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An Age Validation Study of Redfish, *Sebastes marinus* (L.), from the Gulf of Maine - Georges Bank Region

by

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ABSTRACT

Ages of redfish up to seven years were validated by noting the seasonal formation of hyaline and opaque edges on otolith sections, and by comparing age and growth estimates with observed modal lengths of the 1971 year class.

One hyaline and one opaque edge is formed per year. Hyaline edges predominate from November through April and opaque edges from May through October. Hyaline formation, as indicated by the presence of a very narrow edge generally begins in August, and opaque formation begins in April.

Growth rates obtained from otolith readings are similar to observed lengths at age as indicated by the progression of length modes of 1971 year class redfish through 1978.

INTRODUCTION

With increased use of analytical stock assessments in providing management advice, reliable and consistent age determinations are imperative. However, the interpretation of annular markings on the scales and otoliths of redfish, *Sebastes marinus* (L), has been a controversial topic for some time (Kotthaus 1958; Parrish 1958; Surkova 1961). The hypothesis that redfish are relatively moderate to fast growing fish (Kotthaus 1958) has been the subject of considerable debate (Parrish 1958; Surkova 1961), and the management implications of the slow vs. fast growth hypotheses has been discussed by Gulland (1961). Presently, most researchers in this field accept the slow growth, long-lived hypothesis (Perlmutter and Clarke 1949; Bratberg 1956; Rasmussen 1958; Kelly and Wolf 1959; Sandeman 1969).

The issue has been further confused by the presence of at least two forms of Sebastes in the Northwest Atlantic, a large-eyed deep water form possessing a sharp lower jaw protuberance (Travin 1951) termed the mentella type, and the relatively shallow water marinus type having a rounded protuberance (Templeman 1959). Travin ascribed the former to a separate species, S. mentella, to distinguish it from S. marinus, while Andriiashev (1954) described the mentella form as a subspecies, S. marinus mentella Travin. Given the great temperature induced geographic variation in Sebastes morphometric and meristic characteristics (Templeman and Pitt 1961), Kelly et al. (1961) concluded that it would be difficult to determine whether the different forms of S. marinus are genetically or environmentally controlled. The problem of growth rate determination in Sebastes is compounded since the marinus type reaches a considerably greater maximum length than the mentella type (Sandemann 1961).

Additional complications have arisen because of the diverse techniques employed by various researchers while ageing redfish,including use of scales and otoliths, transmitted vs. reflected with polarized light, whole otoliths vs. sections,both transverse and longitudinal, as well as various staining and preparation methods (Perlmutter and Clark 1949; Bratberg 1956; Kotthaus 1958; Kelly and Wolf 1959; Sandeman 1961; Chekhova 1971; Kosswig 1971). Although it has been reported that results obtained from scales and otoliths do not differ substantially (Bratberg 1956; Sandeman 1961), these observations generally apply only to young redfish. Further, comparisons between various lighting techniques (Kosswig 1971) indicate substantial differences in the clarity of annular rings. Confusion has also resulted from a lack of consistent terminology used by age readers to describe age structures.

Under the auspices of ICNAF a number of projects have been undertaken to clarify the results of redfish age determinations (Keir 1960; Calvin-DeBaie 1964; Blacker 1966, 1967). However, discrepancies among researchers still persist (ICNAF Redbook 1978 p. 44; 1979 p. 58).

In this study we describe the methods of preparation and interpretation of redfish otoliths used by age readers at the Northeast Fisheries Center, Woods Hole Laboratory. Age determinations are validated by documenting seasonal changes in the proportion of hyaline and opaque edges in a sample of redfish otoliths, and by comparing the age composition results with modal lengths of the 1971 year class.

MATERIALS AND METHODS

Collections

Otoliths (sagittae) were collected by port samplers from redfish caught in the Gulf of Maine commercial fishery throughout the years 1976, 1977, and 1978. Monthly collections were augmented by samples obtained aboard research vessels during spring and autumn cruises. In both cases, otoliths were stored dry, in labeled envelopes before processing at the laboratory.

Each otolith was prepared for ageing according to the technique developed by Nichy (1977). The otolith is first mounted on a cardboard tab and covered with a coating of wax. A transverse section is obtained by cutting through the nucleus along the dorso-ventral axis (Figure 1) with a low speed microtome fitted with a pair of separated diamond blades. The resulting section, approximately 0.178 mm thick is mounted on a dark background and the surface moistened with clove oil to enhance contrast between opaque and hyaline zones. Annular zones are read along the long axis from the nucleus to the extreme dorsal edge under a binocular microscope at a magnification of 25x and 50x using reflected light.

From the total collection, 922 otoliths taken from 1971 year class redfish, aged only by the second author, were selected for this study.

Terminology

Each otolith was examined independently for edge type by two age readers. One reader (second author) is the primary redfish age reader at the Woods Hole Laboratory and the other was an experienced age reader at the laboratory. Criteria were established by making visual evaluations of each otolith's hyaline edge relative to the preceding hyaline zone or each otolith's opaque edge relative to the preceding opaque zone. For example, if a section had shown that the hyaline and opaque zones were all fairly narrow, the edge would be evaluated accordingly. During this pahse of the study no numerical measurements were made.

Jensen (1965) suggested that the following 4 categories be used to describe otolith edges:

Hn - Narrow hyaline
Hw - Wide hyaline
On - Narrow opaque
Ow - Wide opaque

In addition to these, we noted 4 more intermediate edge types:

Hnv - Very narrow hyaline edge appearing after a wide opaque zone during the summer or early transition period

Hm - Medium hyaline edge appearing after a wide opaque zone during late transition to mid winter

Onv - Very narrow opaque edge appearing after a wide hyaline zone during the winter or early transition period

Om - Medium opaque edge appearing after a wide hayline zone during late transition to mid summer.

The monthly proportions of hyaline and opaque edges in the sample were calculated for each of the 3 years. Modal lengths of the dominant 1971 year class redfish (Mayo et al. 1979) were discerned from length frequency distributions obtained from NMFS bottom trawl survey cruises in the Gulf of Maine from 1971 through 1978. Age compositions based on otoliths collected during spring and autumn cruises from 1975 through 1977 were compared to the corresponding length frequency modes using the 1971 year class as a benchmark.

