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A METHOD OF AGE DETERMINATION FOR THE SOUTH WEST AFRICAN PILCHARD *SARDINOPS OCELLATA*

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A method of age determination, based on recent research on growth and ring formation, is described for the pilchard of South West Africa. Dates of ring formation from 1971 to 1981 are documented. Illustrated examples of otolith interpretations are given.

*n Metode vir die ouderdomsbepaling van die sardyn van Suidwes-Afrika, gegronde op onlangse navorsing oor groei en ringvorming, word beskryf. Datums van ringvorming van 1971 tot 1981 word gedokumenteer. Geïllustreerde voorbeelde van otolietvertolkings word gegee.

There is a wide variation in the published age compositions of southern African pilchard *Sardinops ocellata* (Davies 1958, Nawratil 1960, Baird 1970, Wysokiński and Krakus 1977). Part of the variation may be explained by differences in growth in different areas and periods, but it is also clear that, even though large numbers of rings can usually be seen, pilchard otoliths and scales are remarkably difficult to interpret. The performance of the staff routinely interpreting age confirms this: few of them persist for long without asking for a break or, this being impossible, they resort to guesswork. It is necessary for such readers to have objective guidelines available and the aim of this report is to attempt to compile such a guideline for the otoliths of the South West African pilchard stock.

Recent work on growth (Thomas in press) and ring formation (Thomas 1983) are used here to outline a method of age determination. Procedures of collection and otolith preparation are also described.

COLLECTION AND PREPARATION OF OTOLITHS

The sampling method at present in use is that of stratified subsampling, first introduced for otoliths by Ketchen (1950). Otoliths are collected on a monthly basis: instructions are given to local samplers to collect up to 30 fish at random from each 0.5-cm length class below 18 cm standard length (L_c), and up to 60 fish from each length class above 18 cm. Further, the collections by length class are made separately for each sex from an L_c of 16 cm. Only

right-side otoliths are extracted, and these are placed in a single vial containing 0.4-per-cent potassium hydroxide solution, each vial being marked with sex and length class. To avoid the possibility of bias as a result of area differences, otoliths are collected from a large number of catches.

At the end of each month the otoliths are washed in distilled water, dipped in alcohol and dried in air. They are then mounted in clear polyester resin on black plastic slides, each slide containing 20 cavities. Twenty otoliths are mounted from length classes below 18 cm and 40 from those larger than 18 cm. Two otoliths are placed inner (medial) side down in each cavity and are retained in position with a small drop of catalysed resin. When this has set, more resin is added and later, when this has also set, the coverslip is placed in position with a few final drops of the resin. These stages are important, otherwise contraction of the resin causes the coverslip to break.

Otoliths are viewed under reflected light by means of a $\times 32$ binocular microscope, fitted with polarizing filters to eliminate light-scattering and glare.

AGE DETERMINATION

Identification of annual rings

When pilchard otoliths are observed under reflected light, narrow translucent rings (hyaline rings) can be seen as dark bands spreading concentrically. These rings are most easily seen on the posterior part of the otolith (i.e. the broad, flat part). Unlike in many other fish, more than one conspicuous ring is laid

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down in a year, sometimes as many as four in seven months (Thomas 1983). In general, however, a narrow yet pronounced hyaline ring forms in about May, later another may form in August or September and another in December. These last two rings, particularly in the larger fish, tend to coalesce into a broad hyaline zone. This is understandable because growth is slow over most of this period (Thomas in press). It is this zone or combination of rings, formed between September and December, that is referred to here as the annual ring. To age the fish these annual rings must be counted.

Pilchard usually spawn during the period September—December (Thomas 1984), and consequently the first ring usually identified on the otolith is the pronounced hyaline ring which is formed in May (referred to here as a secondary ring). Later in the year, at a fish length of 13—15 cm, the first annual ring is formed. Thus, the otolith of a fish at the end of its first year often has a number of rings, and it can easily be misinterpreted in terms of the actual age of the fish.

In the second and third year of life, the fish grows more slowly and the annual rings become progressively closer to each other. In older fish (4—6 years of age) the annual ring is only visible as a narrow dark band and secondary rings are often lost. Sometimes, because of thickening of the otolith in large fish, the earliest-formed rings may become very faint.

Individual year-classes may vary in the manner in which the various rings are laid down, the secondary rings sometimes being missing and the annual ring occasionally being very faint. Absence of rings usually occurs in years when the mean sea-surface temperature is warmer than average (Thomas 1983). To overcome this problem of variability, a table similar to Table 1 was prepared for local otolith readers. This table gives the times of ring formation, from back-calculation and hyaline edge frequency, for a period of 11 years. Such a table is useful, but it is not essential if the age reader proceeds according to the criteria already outlined.

