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

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Abstract

Age determinations of redfish up to age 7 from the Gulf of Maine-Georges Bank region were validated by noting the seasonal formation of hyaline and opaque edges on otolith sections and by comparing estimates of mean length at age with observed modes of length frequencies specific to the 1971 year-class. Evidence was found for the formation in the otolith of one hyaline and one opaque edge annually. Hyaline edges predominate from November to May and opaque edges from June to October. Deposition of hyaline material, as indicated by the presence of a very narrow edge, generally begins in August and the formation of the opaque edge begins in April. Average length at age values based on otolith readings were similar to observed modes of length frequencies known to represent the 1971 year-class on the basis of the seasonal progression of modal length groups from 1971 to 1978.

Introduction

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

The problem 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 protuberance on the lower jaw, termed the *mentella*-type (Travin, 1951), and a smaller-eyed shallower-water form with a rounded protuberance on the lower jaw, termed the *marinus*-type (Templeman, 1959). Travin ascribed the former to a separate species, *S. mentella*, to distinguish it from *S. marinus*, but Andriiashev (1954) described the *mentella* form as a subspecies, *S. marinus mentella* Travin. The distinction between the two forms has been further confused by the geographic variation in *Sebastes* morphometric and meristic characteristics (Kelly *et al*., 1961; Templeman and Pitt, 1961). This tends to complicate comparison of growth rates, particularly off Newfoundland where the distribution of the two forms overlap, because the *marinus*-type grows to a considerably greater maximum length than the *mentella*-type (Sandeman, 1961). Only one form of *Sebastes*, the *mentella*-type, inhabits the Gulf of Maine-Georges Bank region. Although the taxonomy and nomenclature of this form is still under study, the existence of one form in the region, regardless of its taxonomic status, eliminates the confusion which may exist in other areas to the north.

Additional complications have arisen because of the diverse techniques employed by various researchers in ageing redfish, including the use of scales *versus* otoliths, transmitted *versus* reflected polarized light, whole otoliths *versus* transverse and longitudinal sections, and various staining and preparation methods (Perlmutter and Clarke, 1949; Bratberg, 1956; Kotthaus, 1958; Kelly and Wolf, 1959; Sandeman, 1961; Chekhova, MS 1971; Kosswig, MS 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 of various lighting techniques (Kosswig, MS 1971) indicate substantial differences in the clarity of annuli. Confusion has also resulted from a lack of consistent terminology used by age readers to describe age structures. Various projects were undertaken through the scientific committees of ICNAF (International Commission for the Northwest Atlantic Fisheries) to address the problem of age determination in redfish (Keir, MS 1960; Calvin-DeBaie, MS 1964; Blacker, MS 1966, MS 1967), but discrepancies among researchers still persist (ICNAF, 1978, 1979).

In this study, redfish age determinations up to age 7 are validated by documenting seasonal changes in the proportion of hyaline and opaque edges of otoliths, and by comparing the age composition results with modal lengths of the 1971 year-class. The methods of preparation and interpretation of redfish otoliths are described.

Materials and Methods

Redfish otoliths (sagittae), collected during spring and autumn bottom trawl surveys in the Gulf of Maine-Georges Bank region during 1976–78 by research vessels of the National Marine Fisheries Service and during sampling of commercial landings from the Gulf of Maine, were examined in this study. In all cases, otoliths were stored dry in labelled envelopes prior to processing at the laboratory.

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

A sample of 922 otoliths, aged initially by the second author as belonging to the 1971 year-class, was examined independently by two experienced otolith age readers for type and relative width of the edge. In addition, each reader independently re-examined a subsample of 30 randomly chosen otoliths to provide an estimate of precision, agreement being approximately 80% with respect to hyaline-opaque edge identification. Width criteria were established by visual evaluation of the edge relative to the preceding zone of the same type. For example, if a section showed that the hyaline and opaque zones were all fairly narrow, the relative width of the edge would be evaluated accordingly. No numerical measurements were made during this phase of the study.