RESULTS AND DISCUSSION

Seasonal Changes in Otolith Edge

Consistency of edge type determinations was measured for each reader by the ability to reproduce successive identifications in a random sample of 30 otoliths. The percentage agreement for hyaline/opaque edge was approximately 79% for each reader. Of the 922 otoliths examined, 782 or 85% were considered distinct enough to be classified into 1 of the 8 edge categories by both readers. The remaining 140 otoliths are not included in the following analysis.

Agreement between the two readers with respect to the 8 categories, as indicated by the diagonal elements in Table 1, is 76%. When those observations which differed by only one category are included (1 element off the diagonal) the agreement approaches 95%. Overall agreement between readers with respect to hyaline or opaque edge only is approximately 96%, or 748 out of 782 otoliths. Therefore, the analysis of hyaline/opaque edge ratios is based on all 782 otoliths categorized by the two readers. The analysis of the 8 specific edge types, however, is based only on the 594 observations represented by the diagonal elements in Table 1.

The proportion of hyaline to opaque edge type exhibits one seasonal cycle per year (Figure 2). Hyaline edges predominate during the winter and spring months through May when the proportion of otoliths with hyaline edges represents 80-100% of the observations. During summer and early autumn opaque edges predominate, generally representing between 50-80% of the observations. In November, hyaline edges once again become dominant. Kelly and Wolf (1959) reported similar results, and Perlmutter and Clarke (1949) showed that, within a year, scales display one zone of widely spaced circuli followed by a zone of narrowly spaced circuli between November and March.

The proportion of fish which still retains a hyaline edge during the period of maximum opaque edge formation may indicate the extent of variability in the commencement of summer growth. Males appear to be more consistent than females in this respect (Figure 2). Variation in the timing of spawning activity by females during the spring months may partially explain the difference, which is most pronounced in the presumably mature age 7 fish (Figure 2C). Age 5 fish collected during the summer of 1976 possessed otoliths with noticeably wider opaque edges than older fish collected in 1977 and 1978, perhaps indicating increased growth during the earlier year.

Edge formation begins with a large proportion of fish displaying a very narrow zone; this occurs in August and September for hyaline, and March and April for opaque edges (Figure 3). The predominance shifts from very narrow to narrow, medium, and finally to wide as the year progresses. A predominance of fish with a very narrow hyaline edge generally coincides with a predominance of others possessing a wide opaque edge.

Characterization of Edge Types

Each of the 8 edge categories noted in this study are presented in the photographed sections illustrated in Figure 4. The length, age, sex, and time of capture of each specimen are also given. It is evident here, as in Figure 3, that hyaline edges generally occur in winter and spring, and opaque in summer and autumn. Hyaline zones are represented in the photographs by dark bands (translucent on dark background) and opaque are seen as light areas on the otolith section.

The detailed interpretation of edge type presented here is possible because of the widely spaced successive hyaline zones evident in these younger fish. In older fish, which possess closely spaced zones, the distinctions between very narrow and narrow edges, and between medium and wide edges are lost, and Jensen's (1965) terminology should be followed.

Comparison of Length Modes

Examination of otoliths collected on 1975, 1976, and 1977 research cruises and from commercial catches in 1976, 1977, and 1978 indicates the presence of a strong 1971 year class in the Gulf of Maine region (Mayo *et al.* 1979). A series of length frequencies obtained from research vessel cruises sampling inshore Gulf of Maine strata (<111 m) illustrates the progression of the length modes of the 1971 year class through the autumn of 1978 (Figure 5). A similar series was reported by Sandeman (1961) for redfish collected in Hermitage Bay, Newfoundland, between 1953 and 1957 and by Perlmutter and Clarke (1949) for Nova Scotia redfish. The seasonal progression of these modes affords an excellent opportunity to study early growth and document results obtained from otolith readings.

Redfish in this cohort first appeared in the research survey catches in the autumn of 1971 at a modal length of 6 cm. This was followed every season thereafter by progressively larger modal lengths through the autumn of 1978 when the fish were 7 years old. Modal length at this time was 24 cm. Figure 6 illustrates the seasonal length increments exhibited by the 1971 year class throughout this period. The average increment is about 3 cm per year; most of this increase in length occurs between the spring and autumn cruises, particularly in the first 5 years. This rate is slightly greater than that exhibited by fish captured off Newfoundland (Sandeman 1961) and Nova Scotia (Perlmutter and Clarke 1949) but the seasonal distribution of the growth increments is similar. The period of rapid growth coincides with the period of maximum edge formation observed on the otoliths (Figure 3).

Also plotted on Figure 6 are the individual mean lengths at age of 1971 year class redfish calculated from age/length keys, and a segment of the von Bertalanffy growth curve (Mayo *et al.* 1979) calculated from individual observations of redfish ages from research cruises in 1975, 1976, and 1977. The length distribution of the 1971 year class fish, calculated from the 1975-1977 spring survey age/length keys (Figure 7), generally overlaps the observed length modes for the corresponding times illustrated in Figure 5.

The present analysis substantiates the methods we have used to describe redfish growth based on otolith readings. However, like many other studies, these results can only be strictly applied to relatively young fish. The extremely slow growth rate exhibited by redfish after age 10, and the resultant merging of length modes have thwarted previous attempts to follow modes for any significant time period. Thus, a similar treatment of the 1963 year class, the previous one dominating the population, is complicated by the proximity of a number of relatively strong year classes (Mayo et al. 1979). The unique position of the 1971 year class, with at least 8 years of poor recruitment preceding and following it, should enable continuation of this procedure for another 8 to 10 years, until the fish are between 15 and 20 years old, before this mode merges with that of the 1963 year class.

CONCLUSIONS

Seasonal formation of hyaline and opaque edges on redfish otoliths occurs at a frequency of one cycle per year. Hyaline edges are prevalent from November through April and opaque edges from May through October. The period of rapid increase in fish length coincides with the time of opaque edge formation, generally during the summer months.

The average annual increment in length was observed to be about 3 cm per year up to age 7, a rate slightly in excess of that noted for Newfoundland and Nova Scotian redfish. These results further substantiate the hypothesis that redfish are extremely slow-growing fish. Length frequencies of aged 1971 year class redfish appear to coincide with observed modal lengths during the spring of 1975, 1976, and 1977.