Assignment of age

Once the annual rings have been identified, the fish may be assigned an age. Pilchard are spawned over a long season. Matthews (1964) found spawning from July to April with peak spawning in August/September (spring) and a secondary peak in February. King (1977) found evidence of bimodality, with spring and autumn spawning. Prolonged spawning has continued until recently (Le Clus and Thomas 1981, 1982) despite reduction of the stock.

Table 1: Approximate dates of ring formation for the pilchard off South West Africa, 1971—1981

Year	Dates of ring formation	
	Annual ring	Secondary rings
1971	November (dark)	—
1972	August—December (composite)	July
1973	September (very light)	March (dark), May, June (double)
1974	September—December (dark and composite)	—
1975	—	February—April (double), May
1976	—	—
1977	—	—
1978	September—November (dark and composite)	June
1979	July—October (light)	May (dark)
1980	August—December (light and double)	April (dark)
1981	—	January

— No data

As it is impractical to age spring- and autumn-spawned fish separately, both are considered together and all fish are given a birthdate of 1 January. In general, however, the annual ring does not form on 1 January but three or four months earlier. Thus, for the months January—August, the last annual ring is included in the age estimate. For the months after ring formation (October—December) the last annual ring is not counted. During this period the last ring is usually still close to the edge and not yet enclosed by any opaque material (except in very small otoliths). Experience is needed to decide whether the outside ring was formed two or three months previously or 15 months previously. A young fast-growing fish of about 8 cm L_t lays down more material outside its annual ring in three months than a slow-growing adult of about 20 cm does in 15 months.

Taking these factors into consideration, a three-year-old fish (III-group) will have three annual rings on its otolith from January to August and four after October. From 1 January the following year, it would be considered as a IV-group fish.

When ageing pilchard it has been found to be advantageous to interpret the otoliths in chronological order so as to follow the pattern of hyaline ring formation for that year. Recruits (O-group) are particularly useful for this purpose because they grow fast, lay down much material on their otoliths and consequently show the pattern of hyaline ring formation in some detail.

