thin, and it thus appears translucent when the otolith is viewed under both reflected and transmitted light, i.e., irrespective of whether the new material is opaque or hyaline.

4.2 Collection and storage

The most commonly employed method of removing otoliths entails making a cut in the head of the fish halfway between the posterior edge of the orbit and the posterior margin of the operculum. The cut must be deep enough to permit the front part of the head to be broken open to expose the inner ears, after which the sagittal otoliths may be removed with forceps and cleaned of any adhering organic matter. This method is acceptable for most fish, but a dissecting microscope is needed for small individuals less than 40 mm long.

An alternative technique for removing horse mackerel otoliths is to extract them ventrally. This method is especially useful for small fish and is as follows: turn the fish on its back, i.e., with the ventral surface upwards; next, splay open the operculum and forcibly pull back the isthmus and gill filaments to expose the underlying brain case (if the fish is large it may first be necessary to cut vertically through the anterior end of the isthmus, as it is joined quite strongly to the operculum); and finally, with a sharp knife, cut through the base of the skull immediately in front of the first vertebra (otico-occipital region) at an angle of approximately 45°, slanting the cutting edge of the knife towards the front of the head. The otoliths should then lie exposed in their auditory chambers and may be easily removed with forceps. If they are not immediately visible, the cut is not deep enough, and more of the bone must be carefully pared away until the otoliths are revealed.

Good results are achieved when otoliths are read immediately upon removal, but it is usually necessary to store them for some time. A simple, commonly used storage method suitable in most cases is, after immersion in 5% KOH to dissolve away any remnants of tissue, to place the dry otoliths in small envelopes appropriately labelled with length, sex, and any other pertinent information about the fish.

Otoliths may also be stored in water, alcohol, creosote, glycerine, a 50 % glycerine-alcohol mixture, clove oil, etc., or coated with petroleum jelly, according to personal preference. The storage medium must not alter the otolith structure.

Storage of otoliths in a liquid preservative may in some cases make interpretation easier, but with the passage of time the otolith structure gradually deteriorates to the point where interpretation becomes virtually impossible. A further drawback to the use of clarifying liquids is that the otoliths must be stored in small tubes, which may create problems of space.

4.3 Preparation and methods of viewing

Cape horse mackerel otoliths are rather small, and growth zones are rarely large or clear enough to permit reading by the unaided eye. Nearly all readers therefore make use of a binocular or similar low-power microscope.

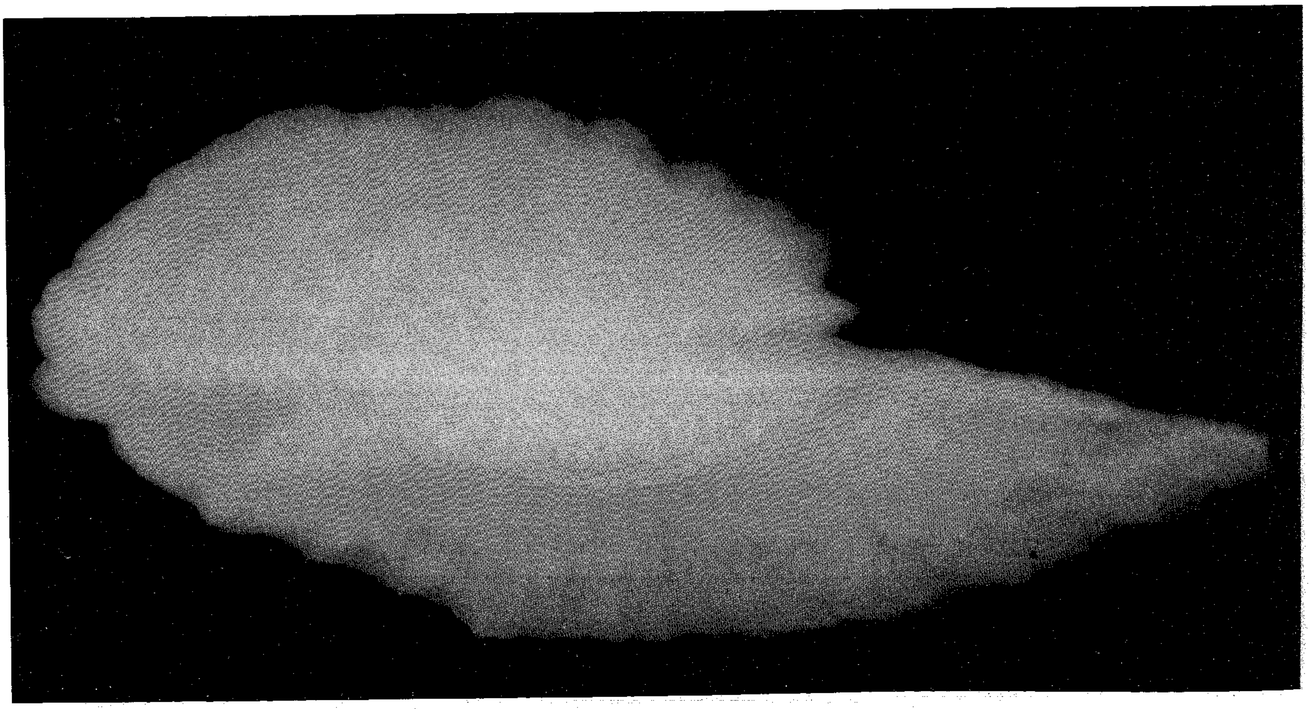


Photo 2. Example of the appearance of Cape horse mackerel otoliths viewed under reflected light

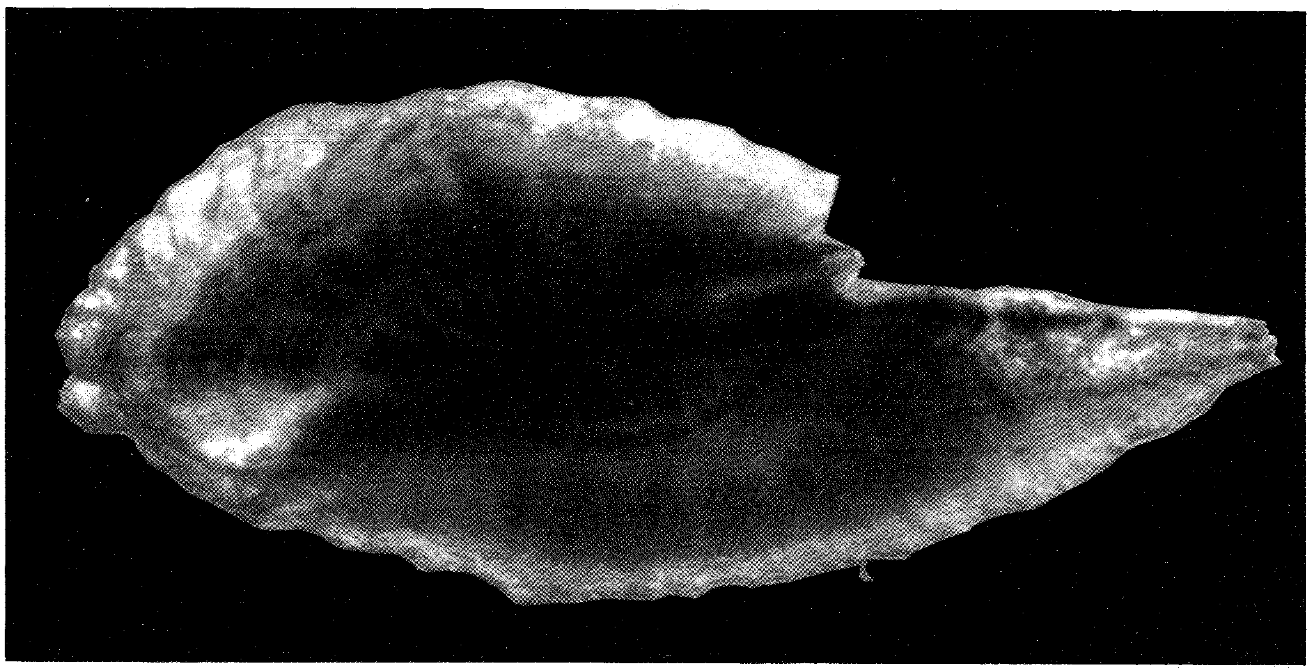


Photo 3. Example of the appearance of Cape horse mackerel otoliths viewed under transmitted light. the otolith shown is the same as the one in Photograph 2

Two different methods of preparing the otoliths for viewing are at present employed by readers working on Cape horse mackerel. Both are considered by their users to give accurate results, and consequently they are outlined in full here. A brief consideration of other methods of preparation that might be of value has also been included.

4.3.1 Uncharred otoliths

Whole otoliths, as opposed to sections, are recommended, because, excepting those from older specimens, Cape horse mackerel otoliths are relatively thin and translucent. Otoliths are placed concave surface up in a clarifying liquid, normally water, glycerine, alcohol, or xylene, in a dish having a black bottom as background. Prolonged immersion in some of these media, specifically glycerine and xylene, should be avoided, because, with the small, thin nature of the horse mackerel otolith, clarification is remarkably swift. Uncharred otoliths held in glycerine for longer than two months become virtually uninterpretable (glassy); just a few hours in xylene suffice to clarify the otolith for reading. In water, two to four hours of immersion before reading is normally adequate. After reading, the otoliths should preferably be cleaned and stored dry.

Readings are usually taken from the concave surface, but in the case of unclear otoliths, improved perception may sometimes be gained from the convex side. Normally, reflected light against a dark background, which shows the hyaline zones as dark and the opaque zones as light (Photograph 2), is preferred, although transmitted light may improve the readability of otoliths which are more transparent than usual. When transmitted light is used, the hyaline zones appear as light areas and the opaque zones as dark (Photograph 3). Terminology referring to light and dark areas should be avoided, for the obvious reason that the appearance of the zones will depend on the method of illumination employed, the appearance under reflected light being the opposite of that under transmitted light.

Experience has shown that a magnification of between 6X and 8X is adequate for virtually all untreated horse mackerel otoliths. Greater magnification tends to result in overinterpretation of the age, as more of the single opaque and hyaline rings are read as annual growth zones (Photographs 4 and 5).

Cross-sectioning or thinly slicing the otoliths are other methods of preparation that have received attention. Sections are made by cutting vertically through the centre, and slices (about 0,5 mm thick) are made by cutting otoliths already embedded in synthetic resin through the same radius.

On completion the sections are mounted on dark plasticine blocks such that the surface to be read is horizontal. Before reading, the surface is brushed with a clarifying liquid such as glycerine, xylene, or 70-% alcohol solution, and read under a binocular microscope at normal magnification. The method of cross-sectioning is, however, time-consuming and is not felt to improve readability to any singificant degree.

The preparation of slices is also quite time-consuming, but it has the advantage that many otoliths may be embedded in the same plane and a slice taken through them all. Such slices are readily viewable on a microscope slide through a binocular microscope under transmitted light.

The surface of untreated otoliths should be viewed in several directions, some workers more readily interpreting the zones in the posterior plane and others those in the anterior plane (along the rostrum). Age should be assigned only after readings have been made in several different planes.

The annual growth zones frequently form a protrusion above the surface of the otolith edge on the rostrum and posterior parts when deposition commences. This is most visible on the concave side and may help readers to distinguish between true growth zones and false rings, since the latter do not project above the surface of the otolith.

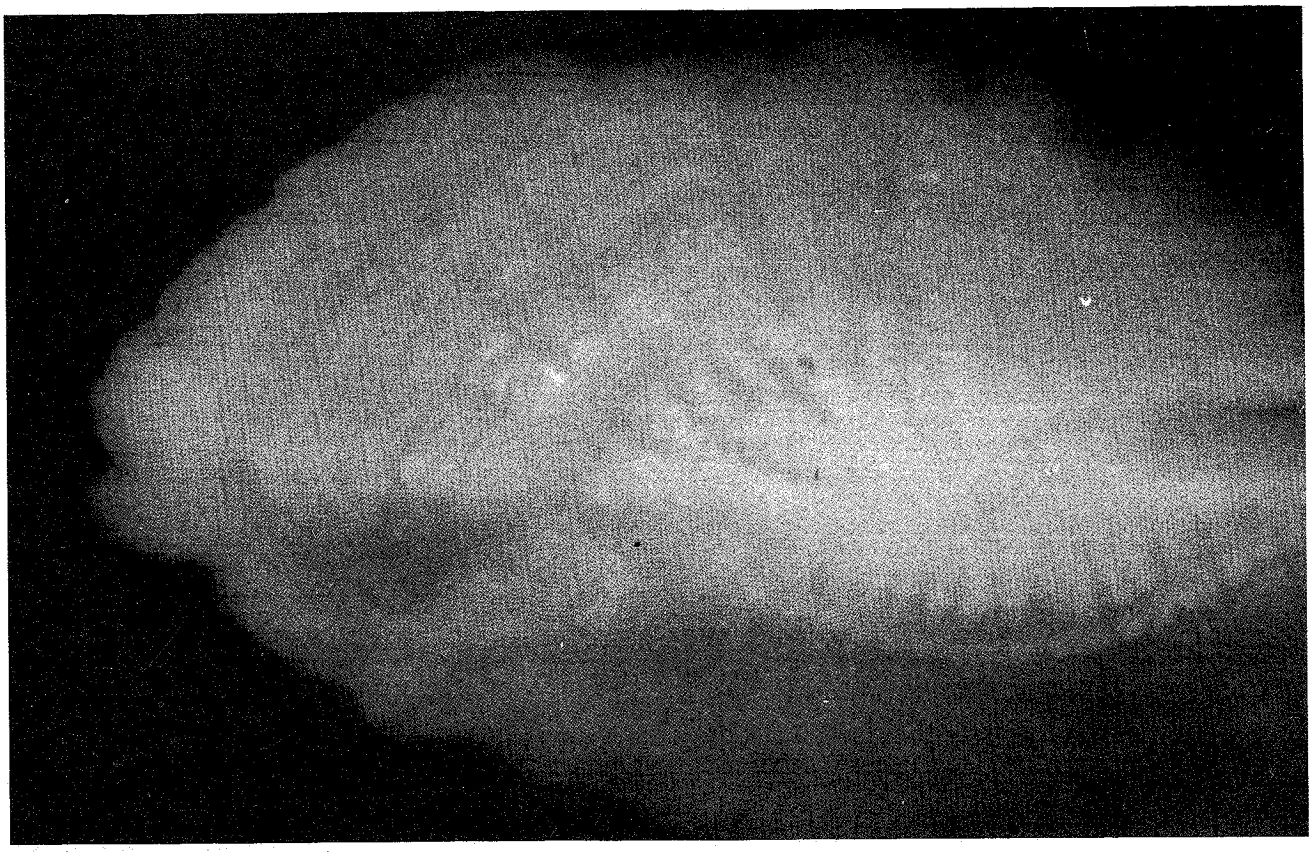


Photo 4. Example of the effect of magnification on the appearance of Cape horse mackerel otoliths: the otolith in Photographs 2 and 3 viewed at a magnification of 12X