The emergence of the 1971 year class as a dominant feature in the age structure of the Gulf of Maine redfish population has enhanced our ability to validate the early growth of the species. The lack of any other year classes of comparable size in proximity should allow examination of length modes to continue for many years.

The results obtained in the present study indicate that, at least for redfish up to age 7, the techniques employed by age readers at the Woods Hole Laboratory provide an accurate assessment of age and growth rates.

ACKNOWLEDGEMENTS

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Table 1. Comparison of 782 edge type determinations of otoliths of *Sebastes marinus* (L), *mentella* type from the Gulf of Maine-Georges Bank region.

Number of Observations

			Reader No. 1								
			Hyaline				Opaque				
			Hnv	Hn	Hm	Hw	Onv	On	Om	Ow	Total
Reader No. 2	Hyaline	Hnv	81	19	1	2	1	0	0	0	104
		Hn	6	94	16	1	0	0	0	0	117
		Hm	0	15	78	26	0	0	0	0	119
		Hw	2	6	28	193	2	1	1	0	233
	Opaque	Onv	0	0	0	0	1	0	0	0	1
		On	1	2	0	1	0	43	4	2	53
		Om	5	1	0	0	0	5	40	13	64
		Ow	15	4	0	0	0	0	8	64	91
		Total	110	141	123	223	4	49	53	79	782

Hnv - Very narrow Hyaline
Hn - Narrow Hyaline
Hm - Medium Hyaline
Hw - Wide Hyaline

Onv - Very narrow Opaque
On - Narrow Opaque
Om - Medium Opaque
Ow - Wide Opaque

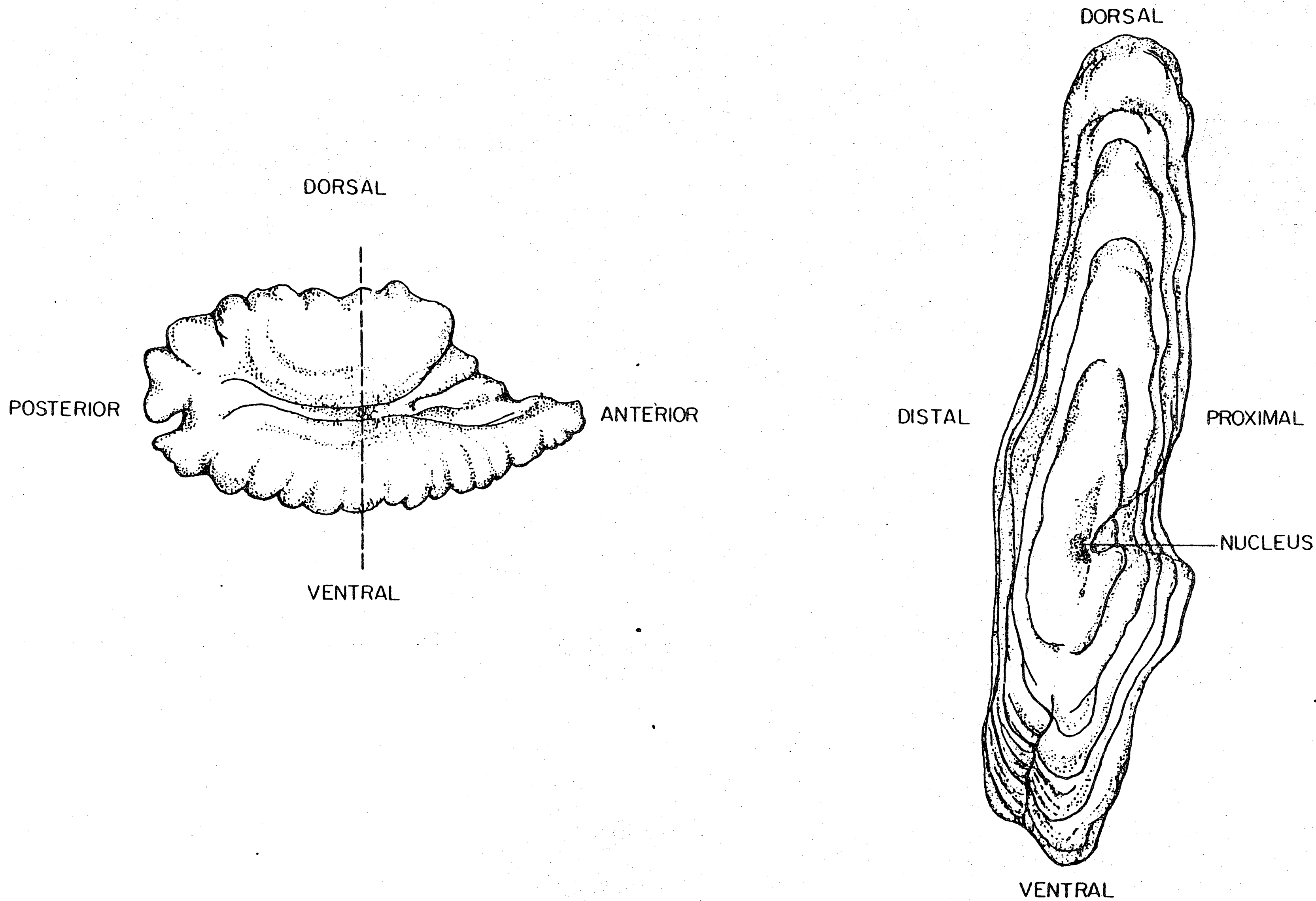
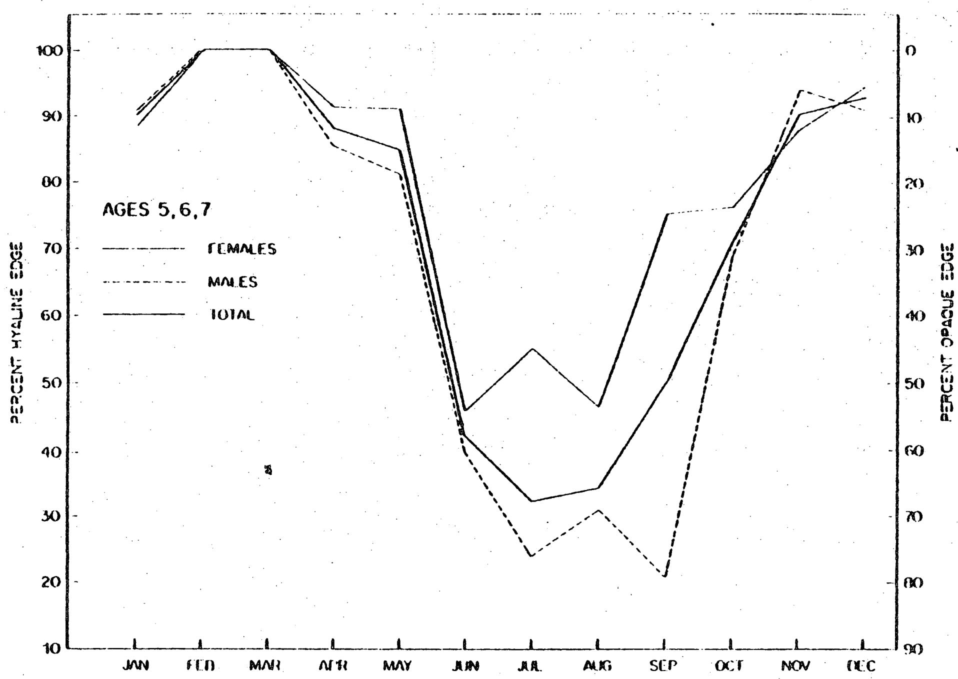
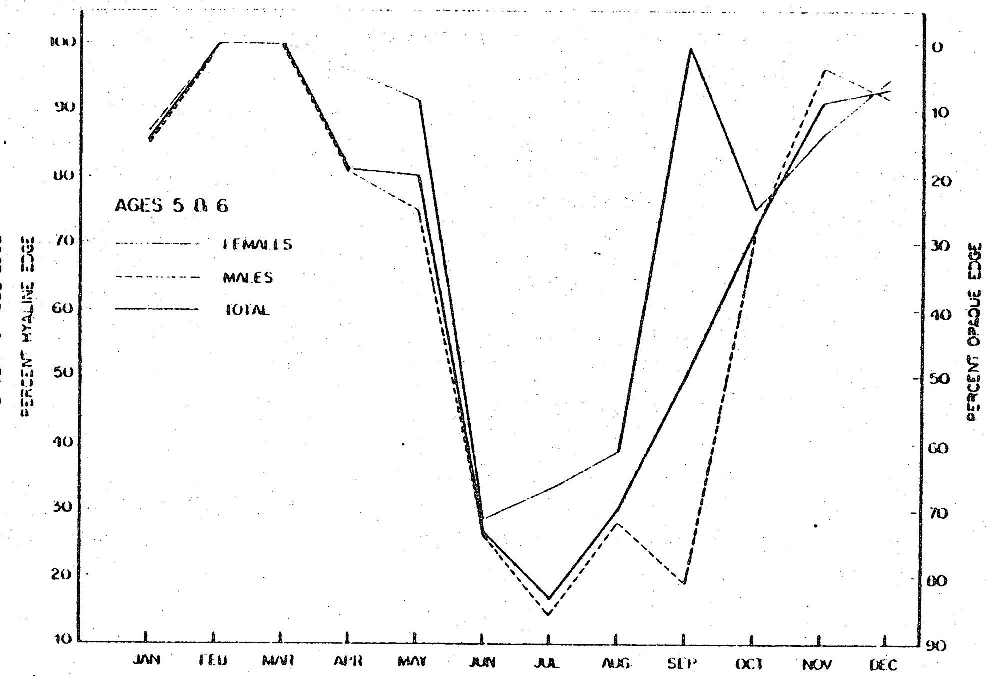