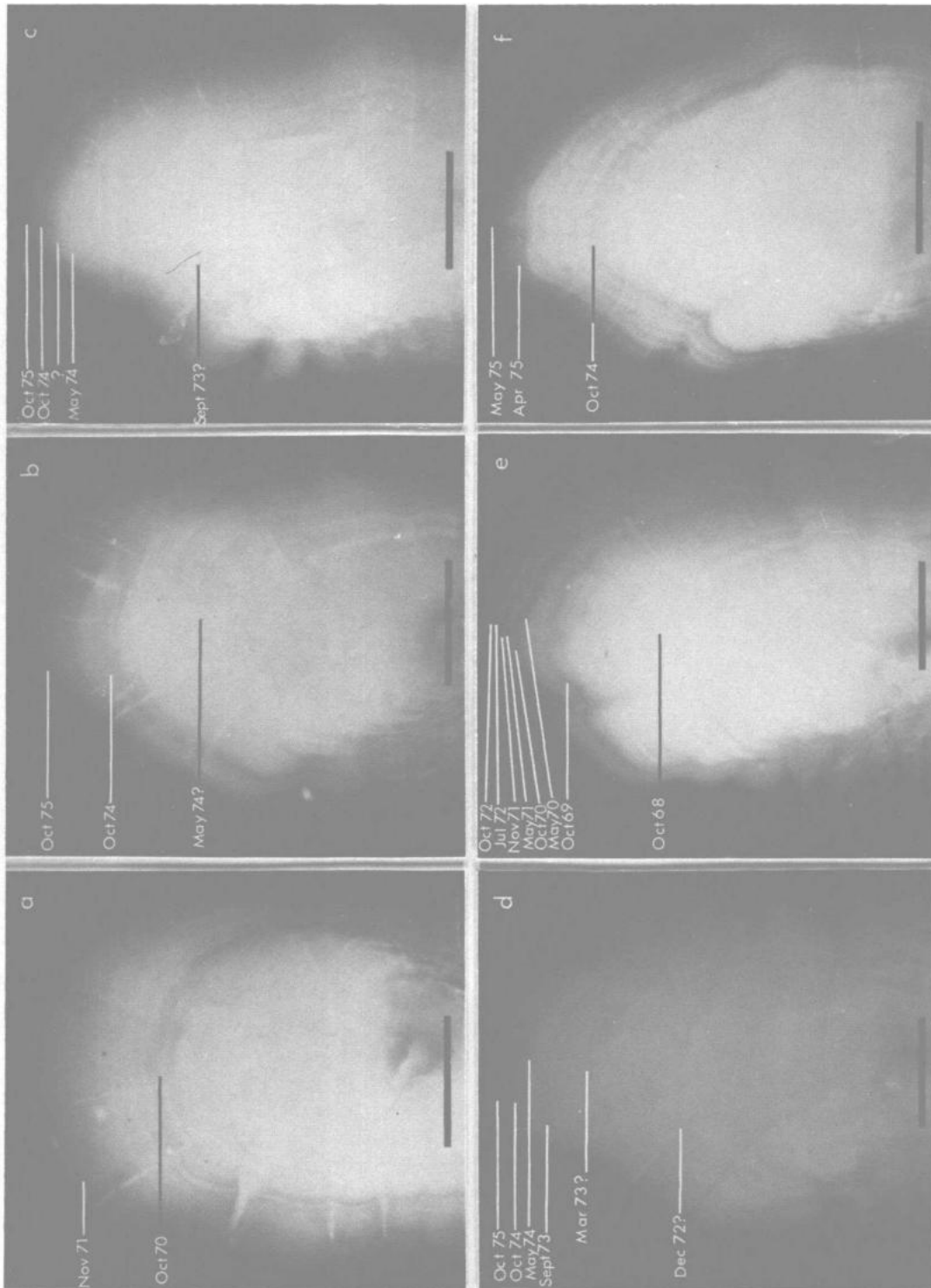


Fig. 1: Interpretation of otoliths, showing months of ring formation. Scale bar is 0.5 mm or 16 e.p.u. (a) II-group, caught January 1972, $L_c = 19.4$ cm. N.B. effect of 1 January birthdate on age group. (b) II-group, caught August 1976, $L_c = 21.25$ cm. (c) III-group, caught May 1976, $L_c = 21.25$ cm. N.B. poorly defined 1973 ring. (d) probably IV-group, caught May 1976, $L_c = 21.25$ cm. N.B. poorly defined 1973 ring, (e) V-group, caught August 1973, $L_c = 23.25$ cm. N.B. secondary rings. (f) I-group, caught July 1975, $L_c = 16.25$ cm



Fig. 2: Interpretation of V-group otolith, caught April 1976, $L_c = 23,25$ cm — ring formation dates are (a) November 1971, (b) August—December 1972, (c) September 1973, (d) May 1974, (e) September—December 1974, (f) October 1975, (g) April 1976 (edge). Scale bar is 0,5 mm or 16 e.p.u.