The terminology used to specify edge types include the four categories proposed by Jensen (1965) and four additional categories for intermediate edge types. Jensen's categories are the first four in the following list:

Hn — Narrow hyaline
Hw — Wide hyaline
On — Narrow opaque
Ow — Wide opaque
Hnv — Very narrow hyaline edge, appearing after a wide opaque zone during the summer or 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 hyaline zone during late transition to mid-summer.

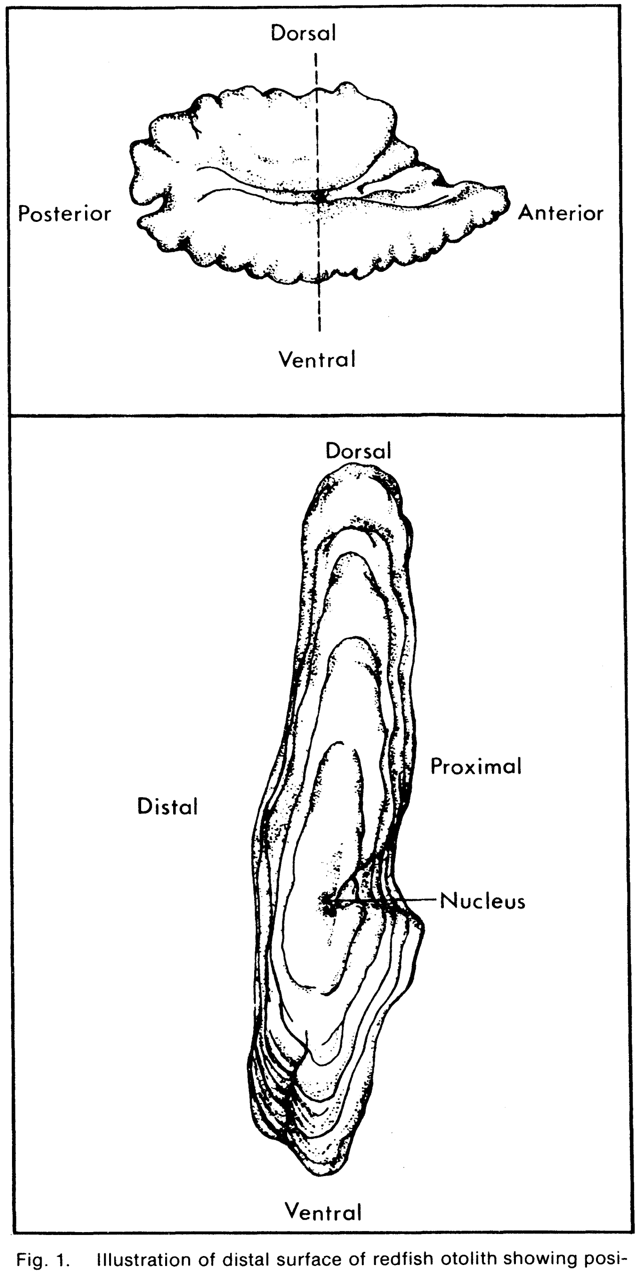

Fig. 1. Illustration of distal surface of redfish otolith showing position of transverse section, and view of the section as seen under magnification.

The progression of length modes of the dominant 1971 year-class were discerned from length frequency distributions of catch in the spring and autumn trawl surveys of inshore areas (<111 m) in the Gulf of Maine during 1971-78. Existing length-at-age data from surveys in 1975-77 (Mayo *et al.*, MS 1979) were used for comparison with the corresponding modal lengths.

Results and Discussion

Characterization of otolith edge types

The eight otolith edge categories used in this study are illustrated in the photographed sections of Fig. 2. Hyaline zones are represented by dark bands (translucent on a black background) and opaque zones are seen as light areas in the otolith sections. The detailed interpretation of edge types presented here is possible because of the widely spaced hyaline zones in the otoliths of young fish. In older fish with more closely spaced zones, the distinction between very narrow and narrow and between medium and wide edges is more difficult to assess, and Jensen's (1965) terminology should be followed. Of the 922 otoliths examined, 782 (85%) were considered distinct enough by both age readers to be assigned to one of the eight edge categories. The remaining 140 otoliths were not considered further in this study.