Figure 1. Illustration of distal surface of redfish otolith showing position of transverse section, and a view of the section as seen under magnification.





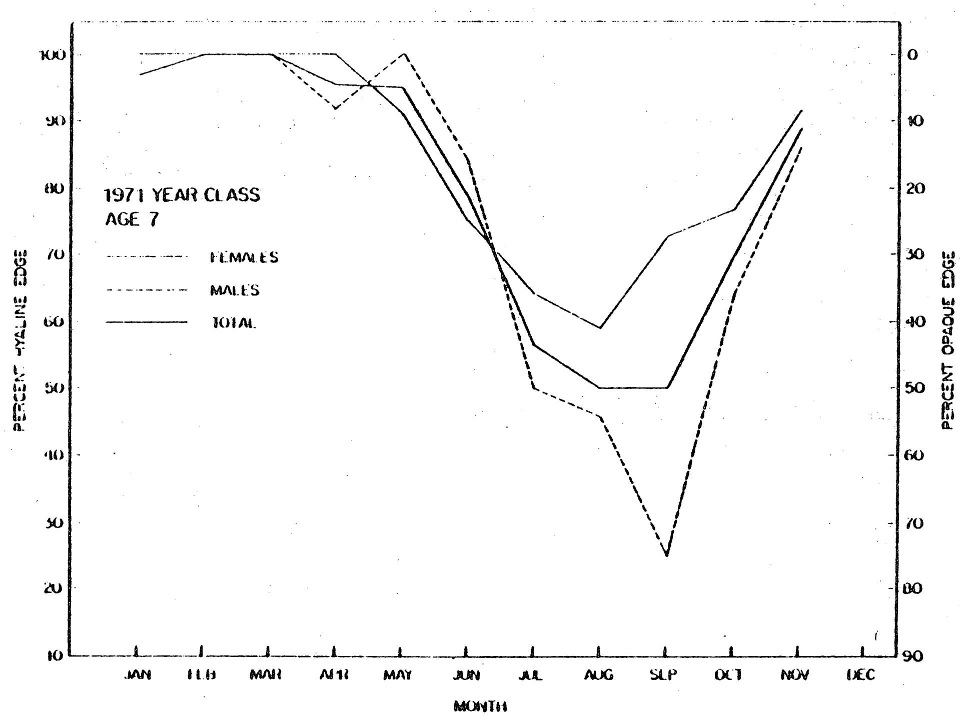


Figure 2. Seasonal changes in the proportion of redfish otoliths showing hyaline and opaque edges. (a) ages 5, 6, 7 combined; (b) ages 5, 6 combined; (c) age 7 only.