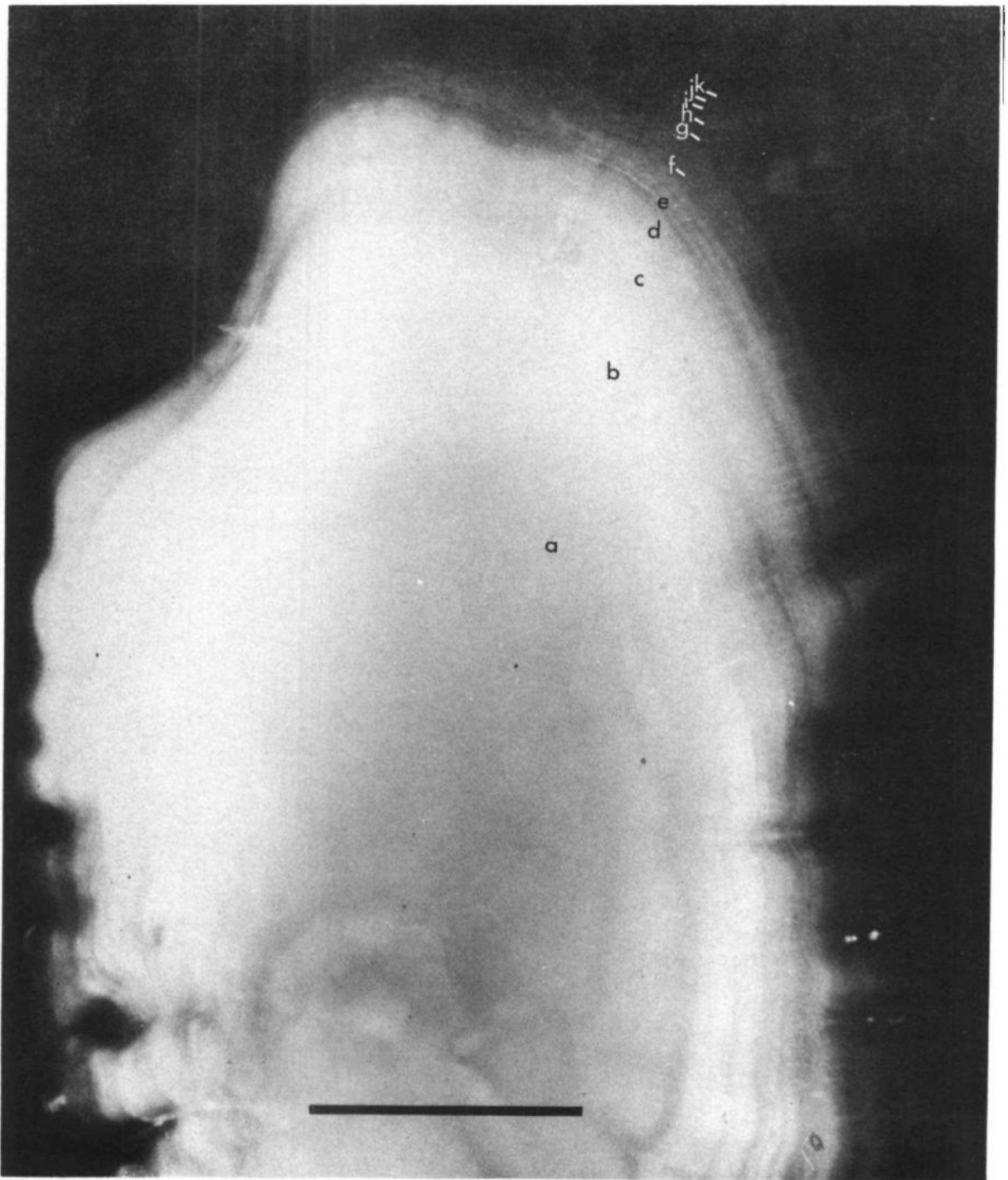


Fig. 3: Interpretation of VI-group otolith, caught July 1976, $L_c = 22,25$ cm — ring formation dates are (a) October 1970, (b) May 1971, (c) November 1971, (d) July 1972, (e) August—December 1972, (f) September 1973, (g) September—December 1974, (h) May 1975, (i) October 1975, (j) ?, (k) July 1976 (edge). Scale bar is 0,5 mm or 16 e.p.u.

