New Information on the Longevity of Pacific Ocean Perch (*Sebastes alutus*)

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A comparison of ages determined from surfaces of otoliths and from sections of otoliths showed that ages were similar up to a section age of 22–24 yr. The growth pattern observed on thin sections of otoliths and from broken and burned otoliths from the region of the nucleus was interpreted to indicate that Pacific ocean perch probably live much longer than previously thought. Because the criteria used to identify annuli from otoliths sections appeared valid for younger fish, there was no justification to reject the application of these criteria for estimating ages of older fish and thus no reason to reject the possibility that Pacific ocean perch might live to be older than 70 yr. Ages determined from sections of otoliths from other rockfish species found off the west coast of Canada such as *Sebastes flavidus* and *Sebastes brevispinis* have ranged from 30 to 60 yr indicating that many species of rockfish may live longer than previously thought.

Key words: age determination, otolith, maximum age, age determination errors, Pacific ocean perch, otolith sections

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Une comparaison des âges déterminés sur des surfaces et sur des coupes d'otolithes démontrent une similarité d'âges jusqu'à 22–24 ans déterminés sur des coupes. Les modalités de croissance observée sur de minces coupes d'otolithes et sur des otolithes cassés et brulés dans la région du noyau indiquent, d'après notre interprétation, que le sébaste du Pacifique a une durée de vie probablement beaucoup plus longue qu'on ne l'avait cru précédemment. Les critères utilisés pour identifier les annuli de coupes d'otolithes semblant valides pour les jeunes poissons, il n'est pas justifiable de rejeter ces critères lorsqu'il s'agit d'estimer l'âge de plus vieux poissons. Il n'y a donc pas de raison de rejeter la possibilité que le sébaste du Pacifique puisse dépasser 70 ans. Les âges déterminés à partir de coupes d'otolithes d'autres espèces de sébastes rencontrés au large de la côte occidentale du Canada, tels *Sebastes flavidus* et *Sebastes brevispinis*, s'étalent de 30 à 60 ans, donnant à croire que plusieurs espèces de sébastes peuvent vivre plus longtemps qu'on ne l'avait cru précédemment.

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PACIFIC ocean perch (*Sebastes alutus*) for many years has been the single most important species in the groundfish fishery off the west coast of Canada. As a consequence of heavy foreign fishing early in this decade, many stocks were over exploited and attempts are now being made to rebuild these stocks. During a routine comparison of age readings from the otolith surface and cross sections (through the nucleus) of the same otolith it became apparent that some of the largest and oldest fish in the sample were much older when annuli were determined from the cross sections. Because of the importance of this species and the probable application of these results to other rockfish species, investigators should be aware of the importance of examining sections of otoliths when estimating the age of rockfish.

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Materials and methods — Pacific ocean perch were obtained in large numbers as part of an exploratory fishing cruise off the west coast of Vancouver Island. The location of sets, a description of gear and composition of catches have been summarized in Sigmund et al. (1979). One of the samples used for this study was obtained when the catch was being processed on shore and consisted of a total sample of the first 411 fish from a bulk lot of a mixture of Pacific ocean perch from all sets. A second sample of 10 individuals was selected from a sample of older fish (by surface readings) collected in 1978 from Moresby Gully

TABLE 1. Surface age determinations for Pacific ocean perch from otoliths collected in this study and from Moresby Gully in 1974[a].

Age (years)	West coast Vancouver Island 1978 No. of fish ♂	♀	♂+♀	% of total	Moresby Gully 1974 No. of fish ♂	♀	♂+♀	% of total
3					2	0	2	—
4					17	25	42	2.1
5					25	19	54	2.7
6					16	17	33	1.7
7		1	1	0.2	21	19	40	2.0
8	1	1	2	0.5	41	38	79	4.0
9	2	3	5	1.2	46	40	86	4.4
10	6	12	18	4.4	61	46	107	5.4
11	16	22	38	9.3	71	51	122	6.2
12	27	28	55	13.5	72	53	125	6.6
13	41	30	71	17.4	73	59	132	6.7
14	36	17	53	13.0	50	16	66	3.4
15	33	18	51	12.5	50	21	71	3.6
16	23	14	37	9.1	57	29	86	4.4
17	15	13	28	6.9	91	35	126	6.4
18	7	4	11	2.7	98	56	154	7.8
19	3	2	5	1.2	98	63	161	8.2
20	0	2	2	0.5	94	67	161	8.2
21	2	3	5	1.2	80	39	119	6.0
22	2	5	7	1.7	55	37	92	4.7
23	1	5	6	1.5	32	29	61	3.1
24	1	2	3	0.7	16	19	35	1.8
25		4	4	1.0	4	6	10	0.1
26		4	4	1.0	2	1	3	—
27		1	1	0.2				
28		1	1	0.2				
Total	216	192	408		1172	795	1967	