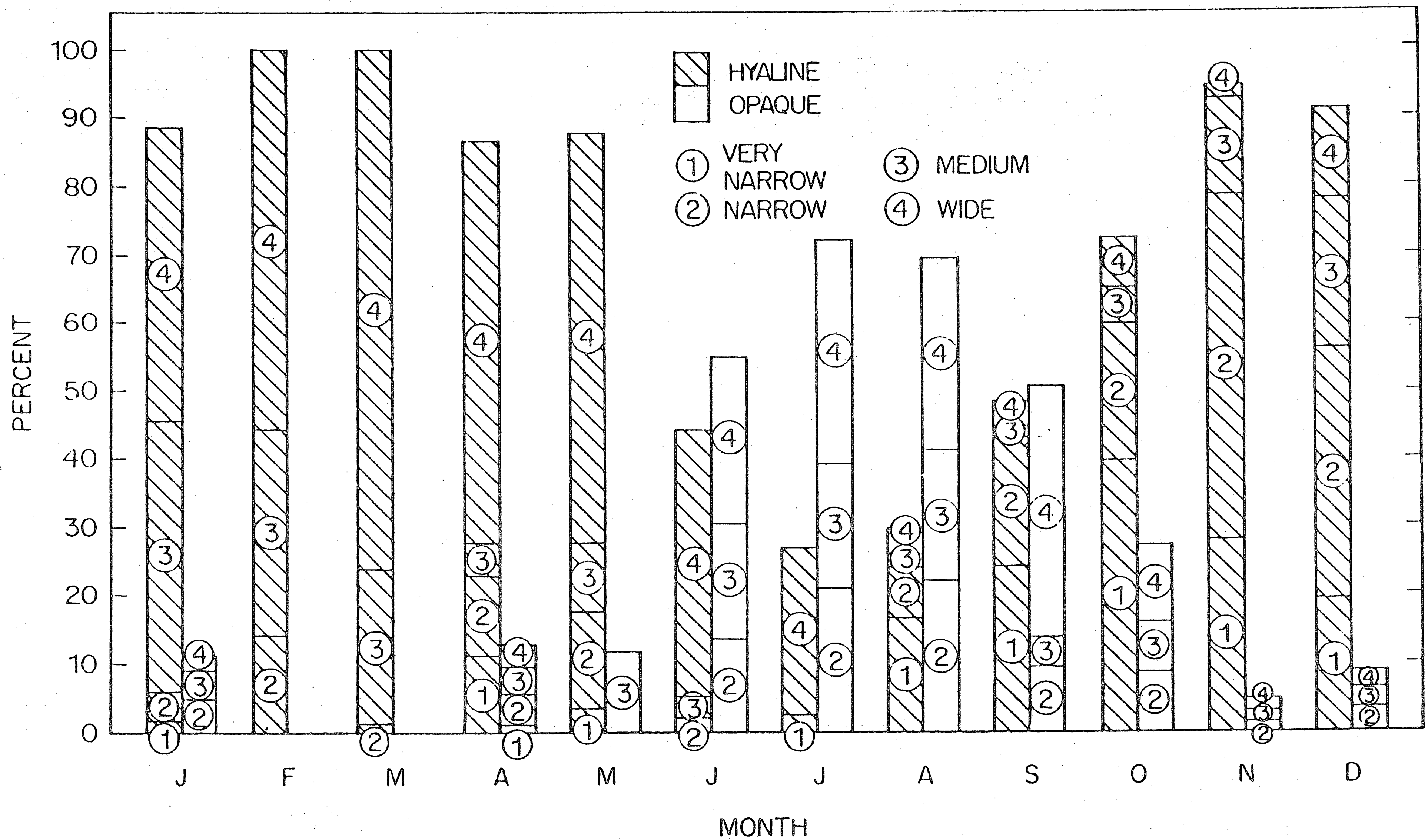


Figure 3. Seasonal progression of very narrow (1), narrow (2), medium (3), and wide (4) hyaline and opaque edge type exhibited by redfish otoliths.

Fig. 4. Photographs of redfish otolith transverse sections dsplaying very narrow, narrow, medium and wide hyaline and opaque edges.

No.	Abbrev.	Edge	Length	Age	Sex	Date landed
1A	Hnv	very narrow hyaline	24 cm	7	M	29 Jun 1978
2	Hn	narrow hyaline	23 cm	7	M	26 Nov 1978
3	Hm	medium hyaline	24 cm	7	F	27 Mar 1978
4A	Hw	wide hyaline	23 cm	7	M	10 May 1978
5	Onv	very narrow opaque	25 cm	6	F	28 Apr 1977
6	On	marrow opaque	21 cm	6	M	6 Apr 1977
7	Om	medium opaque	27 cm	7	F	31 Aug 1978
8	Ow	wide opaque	22 cm	5	M	30 Jul 1976