Overall agreement between the two readers with respect to the eight categories, as indicated by the diagonal elements in Table 1, was 76%. Agreement was 94% when those observations that differed by only one category (one element off the diagonal in Table 1) were included. With respect to hyaline and opaque edges only, overall agreement was approximately 96%. The analysis of seasonal trends of hyaline and opaque edge type is based on all 782 otoliths categorized by the two readers, but the analysis of the eight specific edge

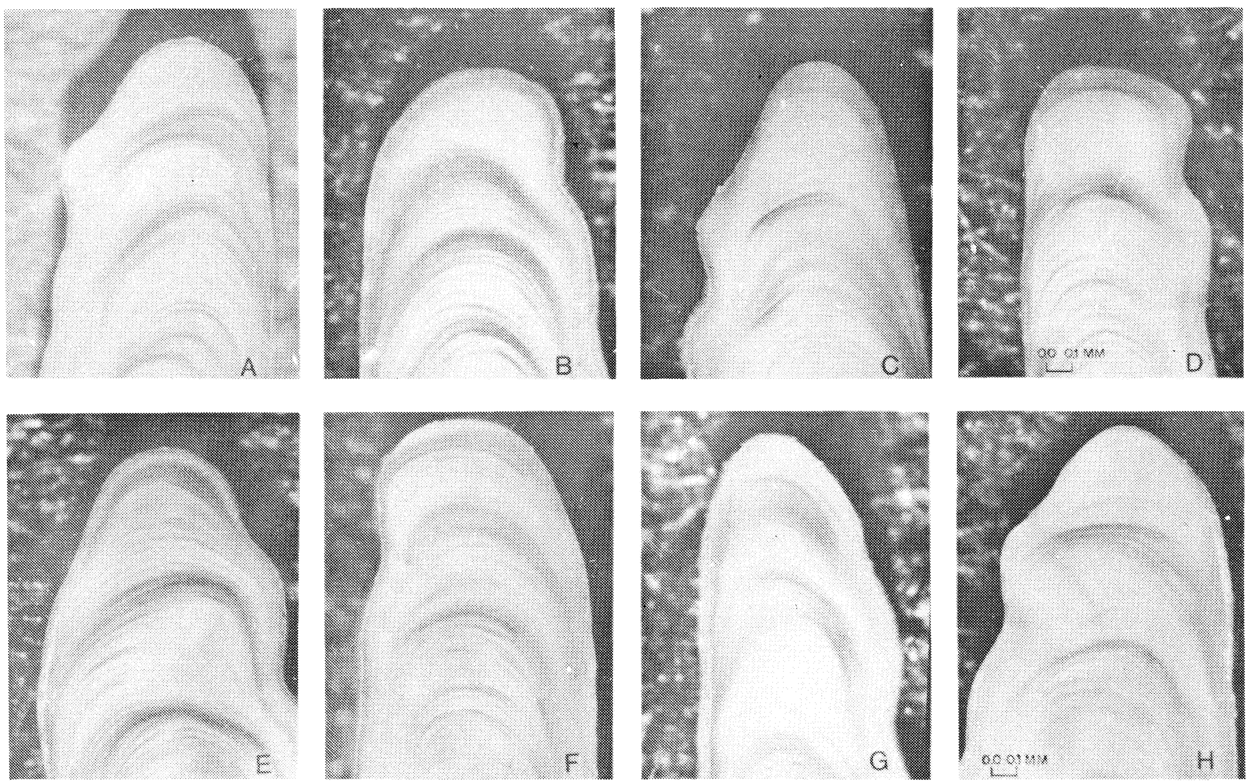

Fig. 2. Photographs of redfish otolith transverse sections displaying the eight edge types:

	Edge type	Length (cm)	Age (yr)	Sex	Date of capture
A.	Hyaline, very narrow	24	5	?	10 Sep 76
B.	Hyaline, narrow	22	7	male	14 Feb 78
C.	Hyaline, medium	24	7	female	27 Mar 78
D.	Hyaline, wide	21	5	male	26 Mar 76
E.	Opaque, very narrow	25	6	female	28 Apr 77
F.	Opaque, narrow	21	6	male	6 Apr 77
G.	Opaque, medium	27	7	female	31 Aug 78
H.	Opaque, wide	23	5	male	19 Aug 76

TABLE 1. Comparison of otolith edge type determinations by two readers for redfish from the Gulf of Maine-Georges Bank region.