[a]Unpublished data courtesy Mr S. J. Westrheim combined from 200, 235, 270, 310, and 340 m. Moresby Gully is located in southern Hecate Strait, approximately 52°30′N, 130°20′W.

in southern Hecate Strait. The surface age of the otolith was estimated according to the method described by Westrheim (1973) by a technician thoroughly experienced with the application of this technique to Pacific ocean perch. A subsample of three individuals from each age-class as determined from surface readings was selected from the west coast Vancouver Island sample for sectioning. Otoliths which were most easily aged from the surface were selected. Otoliths were mounted, sectioned, and examined according to the procedures described by Beamish (1979). A large sample of Pacific ocean perch collected from the relatively unexploited stocks in Moresby Gully in 1974 has been included in the study for comparison with the relatively heavily exploited stocks off Vancouver Island.

If annuli could not be easily identified from the thin section, it was possible to heat the epoxy containing the remaining piece of otolith on a hot plate and soften the epoxy so that the otolith face could be removed and burned in a flame from an alcohol burner. The burned surface was then either ground off until growth zones were clearly visible when painted with cedarwood oil, or painted with cedarwood oil without grinding similar to the procedure described by Chugunova (1959). The breaking, polishing, burning, and cedarwood oil technique was an important alternative approach to the thin section method. Thin sections were preferred in this study because the identification and counting of the narrow zones in otoliths from older fish was facilitated by the use of phase contrast microscopy and higher magnifications.

Results and discussion — Ages determined from the otolith surface (Table 1) ranged from 7 to 28 yr with a modal age of 17 yr. The translucent zone was considered to be the annulus when examining sections of otoliths. In transmitted light this zone appears as a light band that is narrower than the opaque zone in younger fish but becomes equal in width or even wider than the opaque zone for older fish (Fig. 1). Annuli from otolith sections could be distinguished most easily in the area on either side of the central groove or sulcus acusticus, the groove on the interior surface of the otolith that contains the auditory nerve. While an alternating pattern of translucent and opaque zones was visible on all sections, annuli in most sections were not as easily identifiable as from the otoliths shown in Fig. 1. Zones are more difficult to identify from the early period of otolith growth than from the portion of the otolith that corresponds to growth in later years. The difficulty in-