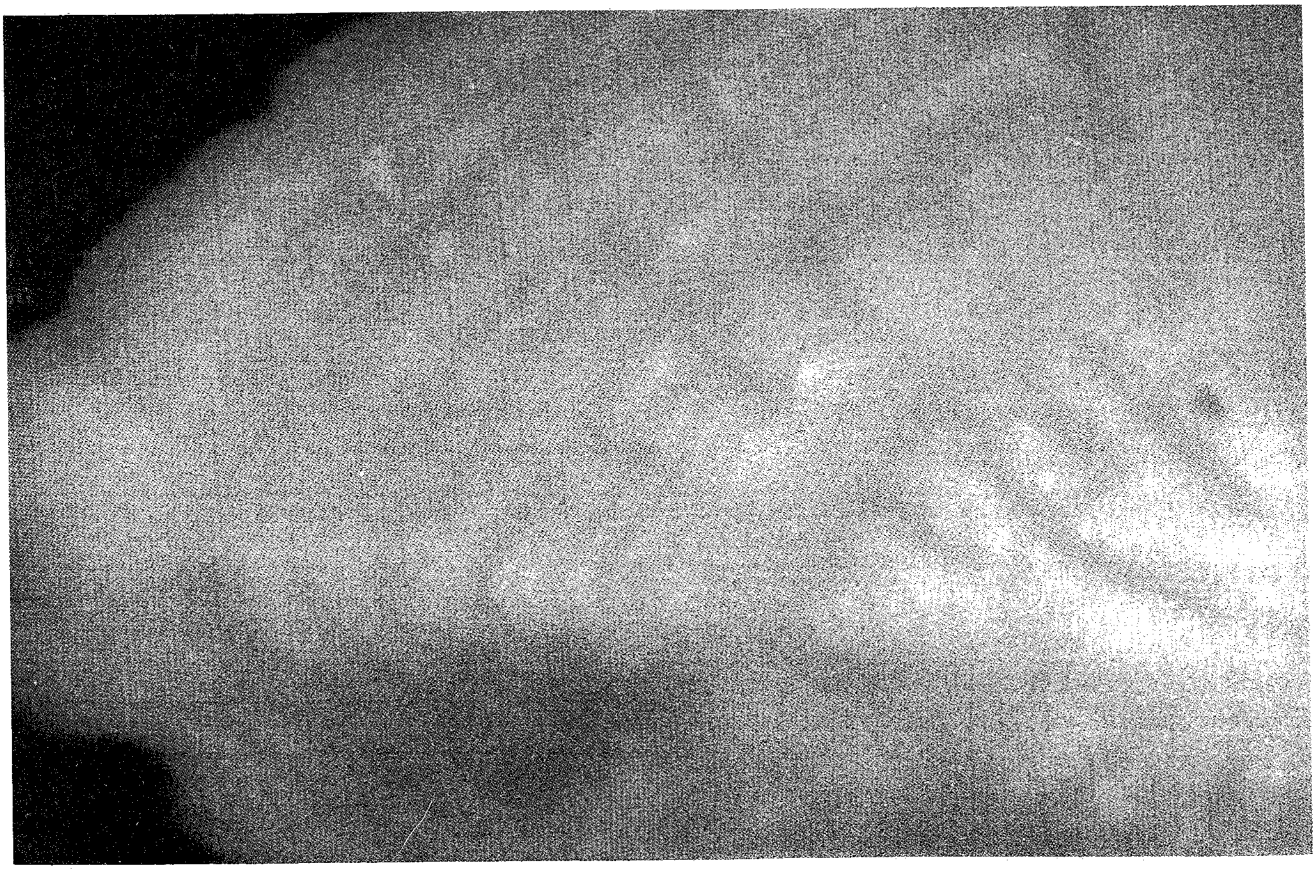


Photo 5. Example of the effect of magnification on the appearance of Cape horse mackerel otoliths: the otolith in Photographs 2, 3, and 4 viewed at a magnification of 22X

Due to the pattern of otolith growth, denser layers of material are deposited on the convex side, which usually prevents clear observation of the false rings when the otolith is viewed from this side.

Little or no difference is evident between the left and right otoliths from an individual fish, hence the use of either is acceptable. However, in order to preclude mistakes being made from reading otoliths with slight irregularities, both otoliths from a fish should be viewed as a matter of course.

As a cross-check, otoliths should be read twice; the readings should be independent and a reasonable length of time allowed to elapse between the two. If the readings differ, a third should be effected, and any two coinciding readings may then be accepted as valid.

4.3.2 Charred otoliths

Some workers feel that charring otoliths before viewing enhances the contrast between opaque and hyaline zones and emphasizes the true annual hyaline zones, since these tend to char most darkly (Photographs 6-9). Several different methods of preparing charred material for interpretation have been employed by experts working on Cape horse mackerel, and all give reasonable results.

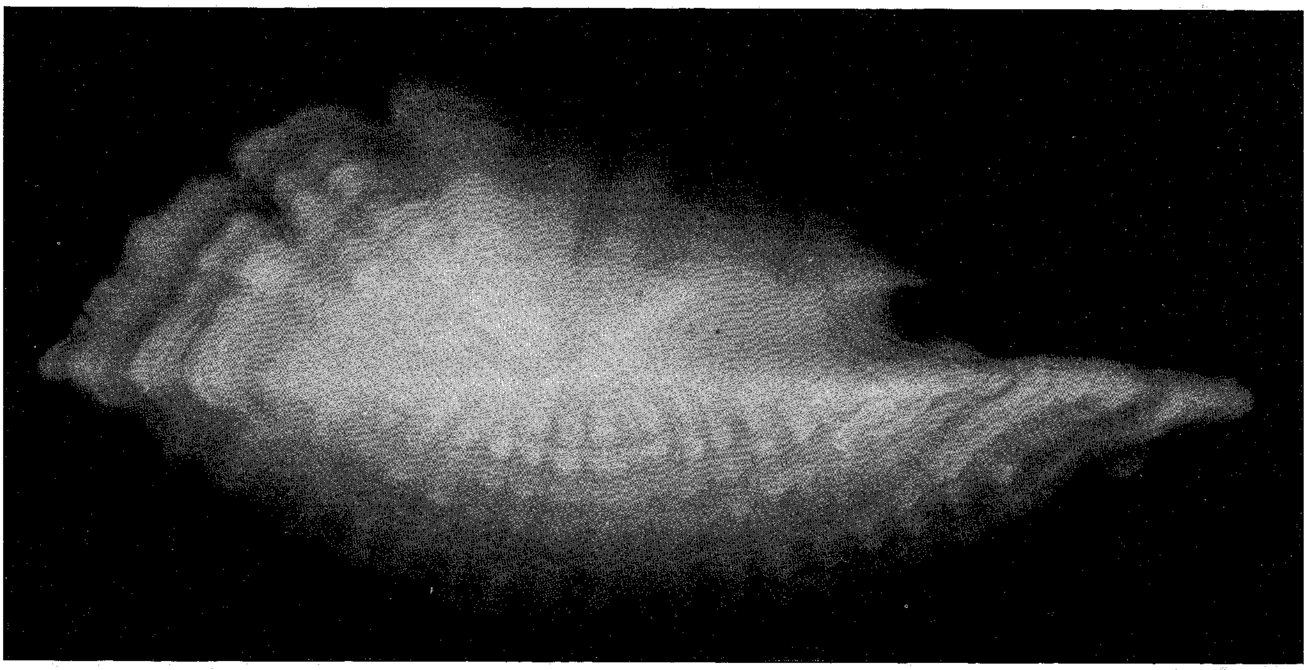


Photo 6. Uncharred otolith: many hyaline rings are visible on the otolith, particularly on the rostrum

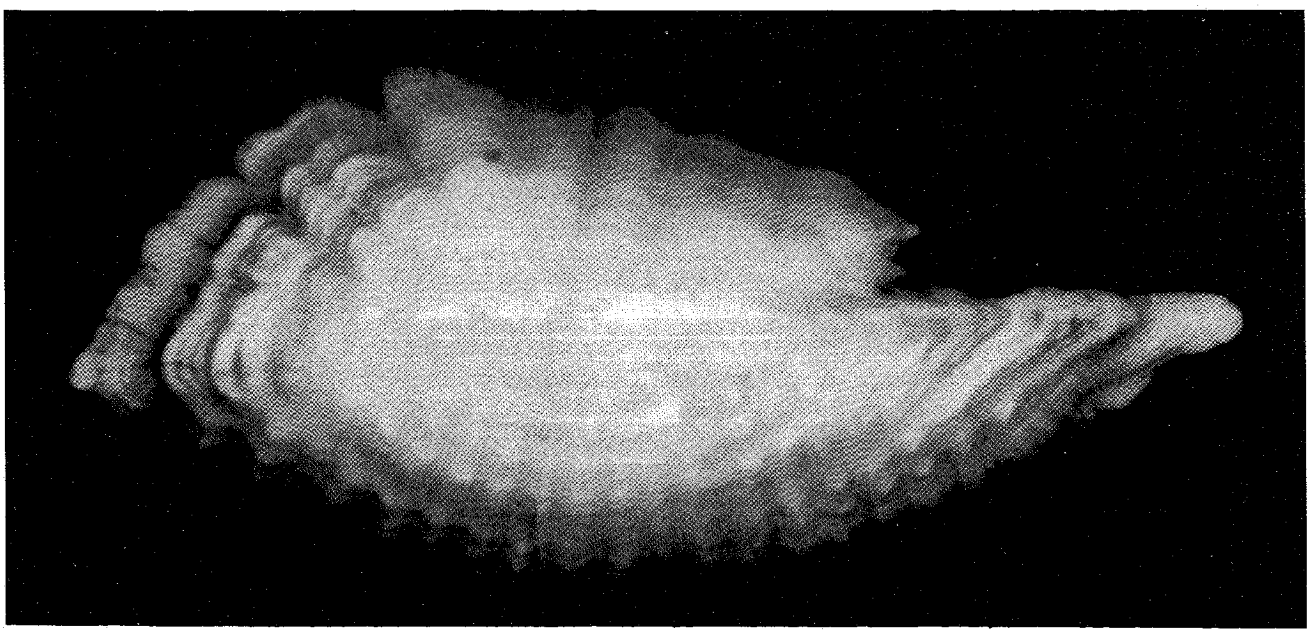


Photo 7. The same otolith as in photograph 6, after charring, the multiple hyaline rings have been resolved into three distinct annual hyaline zones

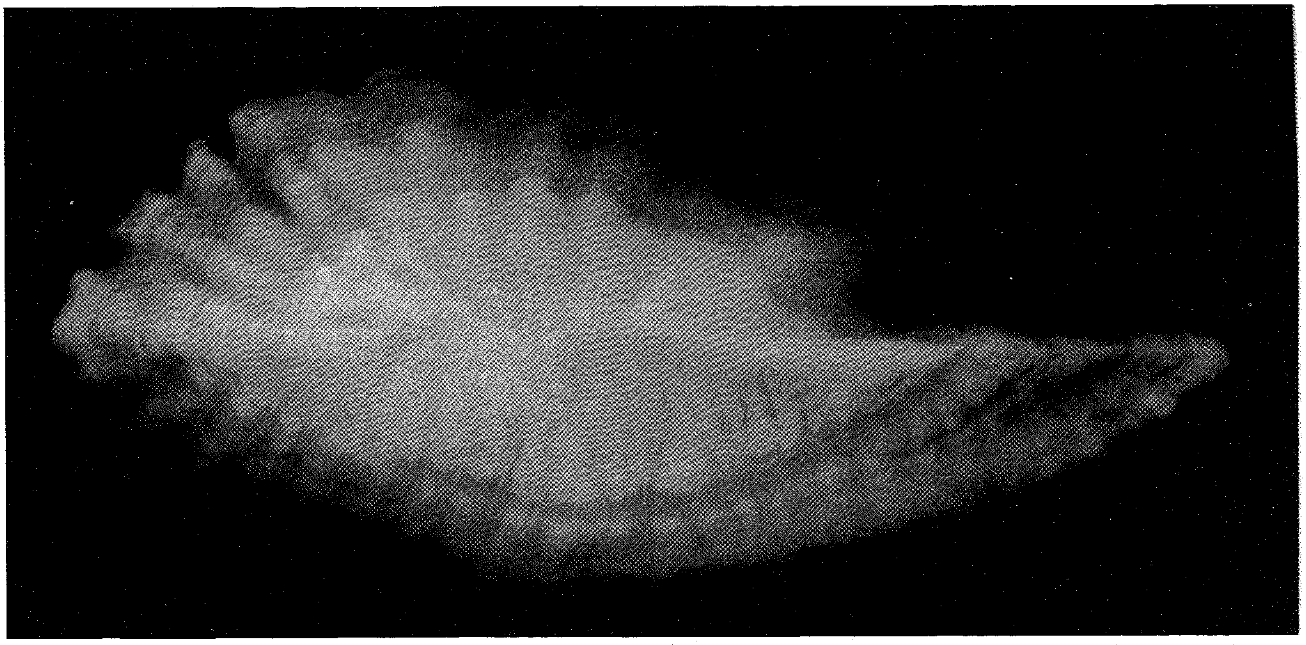


Photo 8. Uncharred otolith: the number of annual zones is indeterminate, although from the rostrum it appears that there could be as many as four

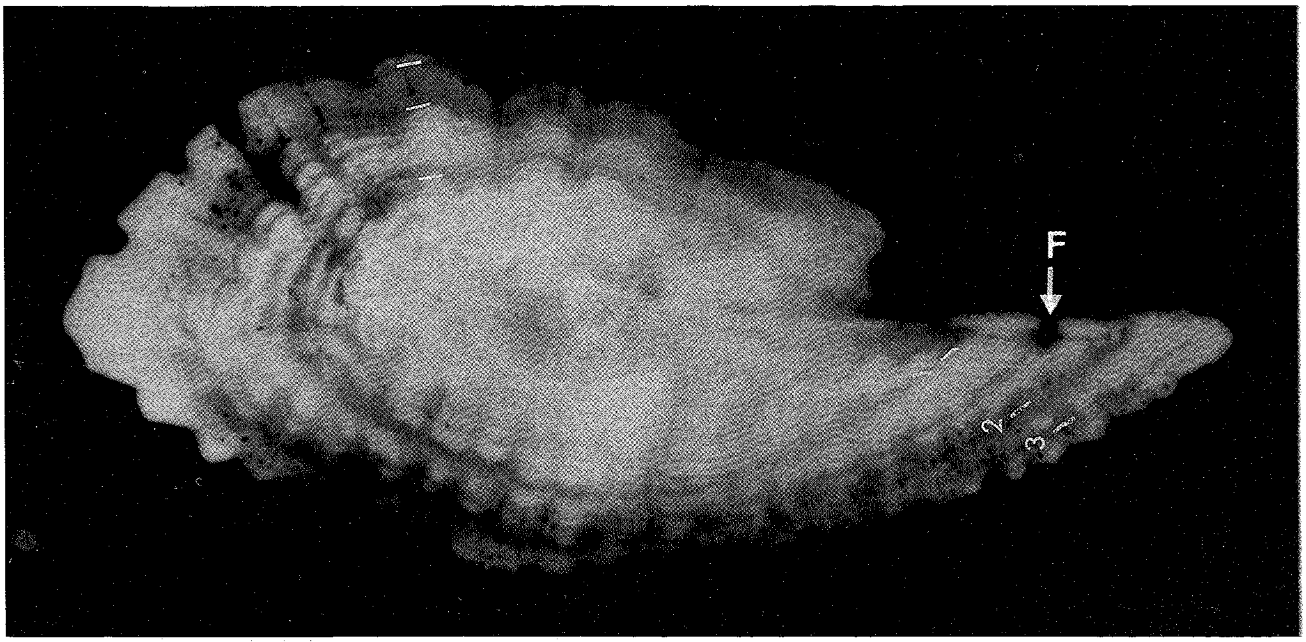


Photo 9. The same otolith as in Photograph 8, after charring, two clear hyaline zones have been highlighted on the posterior portion, corresponding to the first and third rings on the rostrum; the second ring on the rostrum can be seen to be a false ring (F), and the fourth ring is again visible on the rostrum and weakly in the dorsal area

The first commonly used technique is an adaptation of the method of Christensen (1964), in which the otolith is fractured across the transverse axis and its fractured surface held at the edge of a slow-burning Bunsen burner flame. The colour darkens, and the most satisfactory results are obtained when the surface is dark brown. Mounting, clarifying, and reading are then carried out in the same manner as for uncharred, sectioned otoliths.