	Edge type[a]	Reader 1 Hnv	Hn	Hm	Hw	Onv	On	Om	Ow	Total
Reader 2	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
	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

[a]See Materials and Methods for definitions.

types is based only on the 594 observations represented by the diagonal elements in Table 1.

Seasonal changes in otolith edge

The proportion of hyaline to opaque edge type exhibits one seasonal cycle per year (Fig. 3). Hyaline edges predominate during the winter and spring (November-May), representing 80-100% of the monthly observations. During summer and early autumn, opaque edges predominate, generally representing 50-80% of the observations. Similar results were reported by Kelly and Wolf (1959), and Perlmutter and Clark (1949) showed that, within a year, scales display alternating zones of widely spaced and narrowly spaced circuli, the latter being formed between November and March.

The relatively high proportion of otoliths which exhibit hyaline edges during the period of maximum opaque edge formation indicates considerable variation in the initiation of summer growth. Males display less variability than females in the timing of opaque edge formation, as indicated by the lower proportions of the otoliths of males with hyaline edges during the peak period of growth (Fig. 3). Variation in the timing of larval extrusion by females during the spring months may contribute to this difference, which is most pronounced in age 7 fish that are presumably mature.

The formation of hyaline or opaque edges begins with a large proportion of the otoliths displaying a very narrow zone; this occurs in August-October for hyaline edges and presumably in March-April for opaque edges (Fig. 4). The predominance of edge type shifts from very narrow,to narrow, to medium, and finally to wide as the season progresses.

Age validation

Length and age frequencies from research vessel surveys and commercial catches indicated the presence of a strong 1971 year-class of redfish in the Gulf of