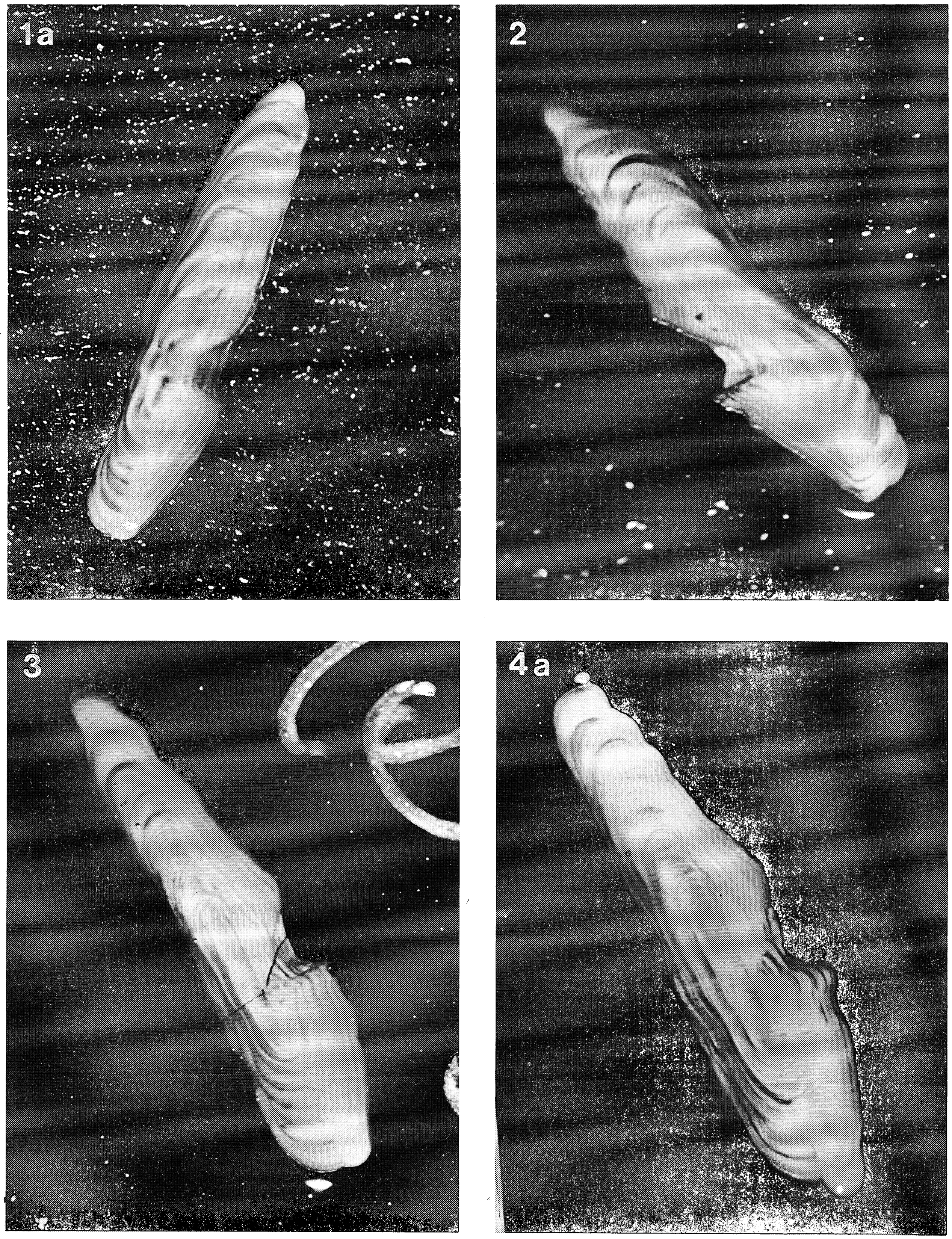


Figure 4.

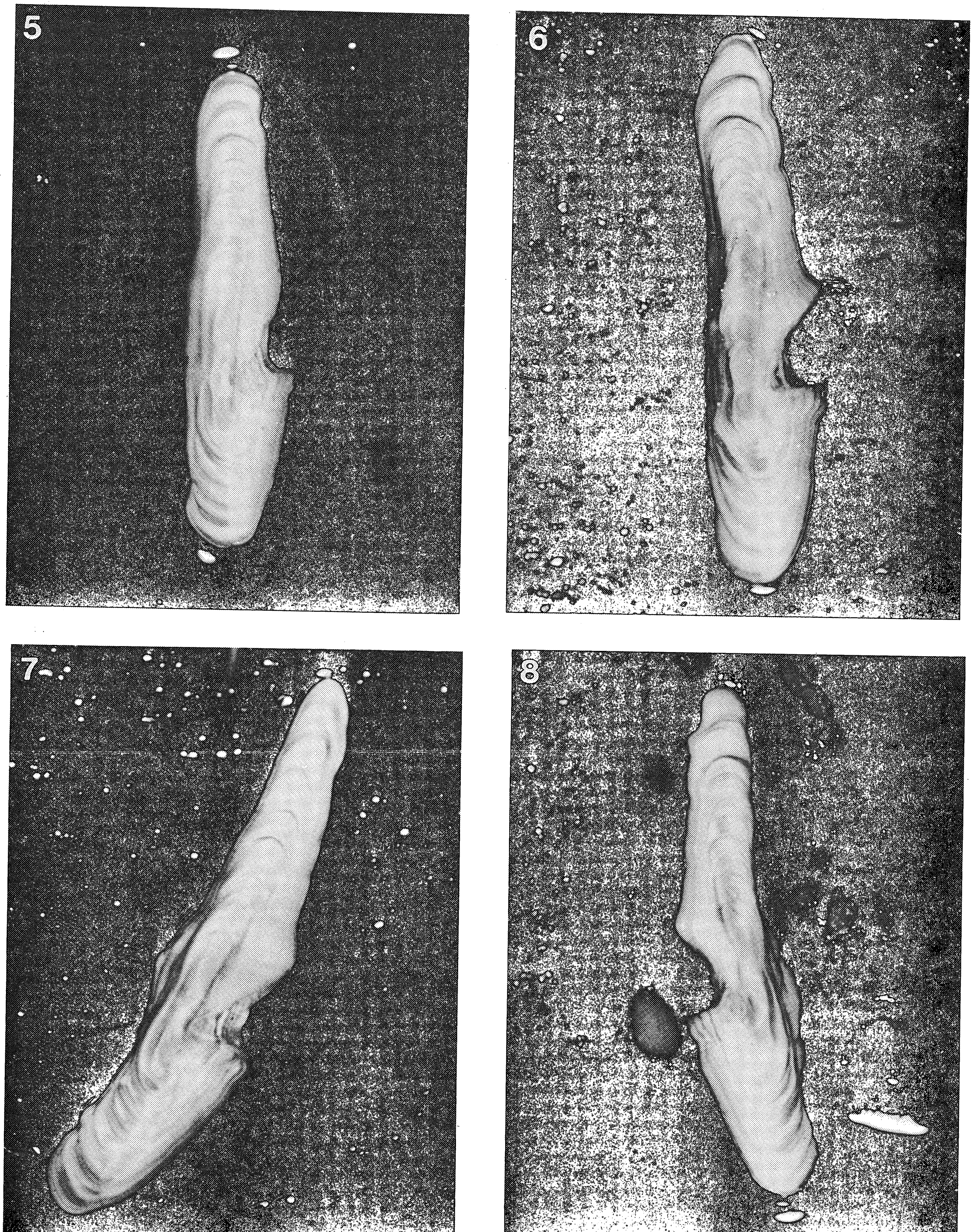


Figure 4 (Continued).