A second method involves baking the otoliths, in their paper envelopes, for about one hour, in a laboratory drying apparatus set at 150-170 °C. These otoliths are also prepared and read in the same manner as uncharred otoliths.

Yet another effective method of charring whole otoliths is to hold them over a slow-burning flame. The otolith may be held with forceps, or it may be placed on a piece of asbestos gauze or thin sheet of metal, such as a razor blade. This permits accurate control of the extent and intensity of charring and normally takes no more than ten seconds. The otolith turns light brown in colour and may be read in glycerine at a magnification of 15X or 20X. This method also returns otoliths that have turned glassy from prolonged storage in glycerine to a readable state.

The same considerations as those set forth for uncharred otoliths concerning cross-checking and acceptance of readings and the direction of interpretation over the surface of the otolith also apply to charred otoliths. In addition, it is sometimes found useful to char only a single otolith of a pair, so that readings of both treated and untreated otoliths may be compared.

4.3.3 Other means of preparation

Two additional preparation techniques have been applied to horse mackerel otoliths with some measure of success. Both, however, involve some time-consuming procedures, and they are therefore not recommended where mass ageing is to be performed.

Protein-staining dyes (Albrechtsen 1968), such as acid methyl violet B, stain the organic layers in the hyaline zones darker, these layers being more numerous, more closely spaced, and/or thicker than in the opaque zones. The concentration of the stain and the immersion time are both critical.

The second method consists of polishing the whole otolith. It is of little value in the case of material from younger fish, because the otoliths are thin and readable, but the thicker, denser otoliths from older fish may be rendered more readable by placing them on a fingertip and gently rubbing them over a fine whetstone.

4.4 Ageing methods other than from otoliths

Generally speaking, the procedures most commonly used to obtain age data can be grouped into two main categories, i.e., those based on length frequency information and those based on age readings of the growth marks present in the bony tissues of fish.

In the first-group (Petersen method and modifications thereof) yearclass modes from length frequency distributions are used to compile age data, especially for younger fish.

Length-frequency-based methods have proved to be extremely well-suited for **Trachurus trachurus capensis**, and accurate growth equations can be derived using such methods, especially in the case of juveniles.

The second group of methods is based on the fact that periodic variations in the growth rate of fish cause growth marks or discontinuities to be deposited in their calcified structures, making it possible to age individuals. The most frequently used structures are scales and vertebrae, and both have been used in ageing Cape horse mackerel. Acceptable age determinations can be made from scales, but the reliability of vertebrae has not yet been established. One major drawback to the use of scales, as explained below, is that they may be lost or damaged in the catching process, thus rendering the ageing of a particular specimen impossible.

Collecting scales from trawl-caught horse mackerel for use in age determination is problematical. The scales from the upper part of the body (below the dorsal fin) are typical in shape and bear clear growth zones for reading. However, by the time specimens reach the deck, they are likely to be missing scales from precisely this portion of their bodies. After processing the catch, scales from one individual can very often be found stuck to the bodies of other individuals. Thus, in most cases, scales from under the pectoral fin are the only ones that can reliably be taken.

The growth zones on scales taken from the middle of the body just below the dorsal fin are normally quite readable. However, in some cases rings may overlap on the edge of the scales in individuals older than 4 years. Consequently, scales are recommended mainly as comparative ageing material and for juvenile fish.

4.5 Relationship between total length and otolith size

Because the rostrum of the horse mackerel otolith is long and pointed, it is frequently broken off on removal. As a result, the radius of the posterior part of the otolith is used as a measure of otolith size (Figure 3). Figure 4 shows a plot of this otolith radius on total fish length. Using multiple regression analysis, the following quadratic equation was obtained for this relationship for material collected in Divisions 1.3 and 1.4:

$$OR = -0{,}00138TL^2 + 0{,}179TL - 0{,}0430$$

where: OR is otolith radius in mm;
TL is total fish length in cm.

The relationship between otolith size and fish body length may vary from location to location within the Convention Area and over time.

5. READING AND INTERPRETING OTOLITHS

The following subsections each provide a general consideration of the main problem areas associated with otolith reading.

5.1 Nucleus and first annual zone formation

The nucleus is the central, opaque area of the otolith, bounded by the first visible hyaline ring, set of rings, or zone. On some otoliths the centre of the nucleus contains a visible, diffuse zone or spot.

Preliminary results indicate that the peak season of hyaline ring deposition in juveniles is winter (June, July, August), and it has been established that the spawning season of horse mackerel in the Southeast Atlantic lies, depending on the area, between September/October and March/April. Thus, assuming that hyaline zone deposition is season-related and not age-related, it is possible for the first hyaline zone to be deposited on the otolith at any time between two and ten months after the fish has been spawned. Obviously, this will have an effect on the radius from the centre of the otolith to the first hyaline ring, i.e., the diameter of the nucleus (Photographs 10-13). If the fish was spawned early in the season, e.g., October, the diameter of the nucleus will be relatively large, because the fish (and otolith) will have grown for approximately nine months prior to deposition of the first hyaline ring (Photograph 13). If, on the other hand, the fish was spawned very late in the season, e.g., March, the otolith will have grown for only three to four months prior to deposition of the first hyaline ring, and the nuclear diameter will thus be much smaller (Photograph 10). This phenomenon can have important consequences in terms of correct age group classification based on back-calculation, since, in the latter case, the central pair of opaque and hyaline zones does not represent one full year of growth. This problem will be dealt with further in Section 6, dealing with assignment of age and year class.

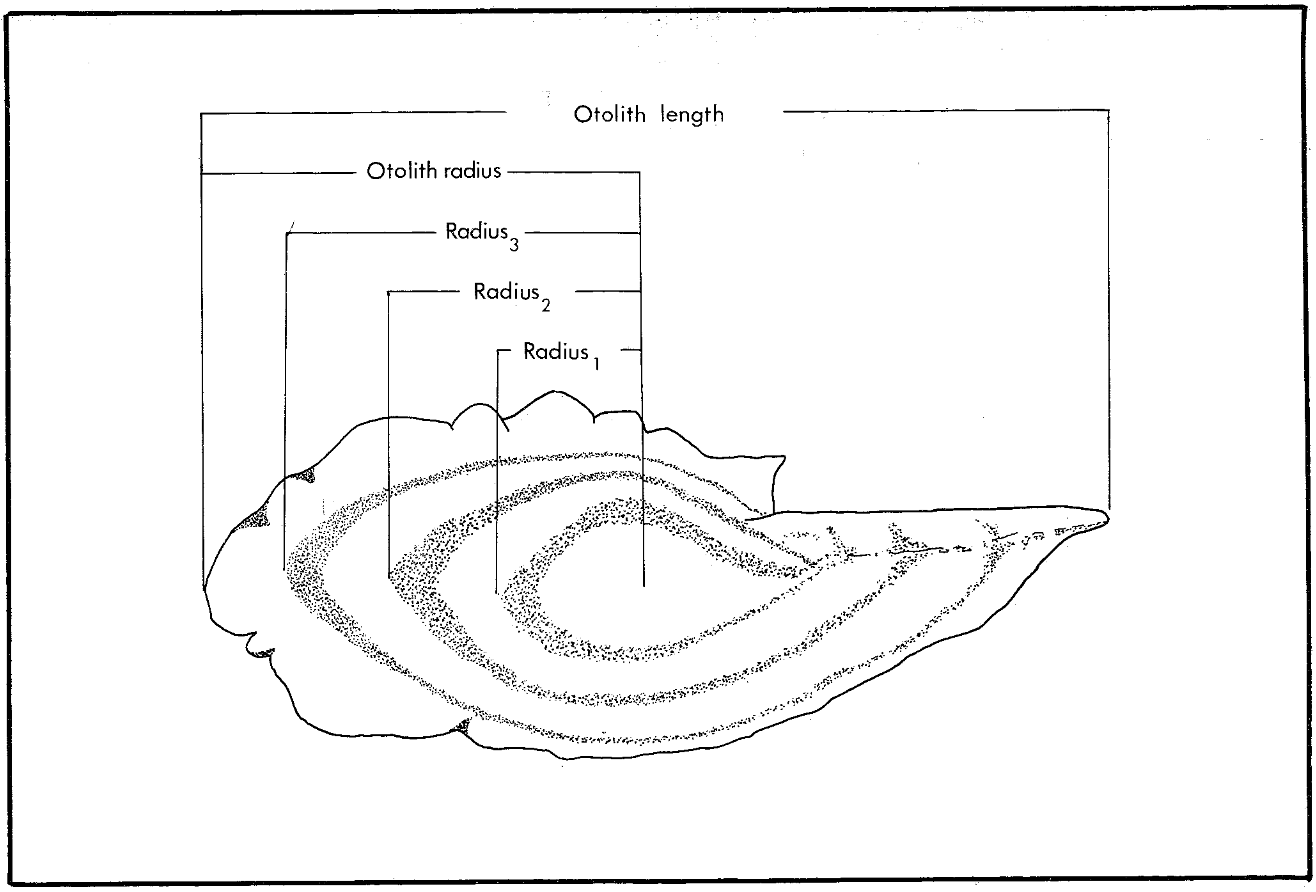


Fig. 3. Otolith radius measurements (from Geldenhuys 1973)

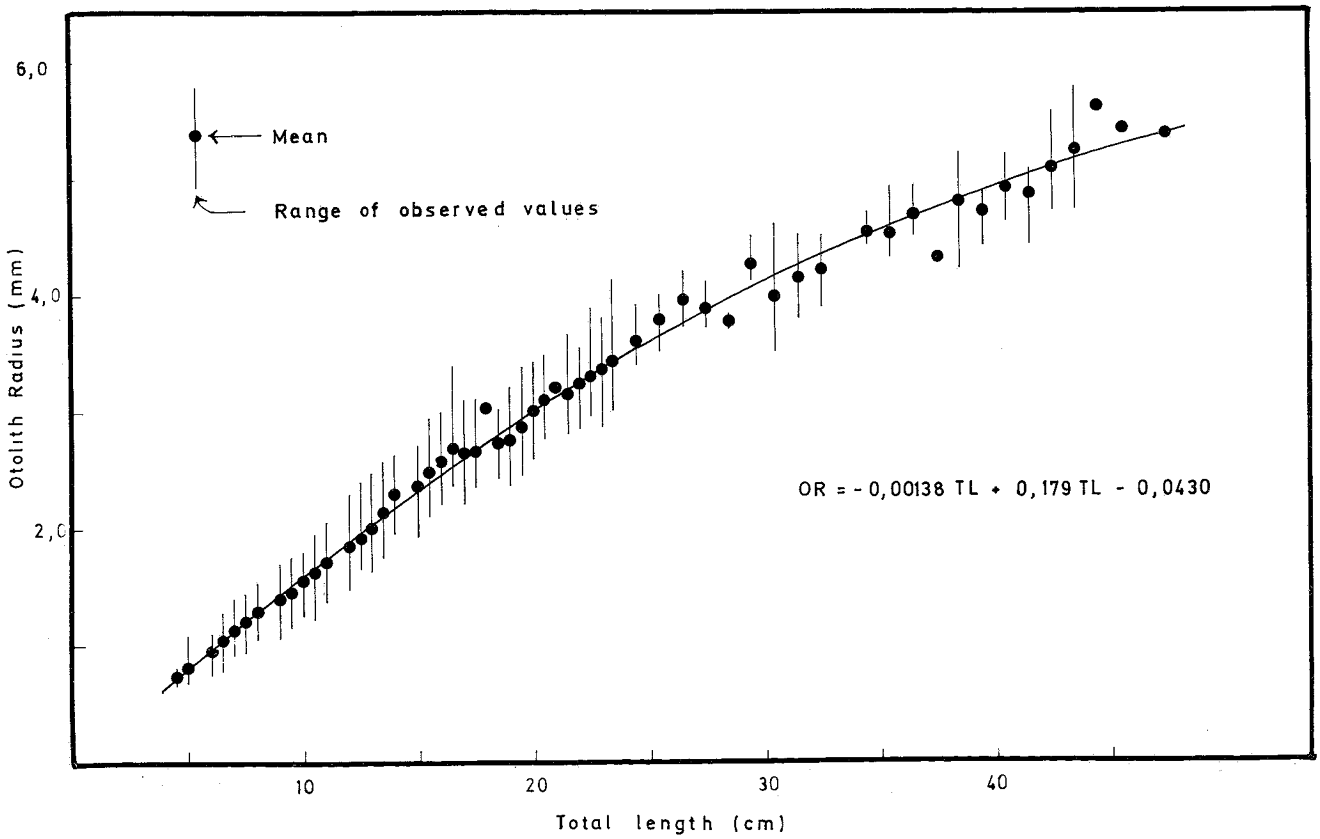


Fig. 4. Example of the relationship between total fish length and otolith radius (from material collected in Divisions 1 3 and 1 4)