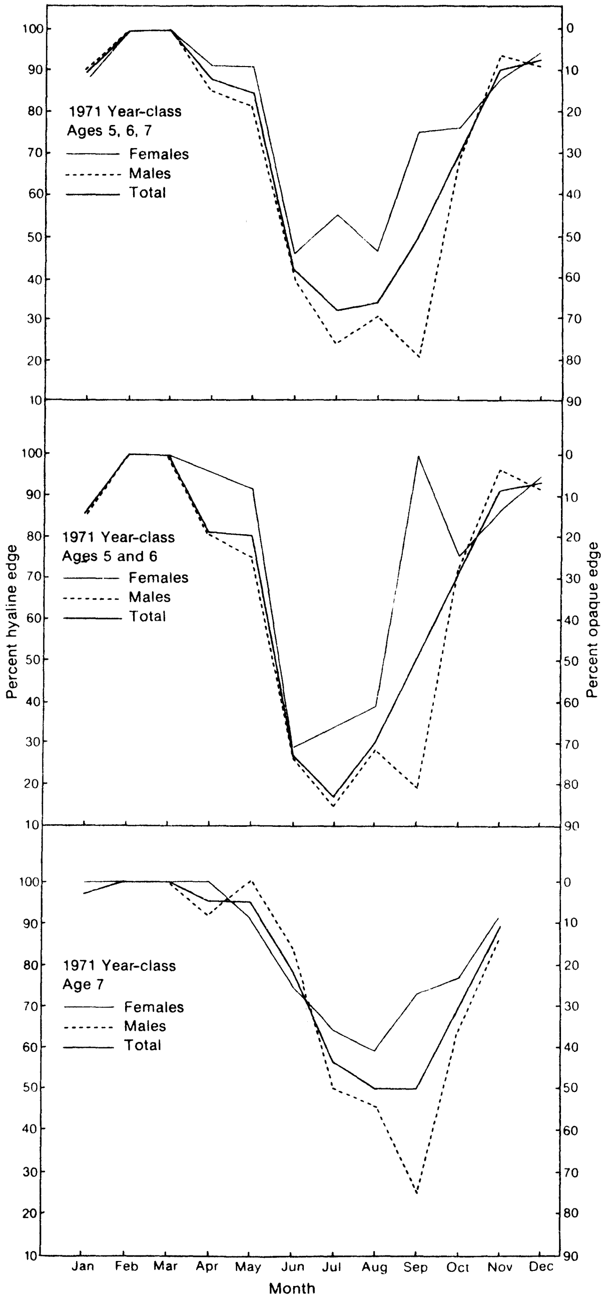

Fig. 3. Seasonal changes in the proportion of redfish otoliths displaying hyaline and opaque edges.

Maine (Mayo *et al.*, MS 1979; Mayo, 1980). A series of length frequencies from spring and autumn surveys of inshore (<111 m) areas in the Gulf of Maine during 1971-78 (Fig. 5) illustrates the progression of length frequency modes of the 1971 year-class. Similar series were reported by Perlmutter and Clarke (1949) for redfish off Nova Scotia and by Sandeman (1961) for redfish in Hermitage Bay, Newfoundland. The seasonal progression of these modal groups affords an excellent opportunity to study early growth and evaluate results from ageing of otoliths.

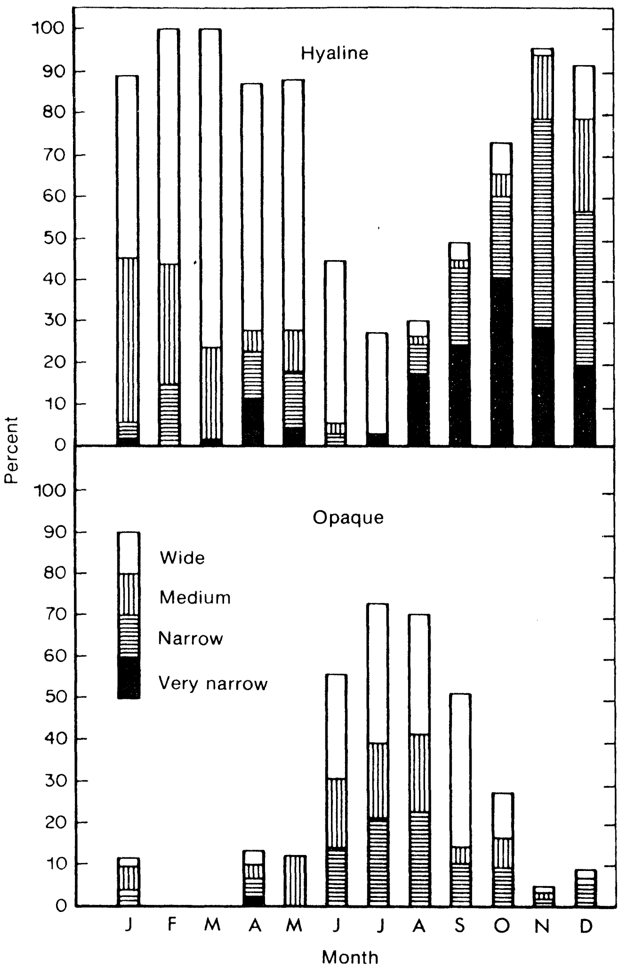

Fig. 4. Seasonal changes in the width of hyaline and opaque edges of redfish otoliths.