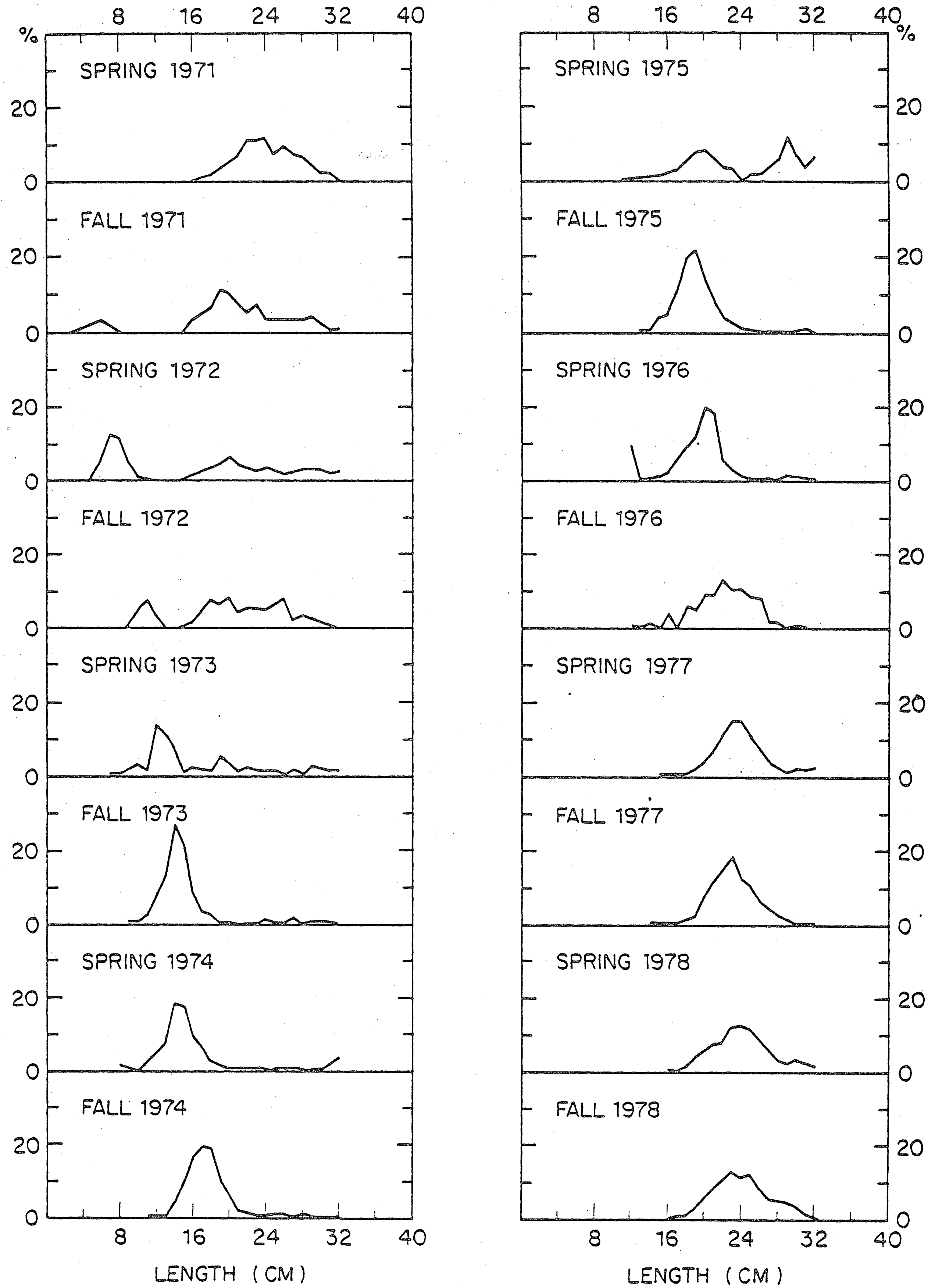


Figure 5. Progression of modal lengths of 1971 year class redfish from inshore (<111 m) Gulf of Maine survey strata, 1971-1978.