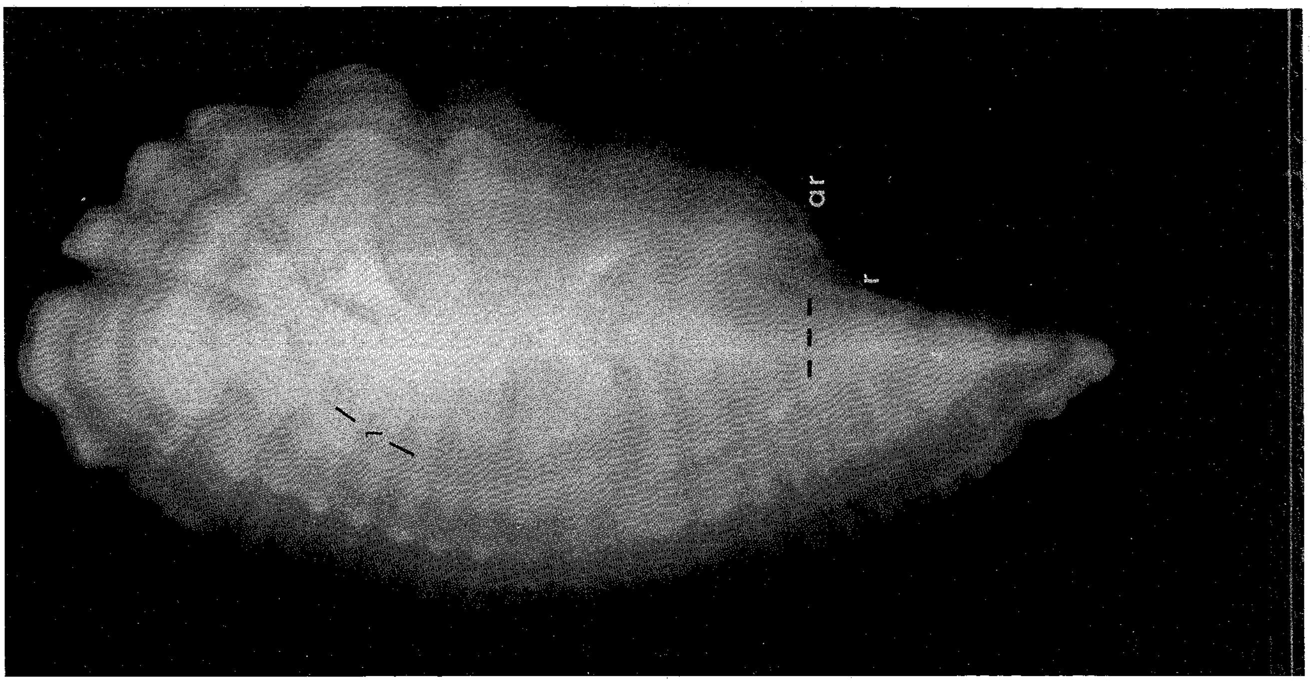


Photo 10. Photographs 10-13 are a series illustrating the varying position of the first hyaline zone in relation to the centre and rostrum (r), depending on the date of birth. Note the increasing relative diameter of the nucleus as a proportion of total otolith length and the extension of the first hyaline zone onto the rostrum In this photograph, the first hyaline zone does not extend onto the rostrum at all (ar = antirostrum)

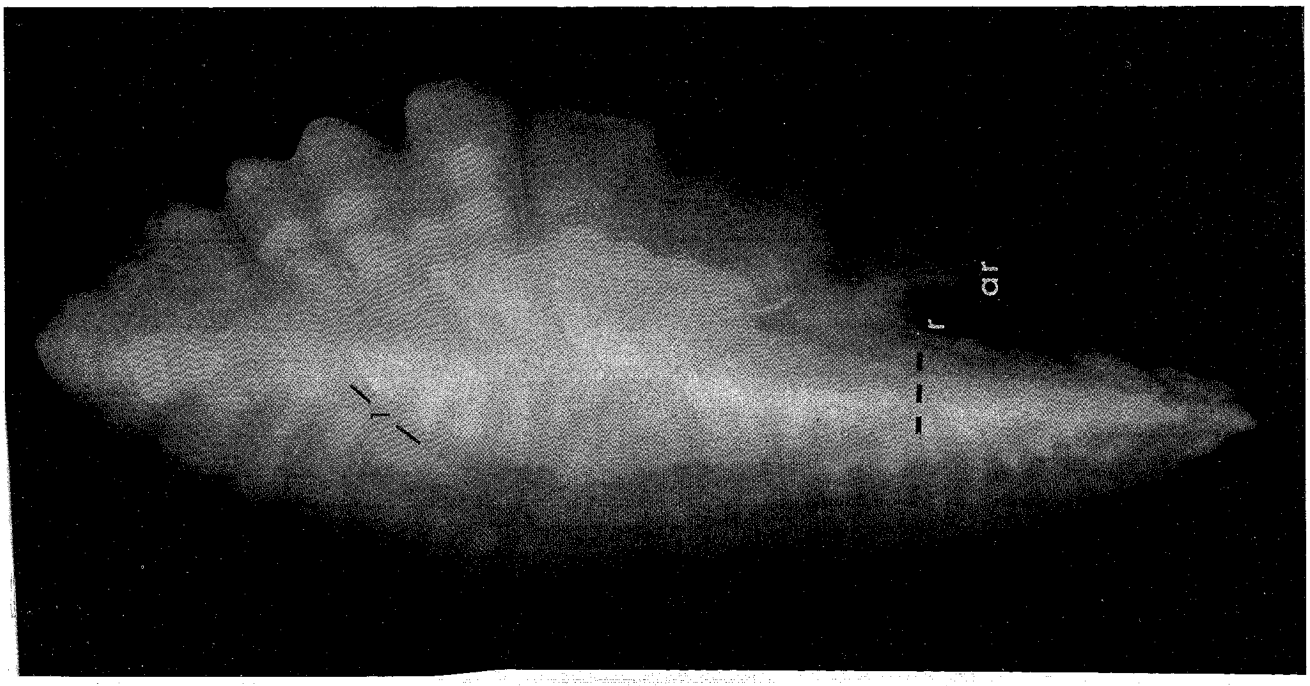


Photo 11. In this otolith the first hyaline zone extends slightly into the rostrum (r) (ar = antirostrum)

Photo 12. Another example of the extension of the hyaline ring into the rostrum (r) (ar = antirostrum)

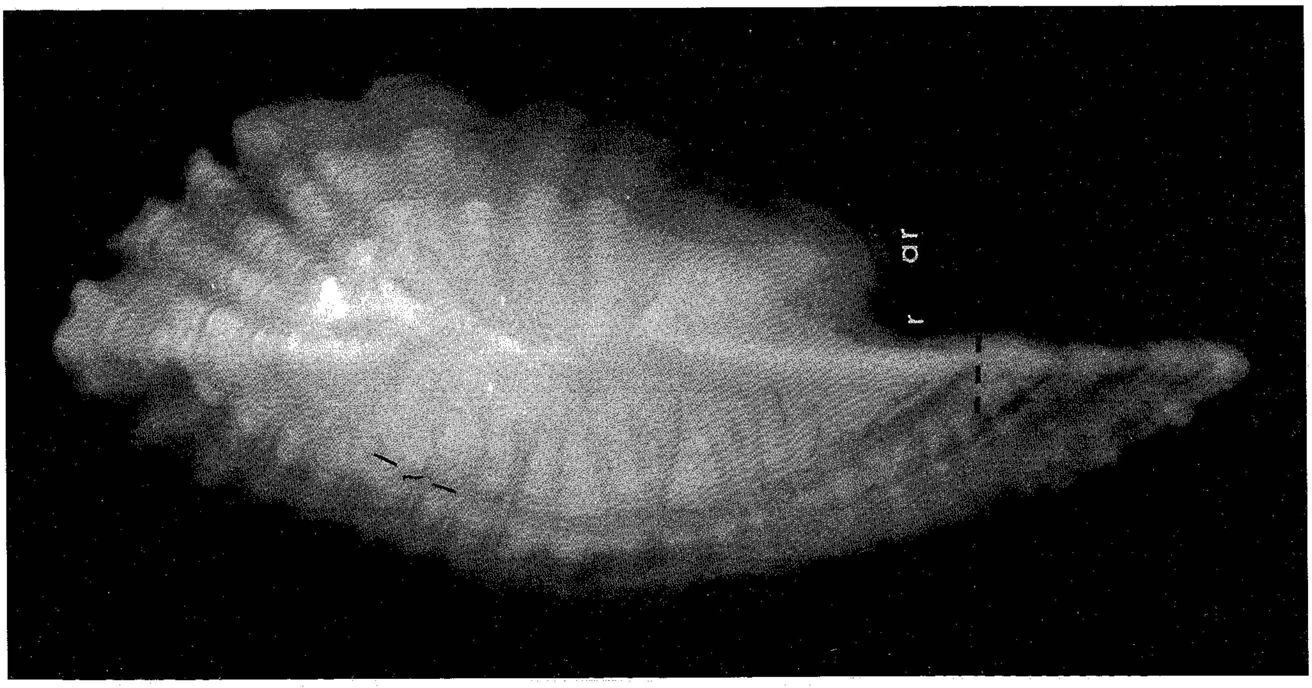


Photo 13. In this otolith the first hyaline ring is pronounced, well beyond the point of formation of the distinct rostrum (r) and antirostrum (ar)

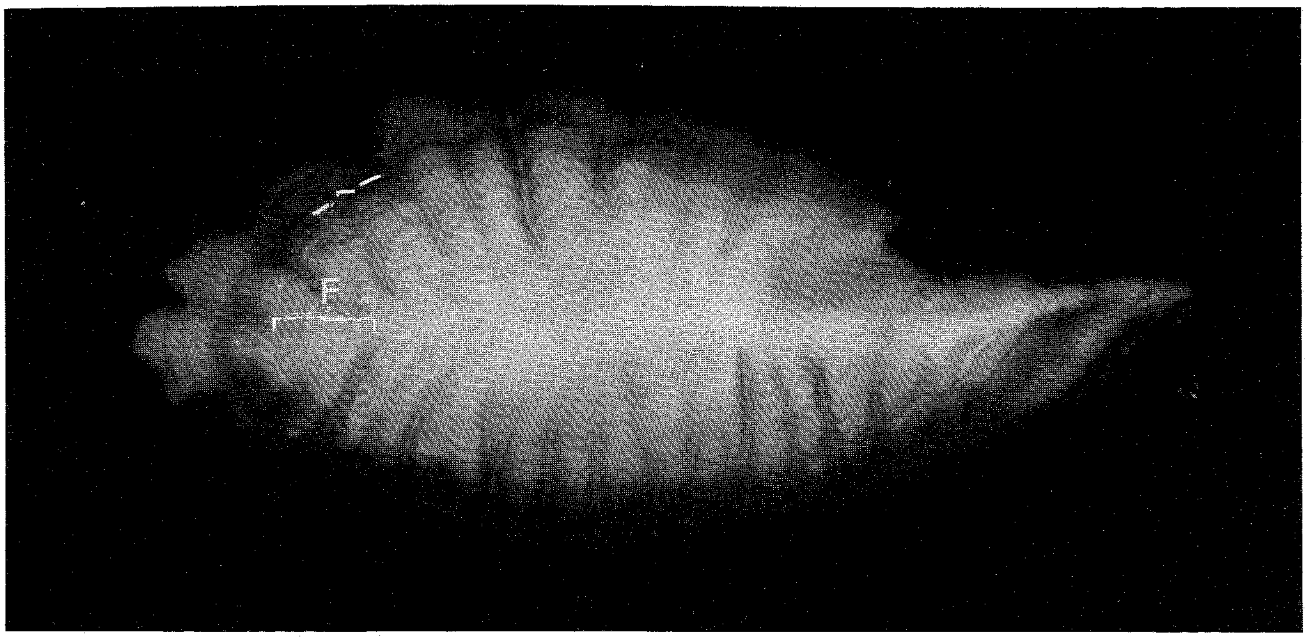


Photo 14. The hyaline zone appears as a distinct ring accompanied by a few weaker false rings (F)

The first hyaline ring, which is not a true annual ring, is normally laid down before the fish has reached 1 year of age and about 10 cm total length. The cause underlying the deposition of this "juvenile" ring is not yet known, but its formation is probably connected with some change in the behaviour of horse mackerel and other fishes at this age. The term "juvenile ring" is advanced for reference purposes only and is used to designate it in this guide.

The juvenile ring, if visible, may appear as a single, rather distinct mark. Some very weak rings may be laid down inside and outside this ring, but the juvenile ring is readily identifiable where the distinct rostrum and antirostrum have not yet formed. The typical juvenile ring may on occasion be replaced by several weak, closely spaced hyaline rings.

The first annual hyaline zone may be laid down either as a distinct ring accompanied by a few weaker rings or as a group of closely packed, fine rings forming an obvious band (Photographs 14 and 15). The first hyaline zone and juvenile ring sometimes fuse together into a single, broad

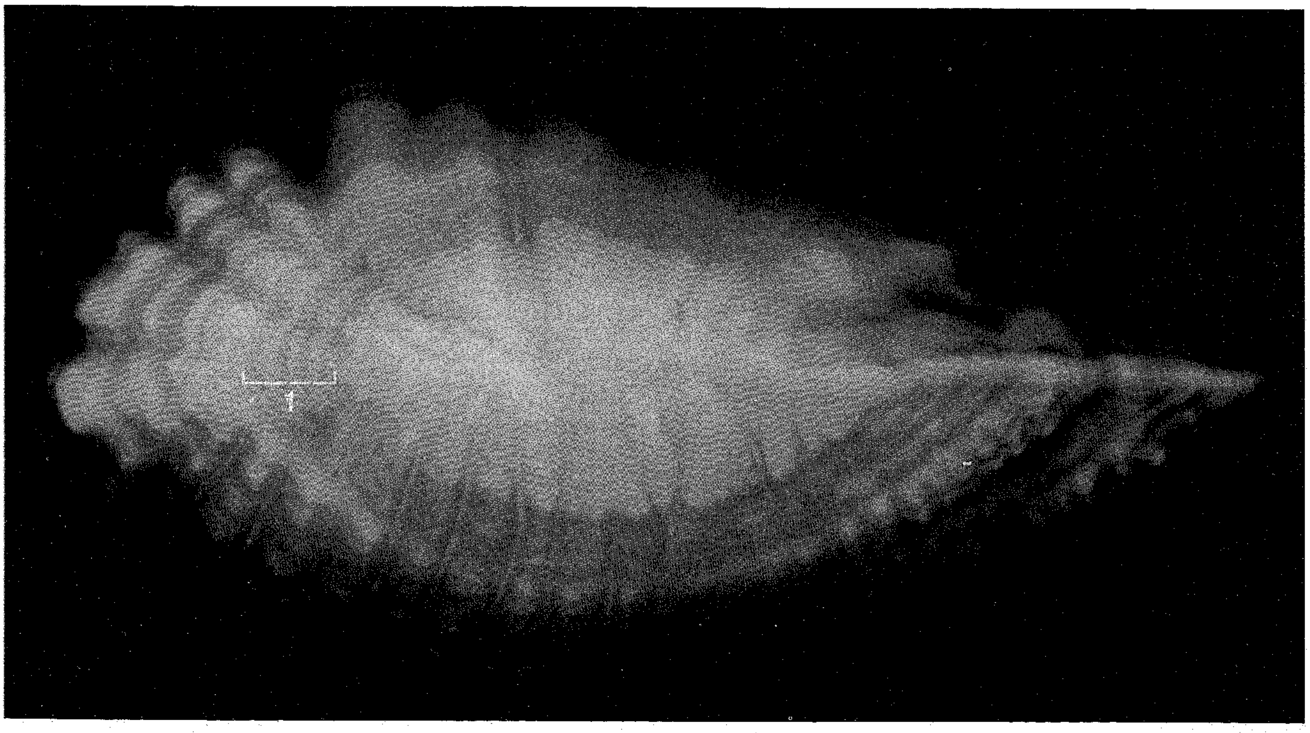


Photo 15. The hyaline zone appears as a band of closely-packed fine rings (1)

hyaline zone. On the other hand, during periods of fast growth, a large, opaque nucleus may form without a juvenile ring.