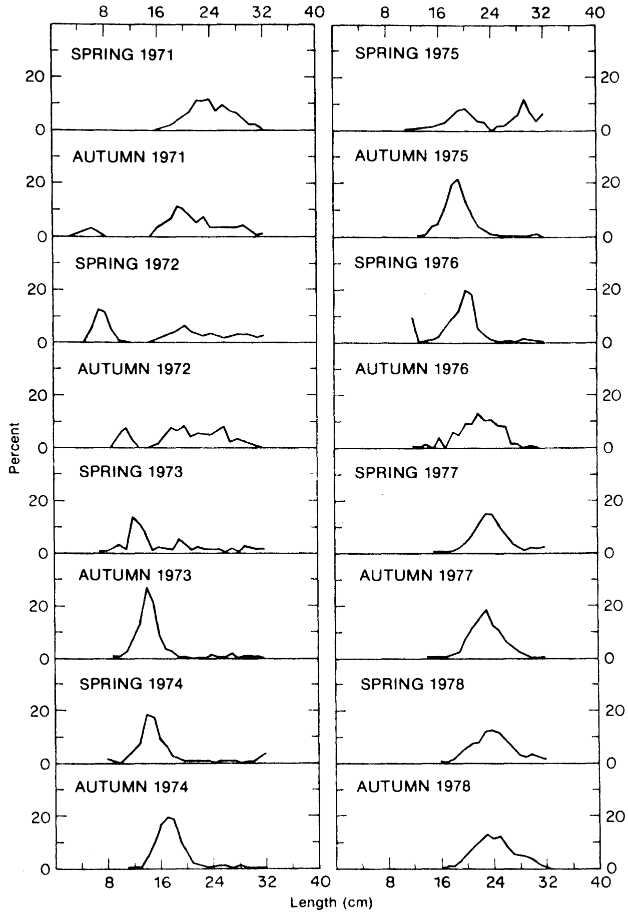

Fig. 5. Length frequencies of redfish, displaying the progression of modal length groups representing the 1971 year-class, from trawl surveys of inshore areas (<111 m) in the Gulf of Maine during 1971–78.

Redfish in this cohort first appeared in the survey catches in the autumn of 1971 with a modal length of 6 cm. This was followed by progressively larger modal lengths in every season to the autumn of 1978, when the modal length was 24 cm and the fish were 7 years old. Figure 6 illustrates the seasonal length increments exhibited by the 1971 year-class throughout this period. Annual increments decreased from about 5 cm during the first 2 years to 1 cm in each of the last 3 years, the overall average being about 3 cm per year. Most of the increase in length occurred between the spring and autumn surveys, particularly in the first 5 years. This average growth rate is slightly greater than that for redfish off Nova Scotia (Perlmutter and Clarke, 1949) and Newfoundland (Sandeman, 1961), but the seasonal pattern of growth increments is similar. The period of rapid growth coincides with the season of maximum opaque edge formation observed in otoliths (Fig. 4).

The mean lengths at age of the 1971 year-class, calculated from age-length keys, and a segment of the von Bertalanffy growth curve, calculated from individual observations of redfish ages from research surveys in 1975–77 (Mayo, 1980), closely agree with the corresponding modal lengths estimated for ages 4 to 6 (Fig. 7). The length distributions of the 1971 year-class, calculated from age-length keys for redfish sampled during the 1975–77 spring surveys in the entire Gulf of Maine region, are similar to the corresponding observed modal length groups illustrated in Fig. 5.

The present analysis substantiates the methods used by researchers at the Woods Hole Laboratory to describe redfish growth based on otolith age determinations. However, these results can only be considered applicable to relatively young redfish. The very slow growth exhibited by redfish after age 10 and the resultant merging of modal length groups in the length frequencies have thwarted previous attempts to follow a cohort for any significant period of time. For example, a similar treatment of the previously dominant 1963 year-class was complicated by the proximity of several relatively strong year-classes (Mayo *et al.*, MS

