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First Evidence of Validity of the Fin-Ray Method of Age Determination for Marine Fishes

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ABSTRACT

In 1978, tagged lingcod (*Ophiodon elongatus*) were injected with oxytetracycline to produce a time mark in the fin rays. Four fish were recovered after being at liberty for approximately 2 or 3 years and all had an oxytetracycline mark. Three of the four fish had formed a number of annual growth zones equivalent to the number of years at liberty, confirming that the mark thought to be an annulus did form once a year. One fish probably formed the appropriate number of annual growth zones but, because growth was reduced, the annuli were difficult to identify. There was no indication that the age of lingcod would be overestimated by the fin-ray method.

The use of fin-ray sections for age determination provides a useful alternative to the more traditional methods that use scales or otoliths (Boiko 1951; Cuerrier 1951; Beamish 1981). The method is best known for its application to estimate the age of sturgeon (Acipenseridae) but it can be used to age other fishes (Beamish 1981). Even though fin-ray sections have been used to age fishes for more than 60 years, there are only a few studies that have validated the method. In particular, we can find no evidence of its validation for any species of sturgeon. There is evidence of the validity of the method for some freshwater fishes (Beamish and Harvey 1969; Beamish 1973; Mills and Beamish 1980) but we could find no documentation of its validity for a marine species.

The importance of validating a method of age determination for any species should never be underestimated. Early studies on age and growth of fishes stressed the need to validate age estimates (Van Oosten 1941). However, it appears that with time the determination of ages became routine, and little attention was paid to proving that age estimates were correct despite the key role that age determinations played in many analyses. Recently, several studies have indicated that previous estimates of age for some common species could seriously underestimate their true age (Beamish and Harvey 1969; Aass 1972; Power 1978; Beamish 1979; Beamish and Chilton 1982). If these new interpretations are correct, then the consequences of not validating age estimates could have significant effects on stock management. Errors in interpretation will occur. However, the fisheries biologist has an obligation to ensure that an accurate age determination method is in use so that there is a solid foundation for understanding the dynamics of a population.

A previous study (Beamish and Chilton 1977) examined the use of scales, otoliths, and fin rays to age lingcod. Their results indicated that sections of fin rays from the second dorsal fin provided the best indicator of age. Scales and otoliths were found to be unsuitable for age determinations of lingcod. This report indicates that the fin-ray technique for age determination of lingcod (*Ophiodon elongatus*) has the potential to provide accurate age determinations. Unfortunately, the sample size is very small. However, because studies that validate ages for most age groups in a population take a number of years and because there are very few validations of the fin-ray method (or any other method), we feel it is important to report the results of our attempt to validate the fin-ray method of age determination for lingcod despite the small sample size.

MATERIALS AND METHODS

During 1978, lingcod were tagged and released off the west coast of Canada. All fish were tagged with a Floy FD68 anchor tag by inserting the base of the tag in the connective tissue at the anterior base of the first dorsal fin. All fish in the June and July cruises and 42% of the fish in the September cruise received an injection of 100 mg/kg of oxytetracycline (OTC) into the peri-

Table 1. Tagged lingcod released in waters off Canada's west coast in 1978 and recoveries to December 31, 1981.[a]

Release period	Releases: Total number	Releases: Injected with oxytetracycline: Number	Releases: Injected with oxytetracycline: Percent	Recoveries: Total number	Recoveries: Injected with oxytetracycline: Number	Recoveries: Injected with oxytetracycline: Percent	Fish at liberty >365 days
June 25–30	144	144	100	4	4	100	1
July 6–26	991	988	99	16	14	88	6
September 8–19	337	133	40	12	5	38	5
Total/means	1,472	1,265	86	32	23	72	12

[a] Releases and recoveries are for lingcod estimated from length frequencies to be age 3 and older at the time of tagging.

toneal cavity. Weight was estimated from fork length.

All fish in the July and September cruises were caught with standard commercial bottom trawls that contained a codend liner with a stretched mesh size of 2.2 cm. Tows were limited to approximately 15 minutes to reduce the possibility of stress. The captured lingcod were released on deck and immediately placed in 1,200-liter tanks that contained flowing seawater. Prior to marking and injecting, lingcod were anaethesized in tricaine methanesulphonate (MS 222). After tagging, lingcod were released directly into the ocean by hand. The method of injection (Beamish et al. 1978) was similar to that used for sablefish (*Anoplopoma fimbria*).

All tagging in June was conducted during commercial trawling operations. Sets ranged from 25–180 minutes and averaged 100 minutes. Tagging and handling procedures were similar to those previously described.

At periodic intervals throughout the release periods, tagged and injected lingcod were kept in holding tanks overnight to assess the mortality that might be associated with the tagging operation.

During September, a number of untagged and uninjected juvenile lingcod were transferred to a 2,400-liter holding tank at the Pacific Biological Station that contained flowing seawater of ambient temperature from the Strait of Georgia. Twelve of 14 fish were tagged, injected, and maintained in holding tanks. Two were not tagged and not injected.