Because Cape horse mackerel otoliths thicken with age, the juvenile ring and first annual hyaline zone may become indistinct and in some cases practically invisible (Photograph 16). Although the presence of the first annual hyaline zone can usually be detected on the rostrum, it should be borne in mind that, on otoliths from older fish, the first clearly visible hyaline zone may in fact be the second, and not the first, anhual hyaline zone (Photo. 17).

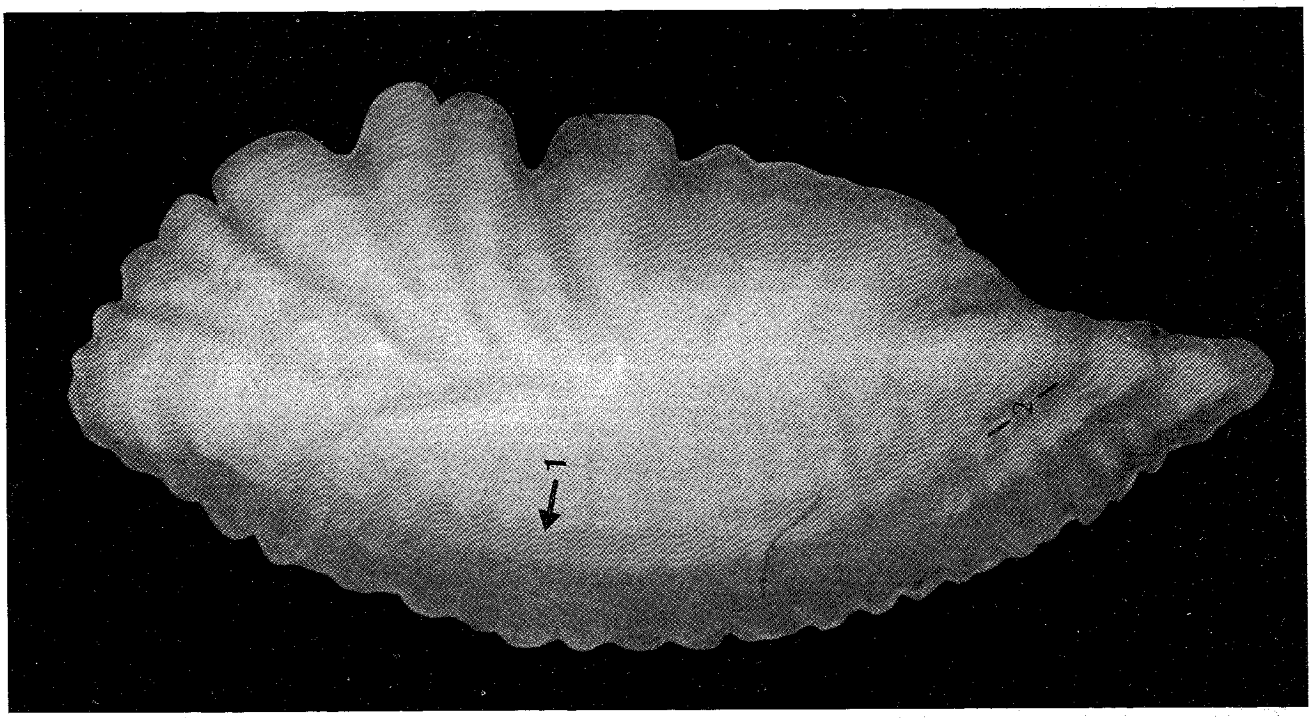


Photo 16. An example of an indistinct first annual hyaline zone (1) on an otolith from an older fish, the first clearly visible zone is the second annual hyaline zone

Photo 17. A further example of a faintly visible first annual hyaline zone (1) on an otolith from an older fish; the first clearly visible zone is again the second annual hyaline zone

5.2 Ring and zone formation in juvenile and adult fish

It is accepted that, as in other fish species, one hyaline and one opaque zone are laid down each year in Cape horse mackerel otoliths, corresponding to periods of slower and faster growth, respectively. However, additional explanation concerning zone formation is required, particularly for immature fish up to 3 or 4 years of age.

5.2.1 In juveniles

Juvenile fish grow faster than adult fish and the annual increment on the otolith is therefore wider. This means that single, intra-annual, hyaline and opaque rings, laid down as a result of short-term fluctuations in growth rate, will be sufficiently separated spatially as to be clearly visible to the otolith reader (Photograph 18). Thus, each individual opaque plus hyaline ring should not always be interpreted as the annual zone.

The pattern of rings laid down on the posterior part of the otolith within any single year may vary considerably by season. Both hyaline and opaque rings are laid down throughout the year. However, during periods of slow growth, hyaline rings predominate, and the overall effect is a broad hyaline band with one or more thin opaque rings within it (Photograph 19). During periods of faster growth, more inorganic material is laid down, and it is then the opaque rings which are generally wider and more prevalent. Consequently, the otoliths of juvenile horse mackerel (up to 3 or 4 years of age) display one growth band each year consisting of a multi-ring hyaline zone and a multi-ring opaque zone.

Completion of hyaline zone formation is normally marked by the deposition of a hyaline ring that tends to be somewhat wider than its predecessors, and commencement of the formation of the following opaque zone (start of the new annual growth zone) is marked by the deposition of a slightly wider opaque ring. The individual hyaline rings that constitute one hyaline zone are usually more visible on the posterior part of the otolith, but they seem to fuse together on the ventral portion of the otolith (Photograph 20) and on the rostrum, where they are readily interpreted as the hyaline zone.

5.2.2 In adults

Multi-ring zone formation tends not to occur (at least not visibly) in older, mature fish, which have a slower growth rate and a regular spawning season every year and chiefly inhabit the bottom layers, where environmental conditions are generally uniform. On the posterior part of the otolith, the number of rings within any one annual growth zone gradually decreases, and the hyaline zones become more delineated. This pattern is normally repeated on the rostrum, but on the ventral part, where growth is slowest, hyaline rings and hyaline zones give the impression of fusion. Because of this process, on the otoliths of older fish, alternating annual zones are only clearly visible on the posterior portion and, to a lesser extent, on the rostrum. Knowledge of the timing of opaque and hyaline zone formation considerably facilitates interpretation of the ring pattern on the otolith. Hyaline zone formation in adult horse mackerel generally coincides with the spawning season, which is different in different parts of the Convention Area (see below), but in juveniles preliminary results indicate that temperature is the controlling parameter. Thus, the slow growth period, when hyaline zones are deposited, is during winter.

5.3 False rings and other types of rings

Any ring or group of rings should be considered false if it does not conform to the definition of the hyaline zone. Therefore, a single ring which is a component of the multi-ring hyaline zone and forms during the season of slower

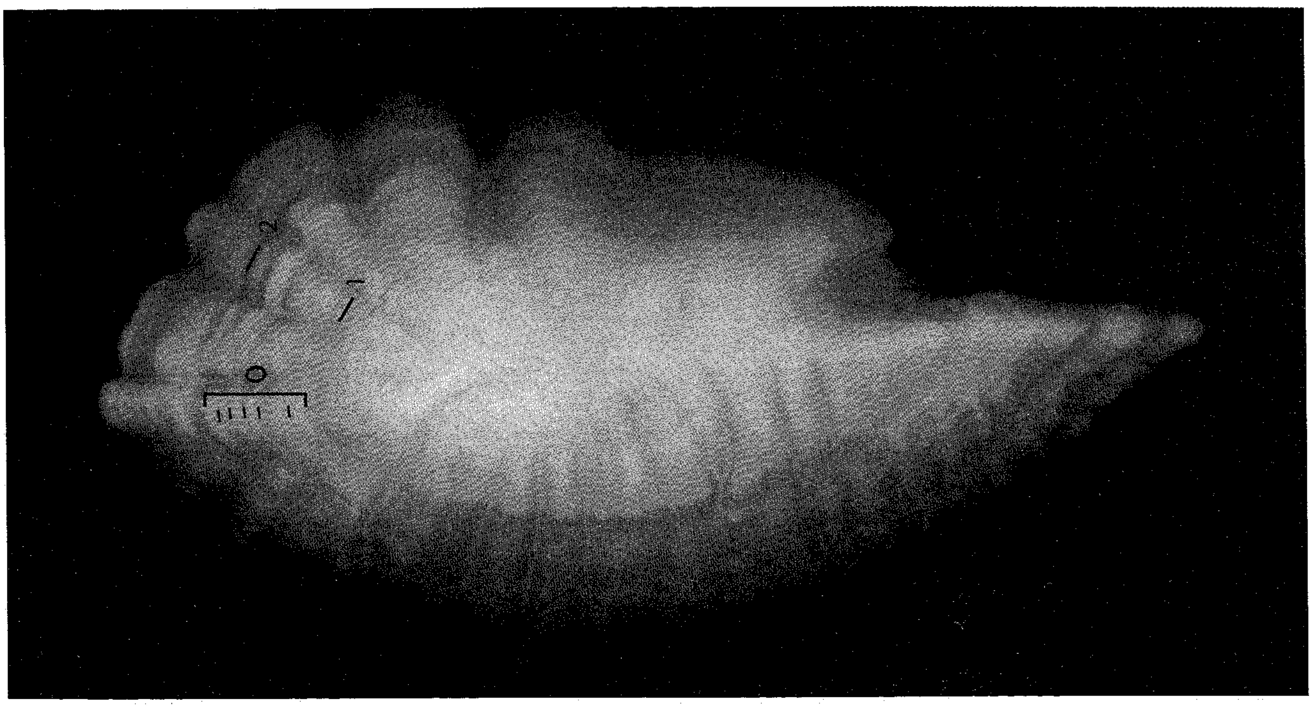


Photo 18. Example of the presence of hyaline rings within an opaque zone, several fine hyaline rings are detectable within the opaque zone (O) between hyaline zones 1 and 2

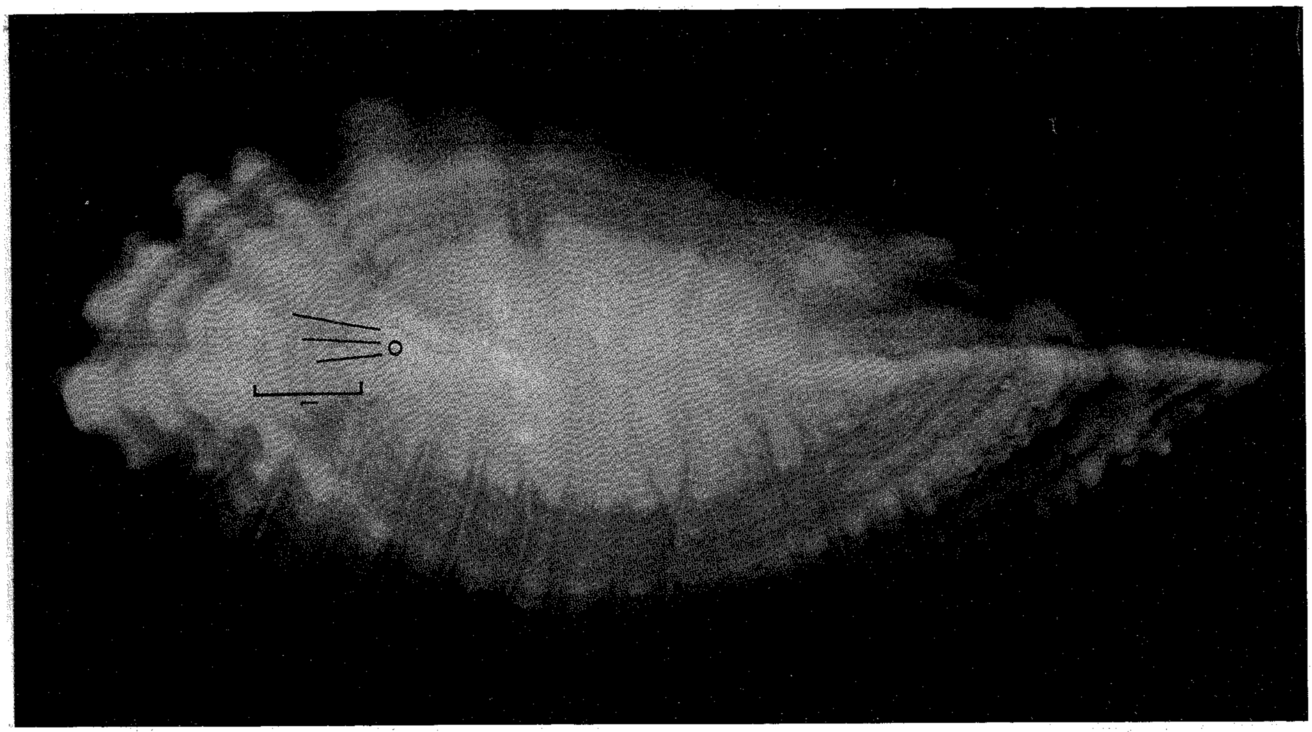


Photo 19. Example of the presence of opaque rings within a hyaline zone; several opaque rings (O) are visible within the first hyaline zone (1)

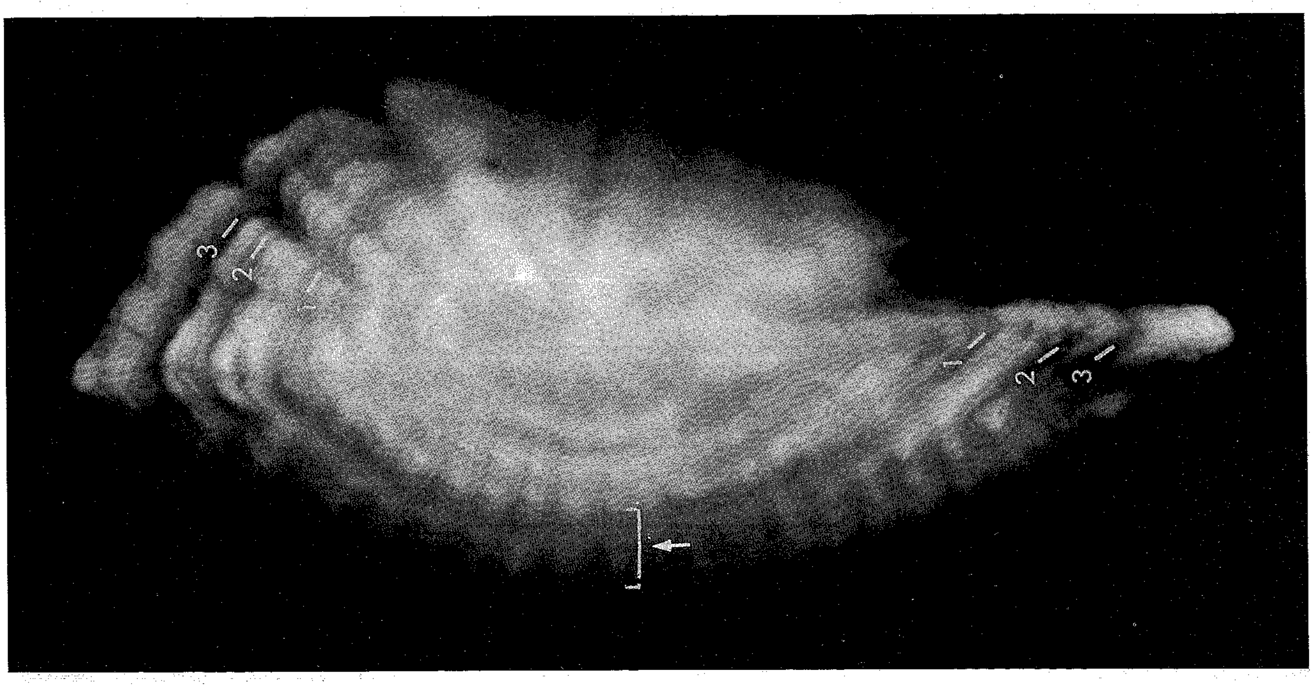


Photo 20. Example of fusion of zones on the ventral part of the otolith; three hyaline zones are clearly visible on the posterior portion and on the rostrum; ventrally, they fuse together, forming an area (arrow) containing an indeterminate number of zones

growth need not necessarily be considered a false ring; yet that same ring, if laid down during the season of faster growth, i.e., within an opaque zone, should de regarded as false.