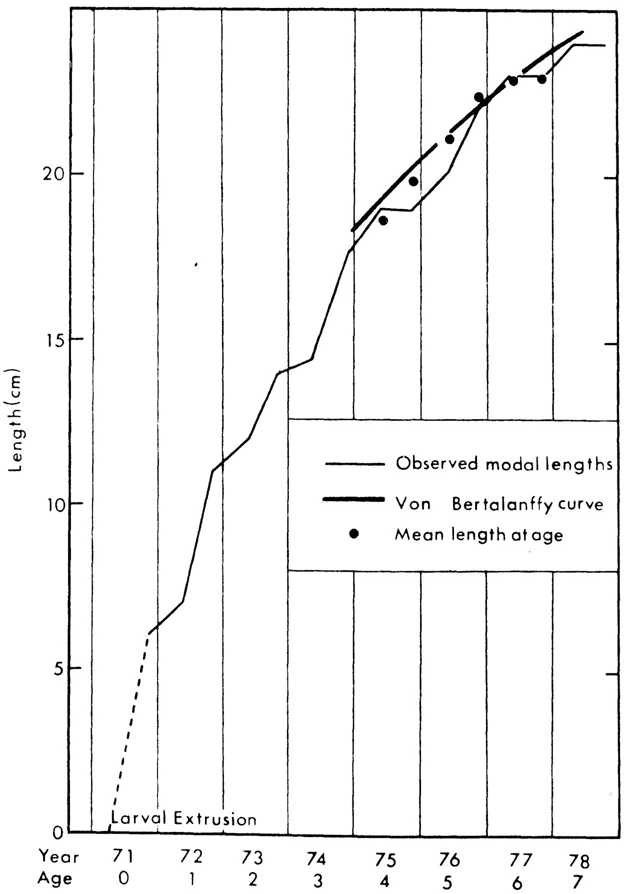

Fig. 6. Growth of redfish in the Gulf of Maine as indicated by observed modal lengths of the 1971 year-class from spring and autumn surveys during 1971-78 and by mean lengths of age-groups 4-6 based on otolith ageing, together with a segment of the von Bertalanffy growth cruve from Mayo (1980).

1979). The unique position of the 1971 year-class, preceded and followed by at least 8 years of poor recruitment, should enable continuation of the procedure used in this study for another 8 to 10 years, until the fish are 15-17 years old, before the modal group 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 to May and opaque from June to 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 growth in length was observed to be about 3 cm per year up to age 7, a rate slightly greater than those reported for redfish off Nova Scotia

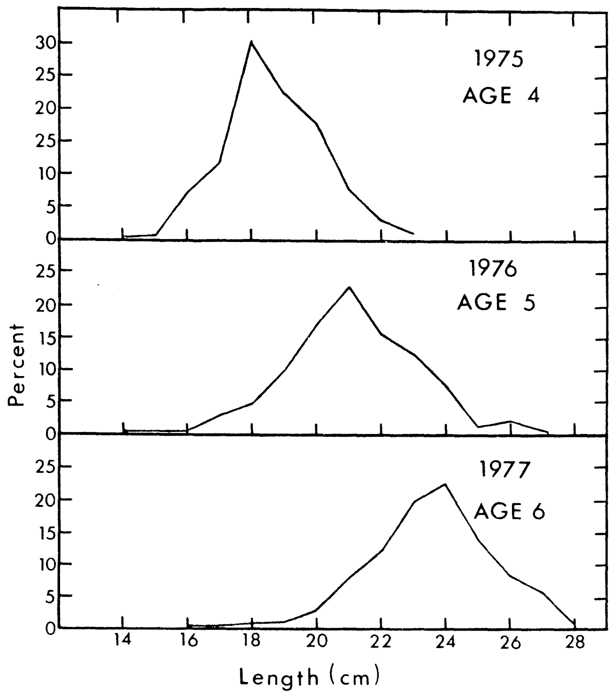

Fig. 7. Length distribution of ages 4-6 redfish of the 1971 year-class from spring surveys in the Gulf of Maine, 1975-77.

and Newfoundland. These results further substantiate the hypothesis that redfish are extremely slow-growing. Observed modal length groups of the 1971 year-class in 1975-77 closely coincide with length frequencies of redfish assigned to age-groups 4-6 based on otolith readings.

The emergence of the 1971 year-class as a dominant feature in the age structure of the Gulf of Maine redfish population has enhanced the study of early growth. The absence of any other year-classes of comparable size for several years before and after 1971 should allow the study of modal length groups to continue for many years.

The results of 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 reasonably accurate information on age and growth.

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