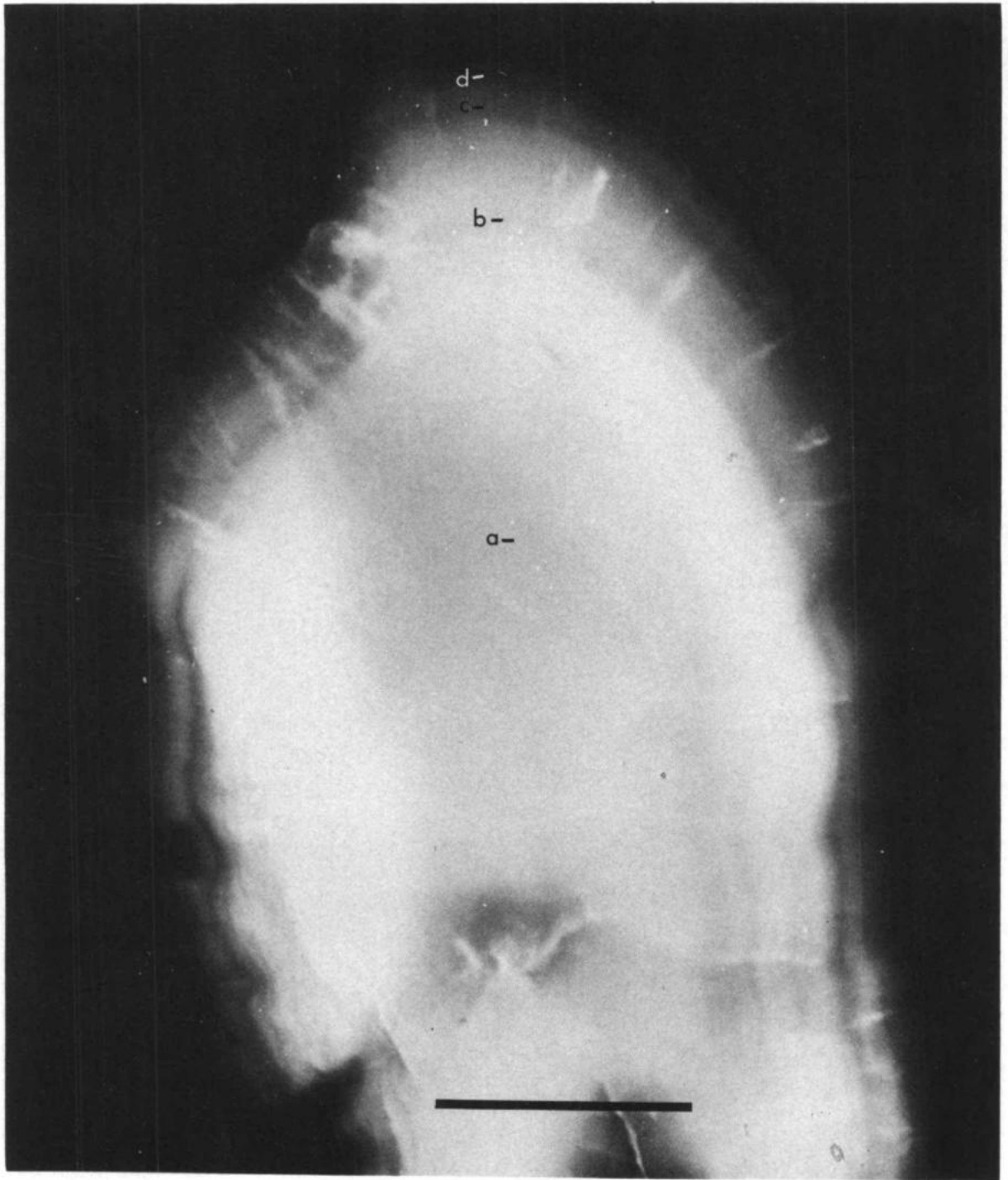


Fig. 4: Interpretation of I-group otolith, caught March 1981, $L_c = 18,75$ cm — ring formation dates are (a) April 1980, (b) and (c) August—December 1980, (d) January 1981. Scale bar is 0,5 mm or 16 e.p.u.

ILLUSTRATED EXAMPLES

Ten randomly chosen otoliths were aged (Figs. 1—4), and their rings interpreted according to the information given in Table I. Figures 1a and 1b are of II-group fish. The first was caught in January and its second annual ring is very close to the edge and barely visible. The second was caught in August and has two clear annual rings. Figure 1c shows a III-group fish. There are three annual rings, the earliest being the faint one of 1973 and the second and third from October 1974 and 1975 respectively. Figure 1d shows a probable IV-group fish, the 1973 annual ring being only faintly visible. A V-group fish is shown in Figure 1e. The third, fourth and fifth rings are clear and pronounced, a normal finding in older fish. Of interest are the thin secondary rings close to the annual ring in three successive years. Figure 1f shows an otolith from a I-group fish caught in July. It has only one annual ring (October 1975) and its age was confirmed by length frequency analysis.

Figure 2 is of a V-group fish caught in April 1976. Five annual rings and many secondary rings can be seen. Figure 3 is of an unusually old fish, VI-group caught in July 1976 with what appears to be six annual rings. The last-formed rings are very narrow on this older fish. Figure 4 is of a I-group fish caught in March 1981 in which the age could be positively identified from length frequency analysis. It was spawned in spring 1979. The first two rings (a and b in the Figure) were formed while the fish was O-group showing, as mentioned earlier, that recruits in particular may be useful for following the pattern of hyaline ring formation.

DISCUSSION

There are two particular problems that interfere with accurate age determination of the pilchard: the large number of secondary rings and the annual irregularity in ring deposition. It is advantageous, therefore, for an otolith reader to initially be given a list of ring formation dates, such as is given in Table I. This is quite easily obtained for the South West African stock by back-calculation (Thomas 1983). When the reader has built up expertise with such information, the list may be dispensed with.

The ideal of 100-per-cent accuracy for all otoliths examined is not likely to be attained with fast-growing pelagic fish in dynamic systems such as that of the Benguela Current. Nevertheless, an age determination method is acceptable if it results in reason-

ably accurate age compositions and mean lengths at age. Age compositions of the South West African pilchard from 1971 to 1980 have already been published (Thomas and Böhme 1981) and mean lengths at age approximately agree with those calculated from independent age-reading methods (Thomas in press). The von Bertalanffy coefficients from age readings are $L_{\infty} = 21,2$ cm, $k = 1,19$ and $t_0 = -0,38$ years and from the independent methods are $L_{\infty} = 22,6$ cm, $k = 1,09$ and $t_0 = -0,003$ years.

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