Some of the synonyms of the term false ring are check ring, secondary ring, and accessory ring. Others, i.e., juvenile ring (or zone), double ring, spawning ring (or zone), and split ring, are not true synonyms because they are characteristic types of rings in their own right, whether false or a component of an annual hyaline zone. Due to their widespread use, they have been retained as synonyms in the standard terminology set forth in Section 2, except for juvenile ring, which is a separate category. The juvenile ring is a specific type of ring that is reasonably easy to classify and is described in Subsection 5.1. The other three types of rings are defined and described below.

A *double ring* is identifiable when an annual growth zone is divided into two hyaline and two opaque rings (Photograph 21). Sometimes they are so regular and clear that, to the inexperienced reader, they may be taken to represent two years of growth, but comparison with "normal" otoliths from fish of similar length facilitates correct interpretation (Photograph 22). These rings are visible mainly in otoliths of young fish up to 4 years of age, and the second hyaline ring should be taken to represent termination of the annual growth zone.

A *spawning ring (or zone)* is laid down when the spawning season does not coincide with the normal season of hyaline zone formation (as determined by the fish's me-

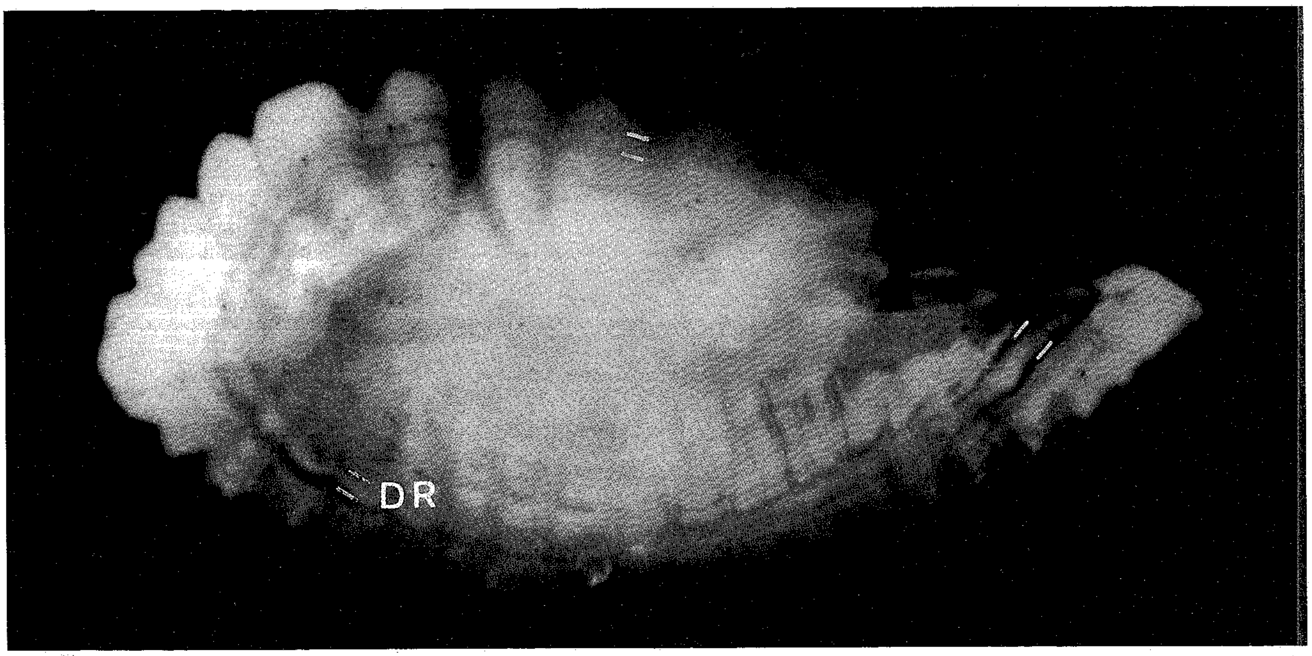


Photo 21. Example of an obvious double ring (DR)

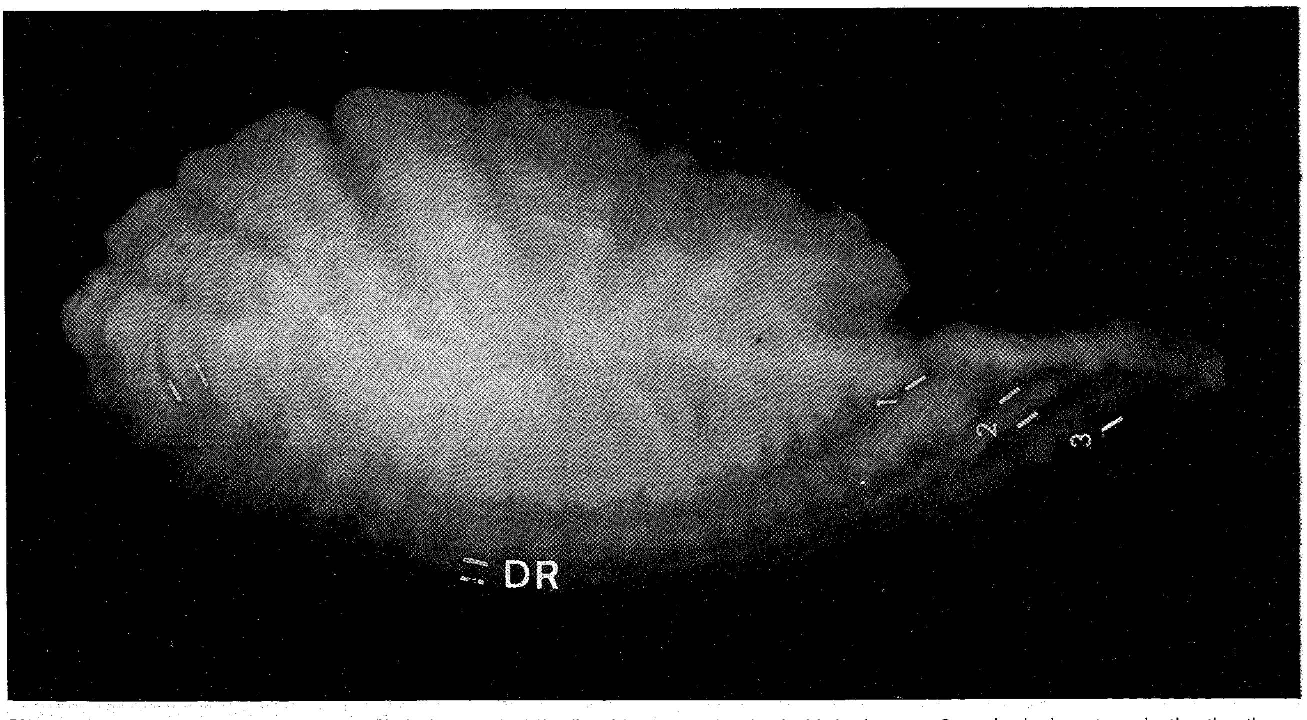


Photo 22. Another example of a double ring (DR); the two single hyaline rings comprising the double hyaline zone 2 are clearly closer to each other than they are to the preceding (1) and following (3) hyaline zones

tabolism) or when a fish spawns twice in one year. It is also a distinct ring, and again it may be interpreted as a double ring by unsuspecting readers who are not sure of its origin.

Occasionally, several hyaline rings may be laid down during the fast growing season and, grouped together, taken to be a spawning zone. Such a phenomenon is mainly restricted to young fish, which tend to form multi-ring zones.

A *split ring* is a hyaline zone divided by some opaque material. Such a split is normally most evident on the posterior part of the otolith and on the rostrum (Photograph 23). It is easy to identify, except on the edge of the otolith, where it may be interpreted arbitrarily either as a false ring or as the beginning of a new annual hyaline zone not yet fully surrounding the otolith.

5.4 Edge interpretation

In horse mackerel older than about 2 years, the edges of the otoliths may be so thin as to appear translucent with the viewing techniques normally employed. For this reason it is advisable to char the otoliths, in order to be able to determine the type of ring on the edge. Care must be taken, however, not to char them excessively, because the thin edge readily turns to ash and therefore appears opaque.

Ring formation in fish younger than 3-4 years is different from that in older fish, probably because of the change from a pelagic to a demersal habitat coinciding with the onset of sexual maturity. This poses problems with regard to edge interpretation, and hence it is discussed separately.

5.4.1 In juveniles

Because several rings are laid down each year on the otoliths of fish less than 3-4 years old, it is very difficult to decide whether a ring forming on the edge of the otolith is part of the last zone or the beginning of a subsequent zone.

When determining the extent to which the outermost zone is complete, readers should bear in mind the width and pattern of previous years' zones, the date of capture, and the birthdate. Even so, such determination is frequently arbitrary. The outermost zone is generally considered to be complete when deposition of the zone corresponding to the next growth period begins.

5.4.2 In older fish

The last annual growth zone on the edge of otoliths from older individuals requires special attention during reading. Correct interpretation is difficult, because of the size and nature of this zone, but it is nevertheless necessary in order to be able to assign the fish to the correct year class and age group.

One of the peculiarities of the Cape horse mackerel is its prolonged spawning period, and in the Southeast Atlantic peak spawning differs with area and from year to year. Normally, the growth of fish and otoliths is faster soon after spawning. This results in the formation of a new opaque zone on the edge. Later, in the course of the same year, when the growth rate decreases in accordance with environmental fluctuations, hyaline material is laid down on the edge of the otolith. The last zone on the edge of otoliths of adult fish may, thus, be opaque or hyaline, depending on the time of spawning and the time of capture.

Deposition of new material occurs first and foremost at the anterior and posterior ends of the otolith in adult fish, and for this reason the last zone can be more readily identified at the extremities of the long axis of the otolith. As with otoliths from juvenile fish, it is also difficult to distinguish the nature of the zone on the edge of untreated otoliths, and, as previously stated, in order to be able to clearly ascertain whether this zone is opaque or hyaline, it may be advisable to char the otolith before viewing.

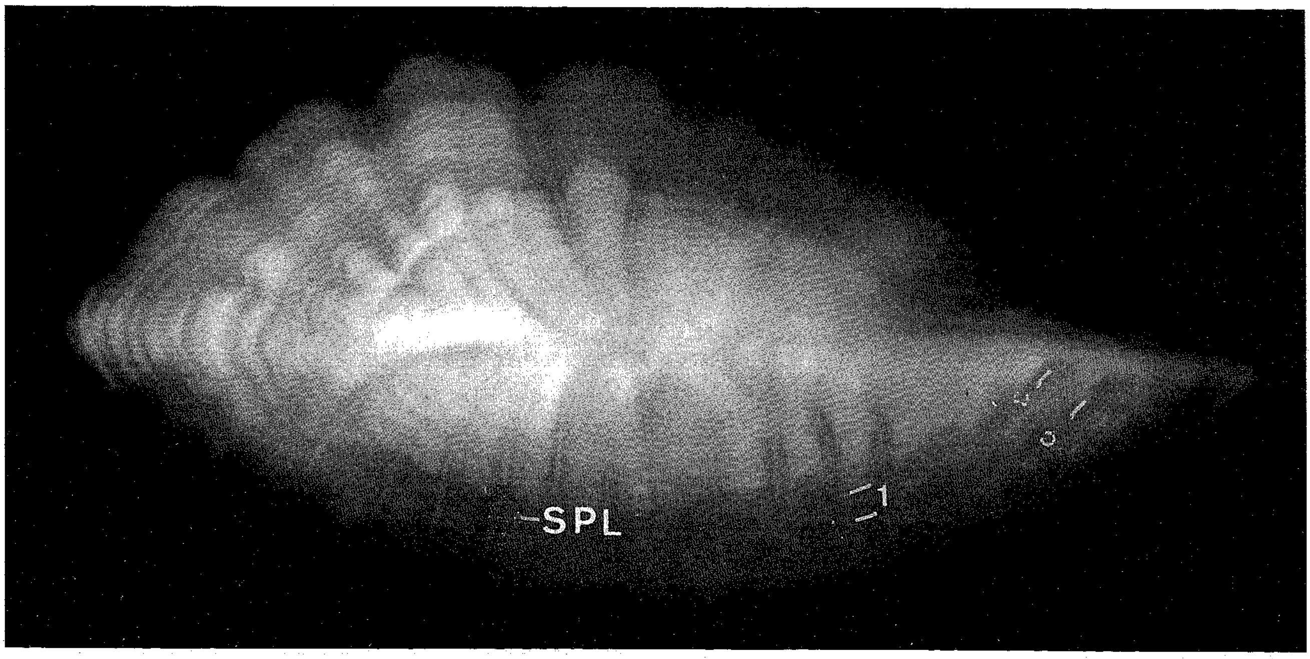


Photo 23. Example of a split ring (SPL); the first hyaline zone (1) splits into two (a, b) on the rostrum

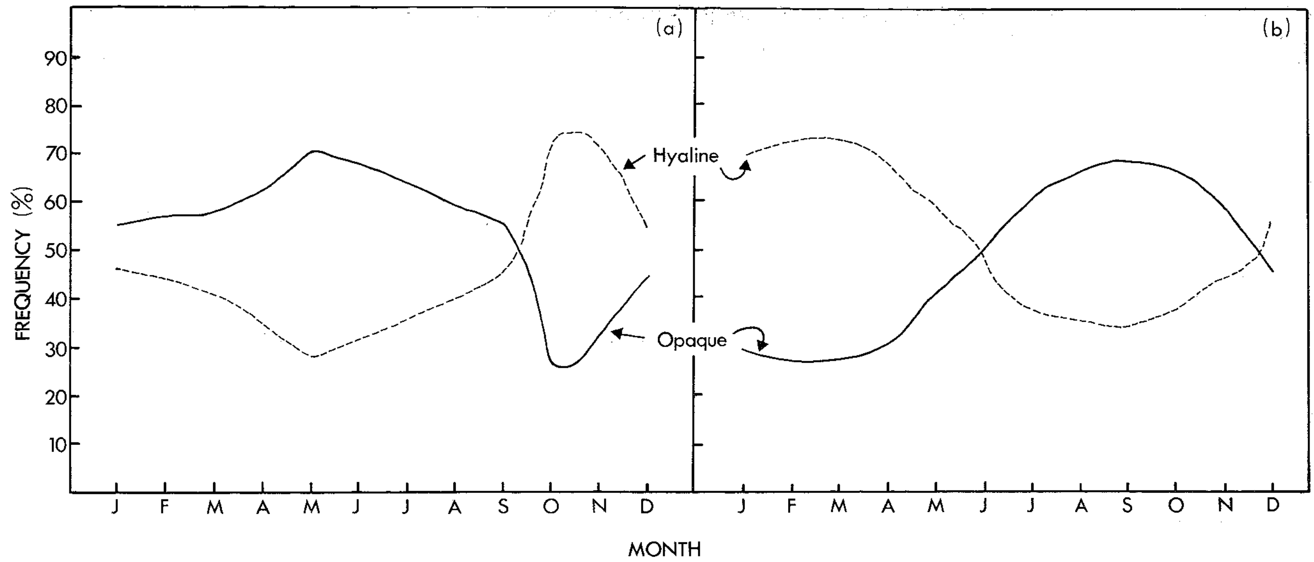


Fig. 5a, 5b. Examples of variability and opaque zone formation on the edge of Cape horse mackerel otoliths: a) sharply defined spawning season in October-December; b) lengthier spring/summer spawning season (December-April)

For a species with such a prolonged and often variable spawning season, it is impossible to demonstrate conclusively when the edge of the otolith may be expected to be hyaline and when it will be opaque. Occurring as it does from the waters off Angola in the north to at least longitude 30° E on the east coast of Southern Africa, Cape horse mackerel has a broad distribution range and hence also a wide range of optimal environmental parameters.