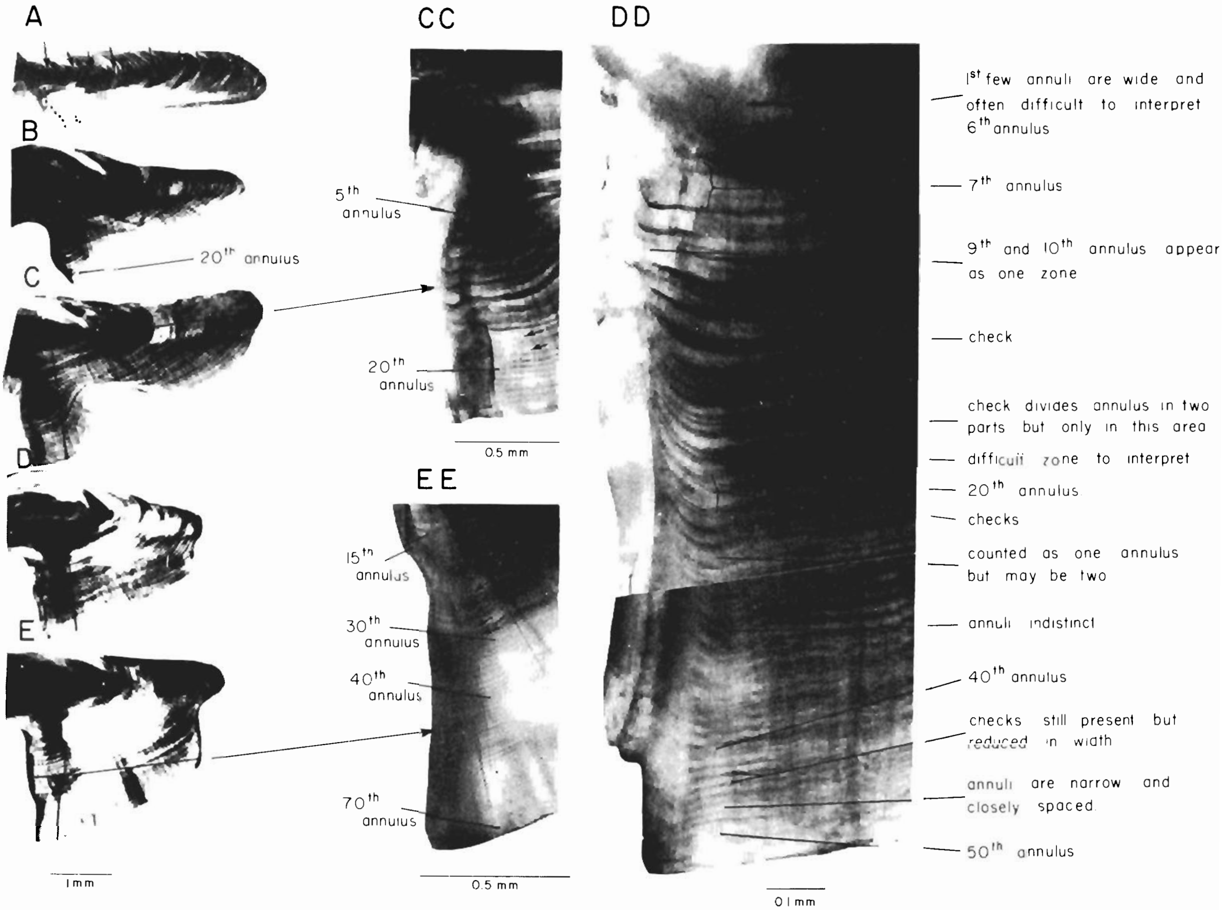

FIG. 1. Sections of Pacific ocean perch otoliths. The narrow annuli representing the older years are not visible from the photography of otoliths D and E but are visible on the enlarged portion in sections DD and EE. Annuli were more distinct when viewed with a microscope than they appear from the photographs. A, ♂ 35 cm, surface age 12, section age 12, arrows indicate position of annuli identified from surface dots indicate annuli identified in the area of the central groove; B, ♂ 45 cm, surface age 24, section age 24, arrows indicate position of discontinuity of an annulus; C, ♀ 46 cm, surface age 24, section age 28; D, ♂ 41 cm, surface age 26, section age 54; E, ♂ 42 cm, surface age 27, section age 72, arrows indicate prominent checks; CC, DD, EE enlarged portion of the central grooves area of otolith C, D, E, respectively, the arrows show prominent checks or areas of discontinuities. Otoliths A, C were from fish from off the west coast of Vancouver Island and B, D, E from fish from Moresby Gully. Section DD enlarged portion of section D showing the relative size of annuli as they became more narrow and closer spaced. Also shown are some of the difficulties encountered when attempting to interpret the growth pattern.

terpreting annuli for the younger years results in part from a lack of prominence of the translucent zone in the vicinity of the interior groove and partly because the first few translucent zones are wide and may contain several checks. Checks are also present in annuli that correspond to older years and such checks can produce a thin opaque zone within a translucent zone. The thickness of the check relative to adjacent opaque zones is usually sufficient to distinguish the check from an annulus. Counts of annuli from sections of very old fish may not be constant simply because of the mechanics of counting the large number of narrow annuli that sometimes are obscure.