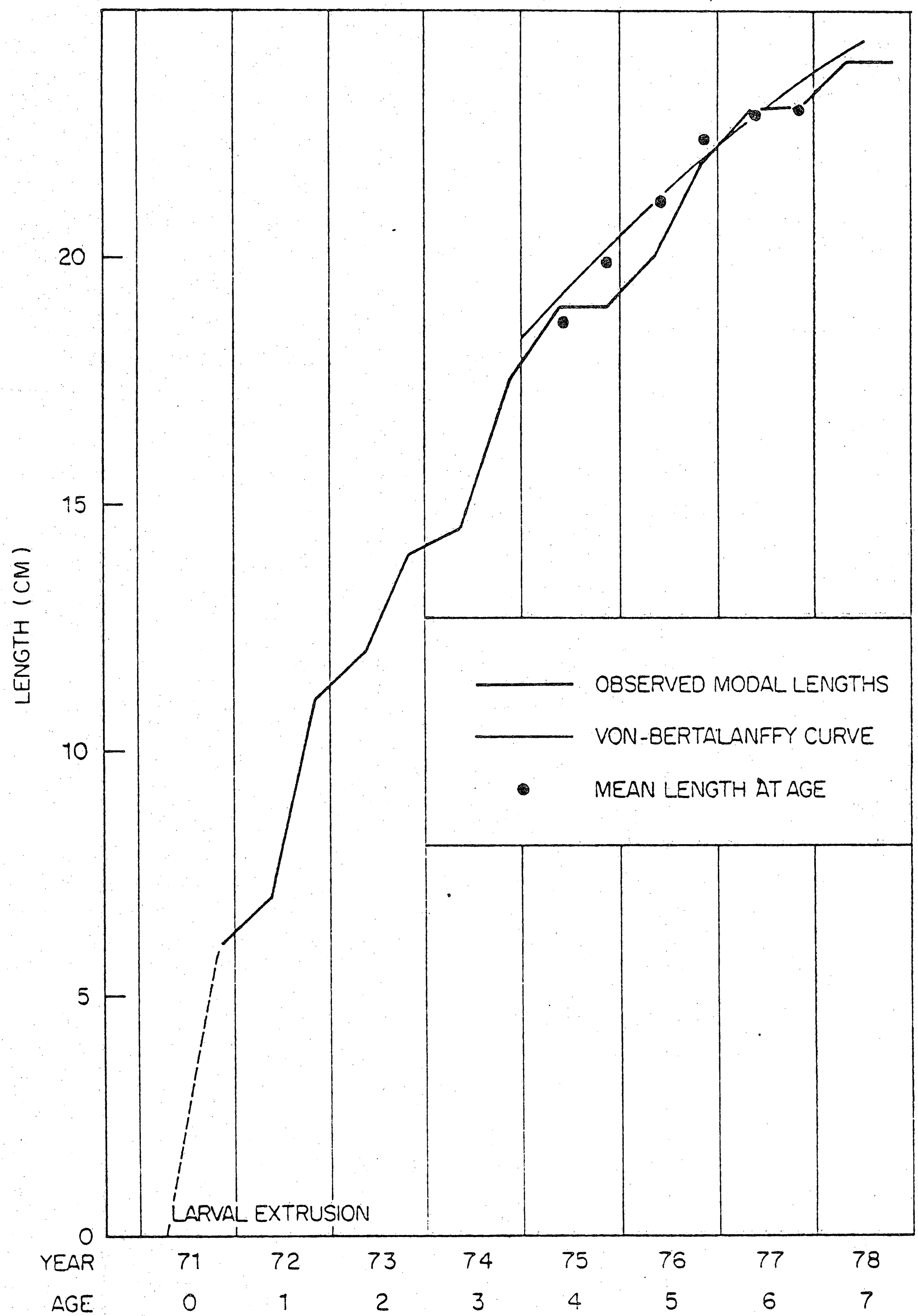


Figure 6. Observed modal lengths and calculated mean lengths at age of redfish collected on spring and autumn research cruises, in the Gulf of Maine, and a segment of the fitted von Bertalanffy growth curve.

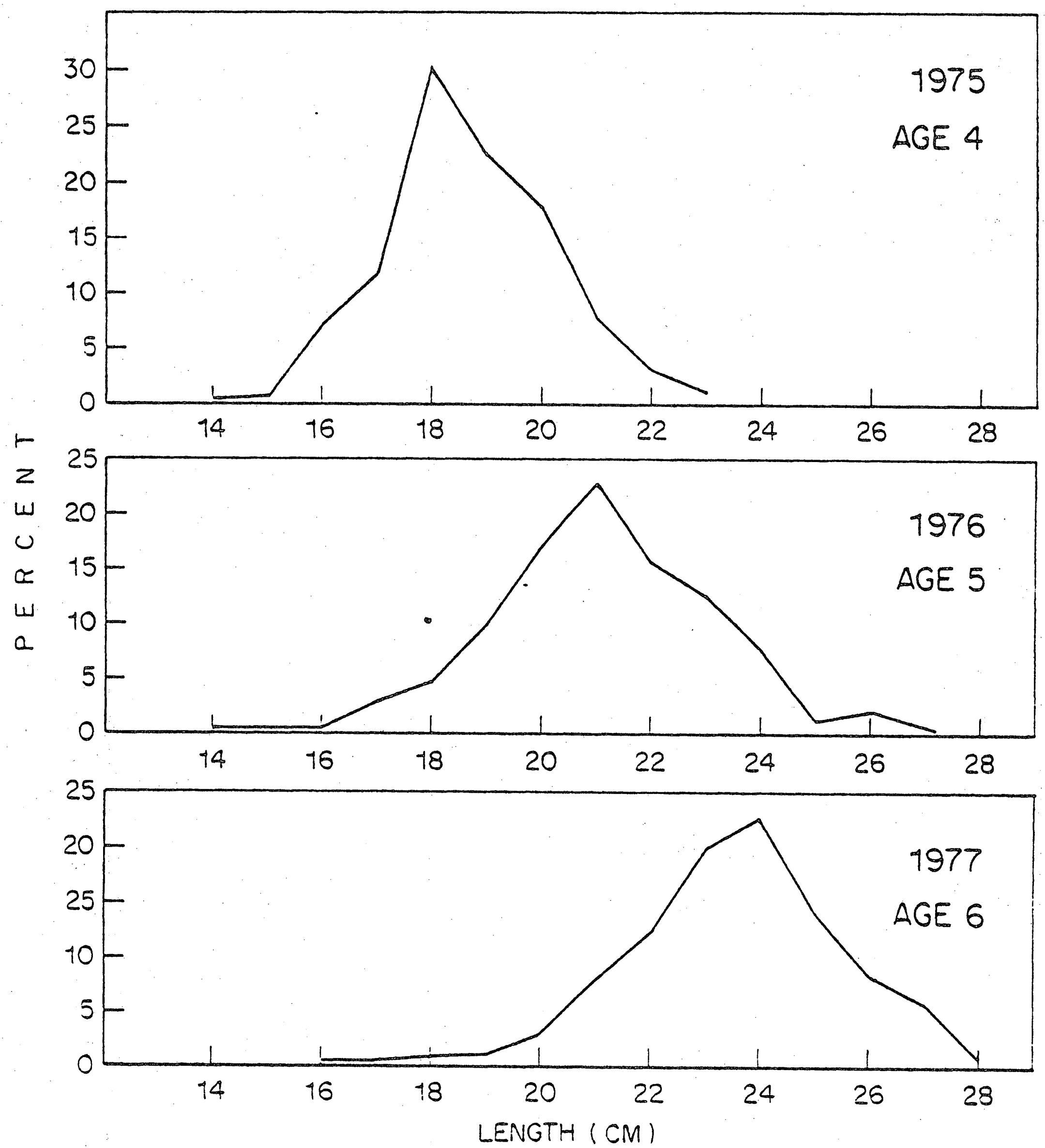


Figure 7. Length frequency of aged 1971 year class redfish from spring research cruises in the Gulf of Maine, 1975-1977.