Different authors, working on stocks in different areas and often during different years as well, have found variable times of spawning and/or of hyaline and opaque zone formation at the edge of the otolith. Two scenarios are presented to illustrate this variability. In Figure 5a, there is an apparent sharply defined season during which hyaline edges predominate, and this may be related to a spring spawning (October-December). Figure 5b illustrates the longer spring/summer (December-April) spawning season apparent in the findings of other workers. It must be stressed that these two possibilities are presented as examples only and that either, or some intermediate possibility, may in fact be found for a given portion of the total stock in any given year.

6. ASSIGNMENT OF AGE, YEAR CLASS, AND AGE GROUP

Once the annual rings on an otolith have been identified and counted, it is possible, given additional information on the date of capture and peak spawning period, to ascertain to which year class a fish belongs and, hence, to assign it to the correct age group. A year class is a cohort of fish spawned within one discrete annual spawning period.

As spawning of horse mackerel in Namibian waters may take place from September to April, it is most sensible to define a cohort as those fish spawned from 1st July of year X to 30th June of year X+1. Such a cohort will be named the X/X+1 year class. Thus, the 1980/81 year class contains all individuals spawned during the 1980/81 spawning season, i.e., from approximately September 1980 to April 1981. The following cohort (1981/82 year class) would contain individuals spawned between 1st July 1981 and 30th June 1982, and so forth.

The age group to which a fish will be assigned depends on the year class in which it was spawned and on the date of capture. The most recently spawned cohort (the "young-of-the-year"), consisting, theoretically, of individuals between 0 and 12 months of age (but, in practice, mostly between 3 and 9 months of age), constitutes age group 0. Individuals spawned during the previous season comprise age group I. In other words, when a new cohort is spawned (beginning, by definition, on 1st July), these individuals are the 0-year-olds, and the previous year class becomes age group I. Thus, the 1980/81 year class will belong to age group 0 until 30th June 1981, but on 1st July 1981 it will become age group I, and the 1981/82 year class will supersede it as age group 0.

Thus, on 1st July of each year, when a new spawning period begins, the fish surviving from previous spawnings will become one age group older. Roman numerals are used to designate age groups, since they may not correspond to the true age of the fish.

6.1 Intepretation according to the assumption of extended hyaline zone formation

In order to establish from the otolith to which year class a fish belongs, it is necessary to calculate back from the date of capture, counting the annual zones from the outer edge of the otolith inwards to the nucleus, thus arriving at the approximate date of spawning (Photographs 24-26). This method has the advantage of making knowledge of the season of hyaline ring deposition irrelevant, because it can be applied at any time of the year regardless of the nature of the edge. Once the time of spawning has been established, the age group can be calculated as the number of spawning seasons that have passed since the one in which the fish was spawned, e.g., if it has been established in 1986 that a particular fish caught in October 1985 was from the 1981/82 year class, the fish will belong to age group IV, because there have been four spawning seasons since the 1981/82 season (1982/83, 1983/84, 1984/85, and the 1985/86 season). During routine otolith examination, the following simple formulae can be used to assign a fish to an age group:

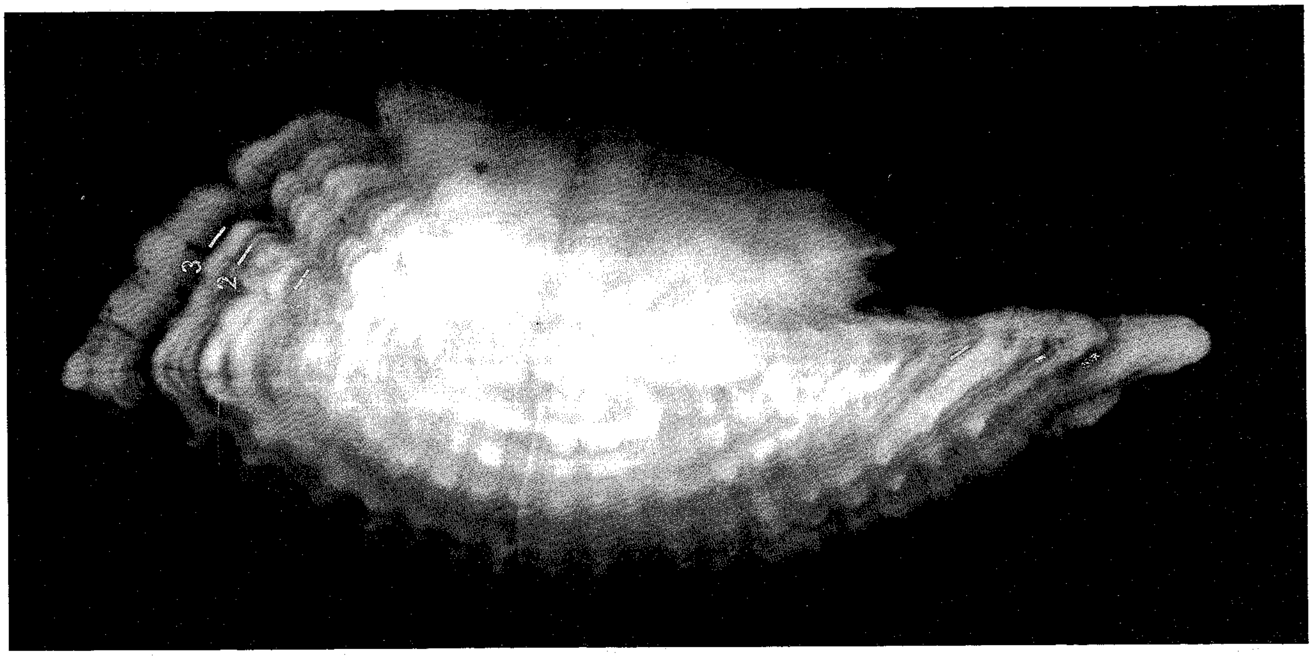


Photo 24. Total length (L_t) 19,0 cm, caught in February 1982, three hyaline zones and an opaque edge: according to method (1) in Subsection 6.1, the age group is equal to the number of hyaline zones (hence age group III), back-calculation indicates that the fish was probably spawned early in the 1978/79 spawning season, making its "official" birthdate 1st January 1979, thus confirming this age group assignment

Photo 25. Total length (L_t) 19,0 cm, caught in February 1982, three hyaline zones and a hyaline edge: since it was caught between January and June and has a hyaline edge, its age group is equal to the number of hyaline zones, i e , age group III

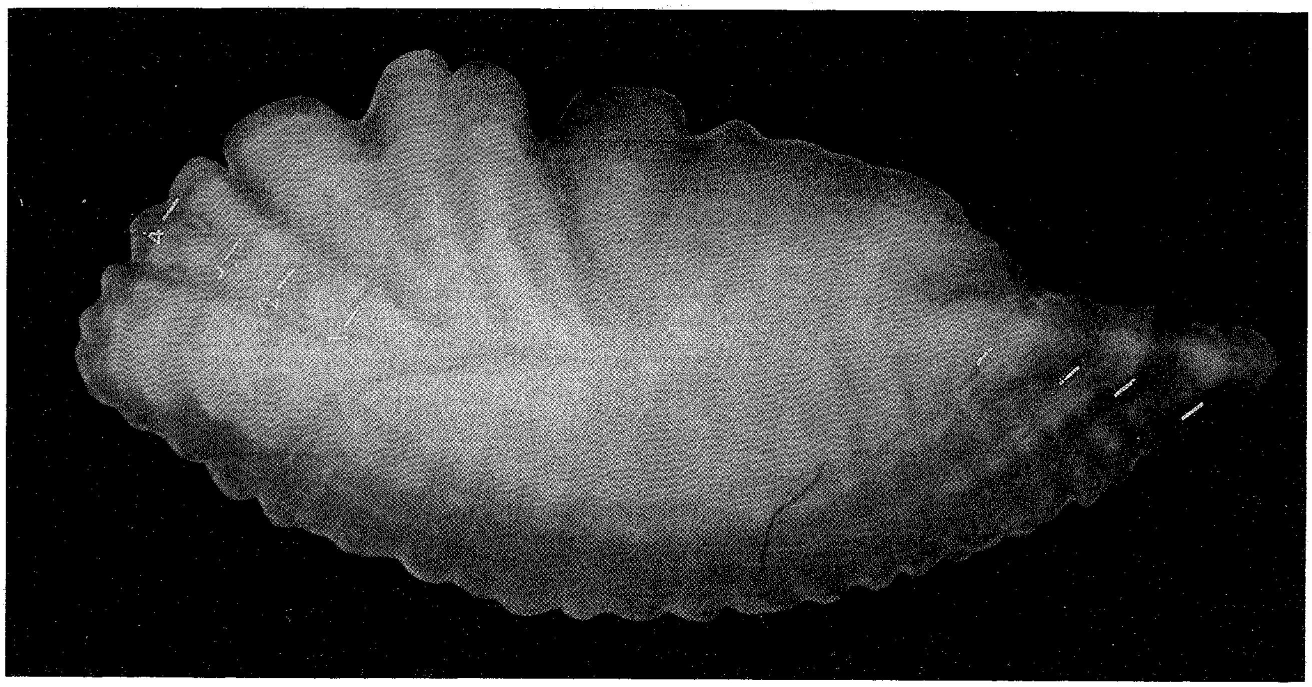


Photo 26. Total length (L_t) 18,5 cm, caught in March 1984; four hyaline zones, the last one on the edge. following the method set out in Subsection 6.1, it is therefore assigned to age group IV (equal to the number of hyaline zones)

1) when the otolith has an *opaque* edge:
   (a) if the fish was caught between 1st January and 30th June, age group = number of hyaline zones;
   (b) if the fish was caught between 1st July and 31st December, age group = number of hyaline zones + 1;
2) when the otolith has a *hyaline* edge.
   age group = number of hyaline zones (irrespective of the time of year at which the fish was caught)

The rationale underlying this procedure is presented in Figure 6.

A difficulty with the back-calculation method is that the outermost and innermost zones may not represent one full year of growth. The zone being deposited on the edge may not be complete, and the first hyaline zone may have been deposited before the fish reached 1 year of age (see Subsection 5.1). The latter problem is more serious but will only have an effect on the establishment of year class if the fish was caught in the first half of the year, because there could be doubt as to whether the fish was born late in one spawning season or early in the subsequent one. However, the diameter of the nucleus can provide a clue, because it will be larger in the former than in the latter. If the fish was caught in the second half of the year, uncertainty will exist only as to whether the fish was born early or late in the *same* spawning season and thus will have no effect on the year class to which the fish belongs. These aspects are illustrated in Figure 7.

6.2 Interpretation according to the assumption of hyaline zone formation at the same time each year

As some authors believe that hyaline zone formation in Cape horse mackerel takes place over a limited period at the same time each year, another method of age assignment becomes applicable, with a birthday of 1st January being used for the purpose of exemplification. Taking this birthdate and November-January as the time of hyaline zone formation, the method is then as follows.

If hyaline zones are counted, otoliths of fish caught before 1st January (i.e., between 1st July and 31st December) with an opaque zone around the edge are assigned to an age group equal to the number of hyaline zones. Fish caught after 1st January (i.e., between 1st January and 30th June) are assigned to the following age group.

If opaque zones are counted, otoliths of fish caught before 1st January with an opaque zone around the edge are assigned to an age group by counting all the opaque zones except the last one; if the fish was caught after 1st January, all the opaque zones are counted when assigning an age group.

According to this method, fish born in a given year and caught by 31st December of that same year should be assigned to age group 0, whereas, if they are caught between 1st January and 31st December of the year immediately following birth, they should be classified in age group I, and so on.

Two examples of the assignment of age are shown in Figures 8 and 9. Assuming that hyaline zone formation takes place in spring (case 1), the age of fish caught in the period from 1st January to winter is equal to the number of hyaline zones, while the age of fish caught in the period from spring to the end of the year is equal to the number of hyaline zones minus one. On the other hand, assuming that hyaline zone formation takes place at the end of the year (case 2), the age of all fish except those having a hyaline zone on the edge is equal to the number of hyaline zones.

a) OTOLITH WITH AN OPAQUE EDGE

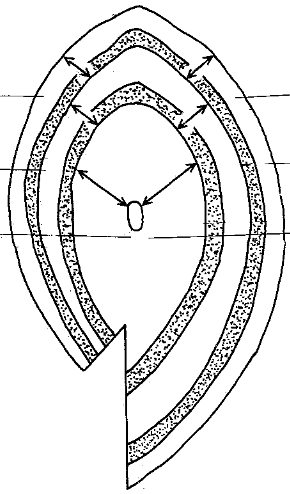
Fish A, caught between
1st January and 30th June 1984

Yearly growth increment from January/June 1983 to January/June 1984.

Yearly growth increment from January/June 1982 to January/June 1983.

Six-month growth increment from July/December 1981 to January/June 1982.

Growth has been back-dated to July/December 1981, hence this was the period in which the fish was spawned. Since the spawning season runs from September to April, the fish must have been spawned during the early part of the 1981/82 spawning season (sometime between September and December 1981), and it belongs to the 1981/82 year class. Two new year classes have been spawned since then (1982/83 and 1983/84), therefore this fish belongs to age group II (= number of hyaline zones).