On many otolith sections it was not possible to show that all the annuli identified from the exterior surface were the same annuli that were counted on the edge of the central groove. However, the otolith sections in Fig. 1 were very good and it is apparent from many of these sections that the translucent zone visible on the surface was the same zone counted in the vicinity of the central groove. In Fig. 1A independent determinations of surface and section annuli resulted in an identical count of 12. The position of the first 2 annuli is unclear in the area of the central groove and the 7th and 8th annuli appear combined in the photograph but could be separated when viewed with a microscope. Note that the 7th and 8th annuli that would be visible from the surface were also closer together. The otolith in Fig. 1B was also aged as 24 yr from sections and surface readings. Otoliths C, D, E all were aged older from sections than from surface examinations. It is very important to note that not only do these Otoliths contain more lines (or annuli), they are thicker than otoliths from the younger fish. There also is a progressive decrease in the thickness of each zone found on the edge of the interior groove. For example the width of the combined 15th, 25th, and 50th opaque and translucent zones in otoliths C, D, E range from 0.052 to 0.033, 0.033 to 0.020, and 0.010 to 0.008 mm, respectively. Otoliths that had more than 25 to 30 annuli had an accummulation of the very narrow zones in addition to the thicker zones that were characteristic of the younger otoliths (Fig. 1, CC, DD, EE). Some annuli on most sections were not as easily identified as others because of checks or because they appeared to become confluent with adjacent annuli (Fig. 1, CC, DD, EE). Annuli seldom could be identified as a continuous zone in all parts of a section and counts of annuli in areas of discontinuities (Fig. 1B) should be avoided. Despite the difficulty in obtaining precise readings and despite the difficulty in identifying the position of a particular zone in all parts of the section it was apparent that a pattern existed and it remained to be shown that the pattern could be interpreted to allow an estimate of the age of the fish.

It would be extremely difficult to verify that all zones identified as annuli from the otolith section did form once a year since no method presently is available to successfully tag and release live Pacific ocean perch. However it is possible to compare section ages with surface ages and for the period of years that the age determination method has been validated by Westrheim (1973) for surface readings it is possible to validate indirectly the interpretations applied to otolith sections.

When this comparison was made (Fig. 2) it was found that up to a section age of 22–24 yr the deviation of the mean surface age from each corresponding section age showed no trend and the values were scattered on either side of the zero deviation line. After section age 22 there was a distinct trend of increasing deviation with increasing section age indicating that surface age determination reached a maximum while annuli continued to be identifiable on the interior surface. Also no very old (>20 yr) ages were obtained by the section method for any of the fish aged less than 20 yr by the surface method. Section ages of younger fish could be considered to be similar to surface ages. It is apparent from Fig. 1 that the zones that form in later years form a very regular pattern. If the zones that form in later years are not annuli it would be necessary to postulate that the growth pattern of the otolith of each of the older fish is different from the younger fish and that a change in the pattern of zone formation occurred after an age of about 22–24 yr. This appears unlikely since after a section age of about 5–10 yr the growth zones (interpreted as annuli) from otolith sections exhibit a similar and constant pattern

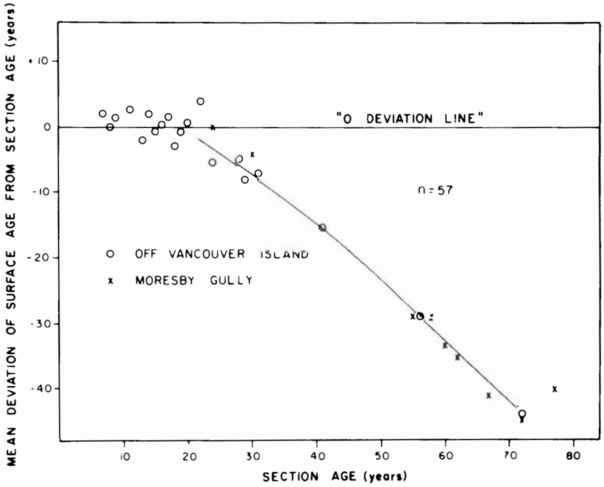

FIG. 2. Mean deviation of mean surface age from section age.

of decreasing thickness. Anomalies in pattern formation are not apparent for fish older than 15–20 yr (Fig. 1). When the technique of breaking an otolith in half and burning the polished face was used, it was possible to examine annuli in more detail than was possible for most thin sections. Using this technique it could be shown that in most cases while the width of the annulus changed with time, the annulus did not bifurcate or change in some way that might result in a zone that formed annually being considered to be two or more annuli.

Older male Pacific ocean perch aged by the section method were smaller than females of similar age but neither males nor females showed a trend towards increased length with increased section age (Table 2). While the sample size in this study is small and the validity of extrapolating conclusions about growth from grouped samples is unknown it is possible that after a certain length, fish may increase in age with little or no increases in length. That is, the maximum length might be obtained before the maximum age is obtained. According to Beverton and Holt (1960) the concept that natural life span extends far beyond the time when maximum size is reached is rare or unknown in fishes. It may be argued that some growth in length perhaps measured in very small units is occurring but certainly growth is minimal and for all practical purposes growth in length appears negligible. Also, if the ages determined from sections are correct, the possibility that decreases in length occur should not be ignored.

The oldest age recorded for Pacific ocean perch is 30 yr (Westrheim 1970) but it is acknowledged that the species may be much older since annuli are difficult to identify from the surface of older fish as they tend to "roll over" the edge of the otolith and can only be viewed by tilting the otolith (S. J. Westrheim, Pacific Biological Station, Nanaimo, personal communication).

TABLE 2. Length and sex of Pacific ocean perch older than 25 yr as determined from the section method. Samples from Moresby Gully are indicated by (M).

Section age (yr)	Surface age (yr)	Fork length (cm)
Males		
30 (M)	27	44
55 (M)	26	41
58 (M)	29	41
60 (M)	28	42
62 (M)	27	43
67 (M)	26	42
72 (M)	27	42
77 (M)	27	41
Females		
28	22	45
28	23	46
28	25	46
30 (M)	25	45
31	24	46
36 (M)	26	46
41	26	47
56	27	48
72	28	45

It may be difficult to believe that the maximum age could be more than double this figure. Yet we can accept that some fishes do get to be very old. Sturgeon (*Acipenser fulvescens*) have been reported to reach a maximum age of over 80 yr (Probst and Cooper 1954) and one report records a sturgeon as being 152 yr old (Anon. 1954). The spiny dogfish (*Squalus acanthias*) is thought to attain ages of over 60 yr (Wood et al. 1979) and Power (1978) has suggested that the life span of lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*) may exceed 50 yr. It also has been reported that ages determined for the rockfish or redfish (*Sebastes mentella*) from the exposed surface of an otolith cracked transversely through the nucleus were much older than previously thought (Sandeman 1961). Sandeman (Biological Station, St. John's, Newfoundland, personal communication) reports that in virgin stocks, a significant portion of the stock ranged in age from 40 to 50 yr and some of the older fish showed signs of senility. The oldest redfish found in their studies was aged as approximately 83 yr. Thus there is evidence that some fishes can live to ages we consider to be old (an obvious relationship to our own life span).

In this study an examination of the pattern of growth visible on the interior of the otolith has shown that surface and section age determinations agree up to a section age of 22–24 yr. The annulus continues to be visible from the otolith section resulting in an accummulation of annuli of progressively narrowing width and an increase in the lateral thickness of the otolith. Thus Pacific ocean perch appears to be simply another fish that can live to be very old.

It would appear from the small sample examined in this study that any fish aged 22–24 yr or older from the otolith surface should also be aged using otolith sections. Otolith readers familiar with Pacific ocean perch otoliths often do not attempt to age fish past an age of 20 yr. Therefore a more cautious approach should be to section any otolith aged to be 20 yr or more from surface readings. In the heavily exploited stocks found off Vancouver Island, 8% of the sample was aged to be 20 yr or older (Table 1). However in the less heavily exploited or relatively unexploited stocks found in Moresby Gully, 24% of the fish were age 20 or older (Table 1). An analysis of the consequences of having some very old fish in a stock of Pacific ocean perch with respect to the population dynamics of the stock and strategies involved in the rehabilitation of overexploited stocks are beyond the scope of this report and are currently being studied as part of the program studying groundfish stocks found off the west coast of Canada.

The procedure of sectioning all otoliths that were aged as 20 yr or older from surface age determinations was applied to other species of rockfish found off the west coast of Canada. In many cases it was found that ages determined from sections were older than the age determinations from the otolith surface. For example surface age determinations of otoliths from *Sebastes aleutianus* that ranged from 24 to 28 yr, ranged from 30 to 40 yr when determined from sections of otoliths. Otolith sections from *Sebastes brevispinis* and *Sebastes flavidus* have been aged as high as 60 and 56 yr, respectively, and similar observations have been found for *Sebastes paucispinis*, *Sebastes borealis*, *Sebastes reedi*, *Sebastes diploproa*, and *Sebastes proriger*.

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