Fish B, caught between
1st July and 31st December

Yearly growth increment from July/December 1983 to July/December 1984.

Yearly growth increment from July/December 1982 to July/December 1983.

Six-month growth increment from from January/June 1982 to July/December 1982.

This fish was spawned during the period January-June 1982, i.e., the latter part of the 1981/82 spawning season. Since the 1984/1985 spawning season was in progress at the time of capture, this fish was spawned three seasons before and therefore belongs to age group III (= number of hyaline zones + 1).

THUS, ALTHOUGH FISH A AND B WERE BOTH MEMBERS OF THE 1981/82 YEAR CLASS, FISH B LIVED LONGER THAN FISH A AND THEREFORE REACHED THE NEXT AGE CATEGORY OR GROUP

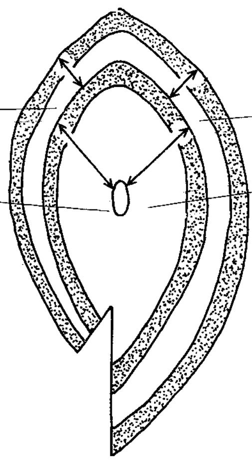
b) OTOLITH WITH A HYALINE EDGE

Fish A, caught between
1st January and 30th June 1984

Yearly growth increment from January/June 1983 to January/June 1984.

Yearly growth increment from January/June 1982 to January/June 1983.

Back-calculation indicates that this fish was spawned during the period January-June 1982, i.e., the latter half of the 1981/82 spawning season. There have been two spawning seasons since then (1982/83 and 1983/84), so it belongs in age group II (= number of hyaline zones).



Fish B, caught between
1st July and 31st October 1984

Yearly growth increment from July/December 1983 to July/December 1984.

Yearly growth increment from July/December 1982 to July/December 1983.

This fish was spawned in July/December 1982 and therefore is a member of the 1982/83 year class. The 1984/85 spawning season was in progress at the time of capture, hence this fish should be assigned to age group II (= number of hyaline zones).

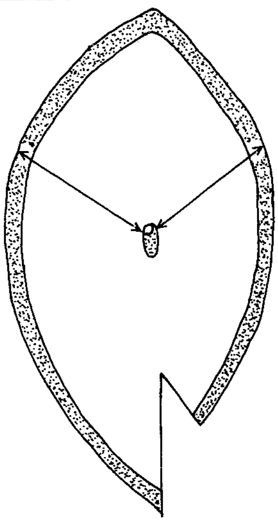
IN THIS CASE, FISH A WAS SPAWNED SIX MONTHS EARLIER THAN FISH B, DURING A DIFFERENT SPAWNING SEASON, BUT FISH B LIVED SIX MONTHS LONGER, CONSEQUENTLY BOTH FISH HAD REACHED THE SAME AGE GROUP AT THE TIME OF DEATH

Fig. 6. Year class and age group assignment: a) otolith with an opaque edge; b) otolith with a hyaline edge

Fish caught January-June 1984

If this radius is large, it will represent a complete annual growth increment, in which case the fish was spawned during the latter half of the 1982/83 spawning season and belongs in age group I

If this radius is small, it will represent less than one year's growth, in which case the fish was spawned early in the current (at the time of writing, 1983/84) spawning season (sometime between July-December 1983) and therefore belongs in age group 0.



Fish caught July-December 1984

If this radius is large, the fish was spawned *early* in the 1983/84 spawning season (sometime between July-December 1983). If it is small, the fish was spawned *late* in the 1983/84 spawning season (January-June 1984). In either case, this fish would be assigned to age group I (= number of hyaline zones).

Fig. 7. Interpretation of the radius from the centre to the first hyaline ring when assigning age group

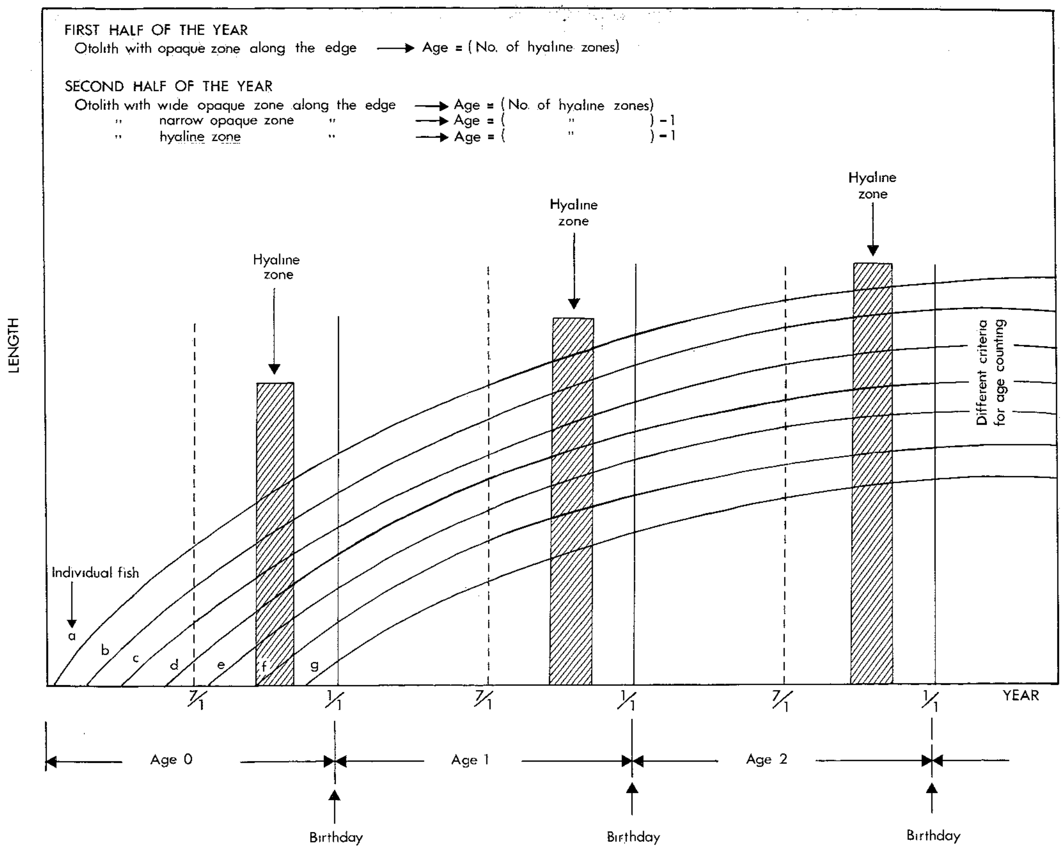


Fig. 8. Assignment of age, assuming that the hyaline zone is deposited in the spring of each year and that the birthday is arbitrarily taken to be 1st January

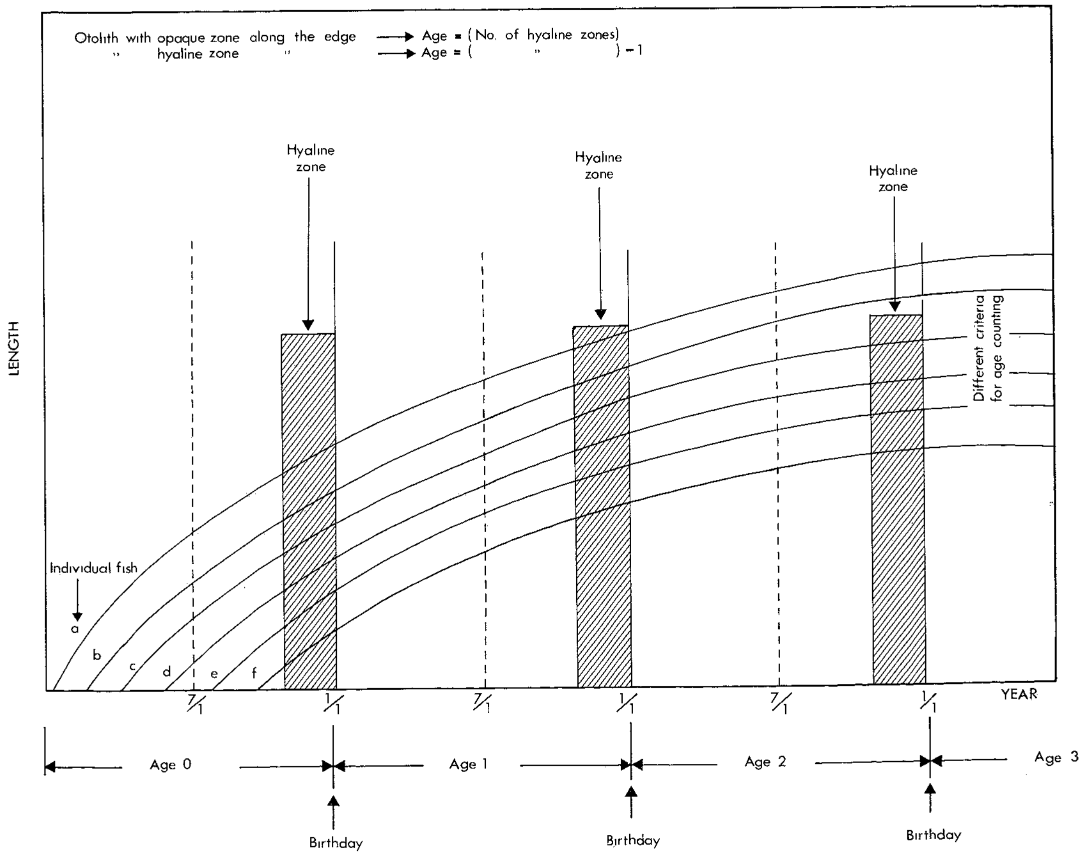


Fig. 9. Assignment of age, assuming that the hyaline zone is deposited at the end of every year and that the birthday is arbitrarily taken to be 1st January

7. SELECTED BIBLIOGRAPHY

ALBRECHTSEN, K. 1968 – A dyeing technique for otolith age reading. *J. Cons. int. Explor. Mer* 32: 278-280.

BELAN, R.A. 1971 – Methods of age determination of South African horse mackerel, **Trachurus trachurus capensis** Castelnau, by means of otoliths. *Trudy Atlant-NIRO* 41: 53-60. (In Russian).

CHILTON, D.E. and R.J. BEAMISH 1982 – Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. *Can. Spec. Publ. Fish. Aquat. Sci.* 60: 102pp.

CHRISTENSEN, J.M. 1964 – Burning of otoliths, a technique for age determination of soles and other fishes. *J. Cons. int. Explor. Mer* 29(1): 73-81.

FAO 1981 – Methods of collecting and analyzing size and age data for fish stock assessment. *FAO Fish. Circ.* 736: 100pp.

FARINA PEREZ, A.C. 1983 – Age and growth of the Galician shelf horse mackerel (**Trachurus trachurus** L.). *ICES C.M. 1983, G26:* 11pp. (mimeo).

GELDENHUYS, N.D. 1973 – Growth of the South African maasbanker **Trachurus trachurus** Linnaeus and age composition of the catches, 1950-1971. *Investl Rep. Sea Fish. Brch S. Afr.* 101: 1-24.

HATANAKA, H. and S. KAWAHARA 1985 – Otolith ring formation in Cape horse mackerel off Namibia. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 12(I): 87-94.

HATANAKA, H., T. SATO, C.J. AUGUSTYN, A.I.L. PAYNE, and R.W. LESLIE 1983 – Report on the Japan/South Africa joint trawling survey on the Agulhas Bank in November/December 1980. Japan Marine Fishery Resource Research Centre. Tokyo. 73pp.

ICSEAF 1983a – *Otol. interp. Gde Hke int. Commn SE. Atl. Fish.* 1: 70pp.

ICSEAF 1983b – Report of the ad hoc working group on otolith interpretation. *Proc. Rep. Meet. int. Commn SE. Atl. Fish. (ICSEAF)* 1982(II): 109-137.

JENSEN, A.C. 1965 – A standard terminology and notation for otolith readers. *ICNAF Res. Bull.* 2: 5-7.

KATSUYAMA, K. 1984 – Growth estimation of the preadult Cape horse mackerel (**Trachurus trachurus capensis**) in ICSEAF Divisions 1.3 and 1.4 on the basis of size compositions. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 11(I): 95-101.

KERSTAN, M. 1985 – Age, growth, maturity and mortality estimates of horse mackerel (**Trachurus trachurus**) from the waters west of Great Britain and Ireland in 1984. *Arch. FischWiss.* 36(1/2): 115-154.

KOMPOWSKI, A. and W. SLOSARCZYK 1976 – Some investigations on horse mackerel (**Trachurus trachurus** L.) in the ICSEAF Area in 1973. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 3: 27-38.

KUDERSKAYA, R.A. 1983 – Age and growth of the Cape horse mackerel (**Trachurus trachurus capensis** Castelnau). *Colln scient. Pap. int. Commn SE. Atl. Fish.* 10(I): 97-101.

LIPSKAYA, N.Y. 1972 – Some data on the growth and feeding habits of **Trachurus trachurus** Linnaeus off the western coast of Africa. *Trudy VNIRO* 77(2): 186-196. (In Russian).

MACER, C.T. 1977 – Some aspects of the biology of the horse mackerel (**Trachurus trachurus** L.) in waters around Britain. *J. Fish. Biol.* 10: 51-62.

MORALES, B. 1982 – Considerations on scorpionfish, horse mackerel, and kingklip otoliths in the Southeast Atlantic and proposed guidelines for interpretation. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 9(II): 199-219.

NEKRASSOV, V.V. 1970 – Carangids (Fam. Carangidae) off the east coast of Africa. *Trudy AzCherNIRO* 29: 89-138. (In Russian).

SOSA, M. 1981 – Edad y crecimiento del jurel (**Trachurus trachurus** Linnaeus) de las Divisiones 1.3 y 1.4 del Area de ICSEAF. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 8(II): 255-266.

TERRE, J.J. 1976 – Crecimiento y fecundidad del jurel (**Trachurus trachurus** Linnaeus) de las Divisiones 1.3 y 1.4 del Area de CIPASO. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 3: 39-44.

UOZOMI, Y. and S. KAWAHARA 1983 – A preliminary growth estimation of preadult Cape horse mackerel (**Trachurus trachurus capensis**) on the Agulhas Bank on the basis of size composition. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 10(I): 203-208.

VENTER, J.D. 1979 – 'n Verbeterde tegniek vir die brand van heel otoliete. *Fish. Bull S. Afr.* 12: 49-52.

WENGRZYN, J. 1975–Age et taux de croissance du chinchard (**Trachurus trachurus**) de la région de la CIPASE *Colln scient. Pap. int. Comn SE. Atl. Fish.* 2: 34-35.

WENGRZYN, J. 1976 – Results of investigations on age and growth rate of horse mackerel (**Trachurus trachurus**) in Southwest African waters. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 3: 51-57.

WYSOKINSKI, A. 1985 – Horse mackerel age determination using otoliths. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 12(II): 199-203.