The dosage of OTC was tested in the laboratory and found to produce a strong mark in the bone without any mortality. However, subsequent studies have demonstrated that this dosage does cause mortality of sablefish in the natural environment (Beamish et al. 1980), but not in the laboratory (Beamish and McFarlane, unpublished data). Therefore, we suspect that this dosage is too concentrated and recommend approximately 25 mg/kg according to the studies of Beamish and McFarlane (unpublished data).

Rewards were paid for the return of whole fish. When whole fish were returned, they were measured for fork length, sampled for sex and maturity, and a portion of the dorsal fin was removed for age determination according to the procedures of Beamish and Chilton (1977). Sections of fins were viewed with reflected ultraviolet light, which caused the OTC mark to fluoresce, and regular transmitted light. Care was taken to keep material in the dark when not in use and not to expose the fin section to prolonged periods of ultraviolet light. Photographs were taken using standard photographic techniques (Chilton and Beamish 1982).

RESULTS

A total of 45 juvenile lingcod were held in holding tanks overnight during the tagging operations and no mortality occurred despite some bleeding from the tag wounds. The 12 tagged and injected fish held in the laboratory survived for 3 months without any mortality.

A total of 3,744 lingcod were tagged of which 2,673 received an injection of OTC and 1,472 of these fish were estimated to be age 3 or older from the relationship between length and age. In this report, only the fish estimated to be age 3 and older at the time of tagging will be considered (Table 1) because recoveries of younger tagged fish were either uninjected or reported without the return of structures used for age determination.

There were 32 recoveries, 23 of which had

Table 2. Release and recovery information for the four tagged lingcod that were injected with oxytetracycline and recovered more than 365 days after tagging.

Tag numbers	Release date	Sex	Fork length at time of tagging (centimeters)	Fork length at time of recovery (centimeters)	Recovery date	Days at liberty
B7735003	July 16, 1978	♂	69	74	May 23, 1980	660
B7738057	June 27, 1978	♂	58	67	June 9, 1980	712
B7735931	September 11, 1978	♀	60	77	August, 1981	1,053–1,084
B7736519	September 13, 1978	♂	77	65[a]	September, 1981	1,082–1,112

[a] Dressed length. The estimated fork length was 80 cm using the conversion of Wendler (1953).

received an OTC injection and 12 of these had been at liberty for more than 365 days after tagging. Unfortunately, only 4 of these 12 fish were returned in a condition such that the dorsal fin rays could be removed. Fin-ray sections from all four of these fish were examined (Table 2).

The recovery rate of tagged fish as of December 31, 1981 was 2.2%. The rate in this study was less than recovery rates of 19.8% (Forrester 1973), 65.0% (Reeves 1966), and 13.3% (Chatwin 1956) observed in other lingcod tagging studies. In the one cruise where approximately 40% of the fish received OTC injections and 60% did not, the recovery rates of the uninjected and injected fish were similar, suggesting that there was no mortality associated with the injection of OTC. However, as mentioned, the results of other studies (Beamish et al. 1980, Beamish and McFarlane, unpublished data) indicated that the dosage used in this study would be too concentrated for sablefish and this probably was true also for lingcod.

Of the fish recovered approximately 2 years after release, Number B7735003 (Fig. 1A, B) was a male 74 cm long when recovered on May 23, 1980, and 69 cm long when tagged in July 1978. The OTC mark is faint but visible just beyond the annulus (Fig. 1B). Two clear opaque zones plus one distinct and one narrow translucent zone formed beyond the OTC mark in the 660 days following release. There were six annuli prior to tagging (Fig. 1B) and the fish was aged as 8 years when recaptured, assuming a January 1 birthday even though the last annulus is barely distinguishable on the edge of the fin ray. Thus, this fish formed two distinct annual growth zones, each consisting of an opaque and a translucent zone in the 2 years following release.

The formation of the OTC mark in the opaque zone just beyond the sixth annulus (Fig. 1B) and the absence of opaque growth on the edge indicates that the period of opaque growth began late in June or early in July. Because of the clearing action of mounting media and the difficulty in viewing the edge of the fin-ray section, it is difficult to see an annulus on the edge in Fig. 1A but it was visible in other fin-ray sections.

Number B7738057 was recovered June 9, 1980, 712 days after release and aged as 5 years (Fig. 1C). This fish was a mature male when recovered and measured 67 cm; 58 cm when tagged in June 1978. The position of the OTC mark (Fig. 1D) corresponded to the position of the third annulus (Fig. 1C), and it is clear that two opaque and two translucent zones (annuli) have formed beyond the OTC mark. In a 2-year period, two growth zones, each consisting of an opaque and a translucent zone, were formed. The annuli deposited 1 and 2 years after release are clearly identifiable and exhibit some separation or "splitting" in the faster growing areas of the fin ray.

A narrow zone of opaque material is visible outside the last annulus, indicating that the period of more active growth probably started in May just prior to capture. Although it is difficult

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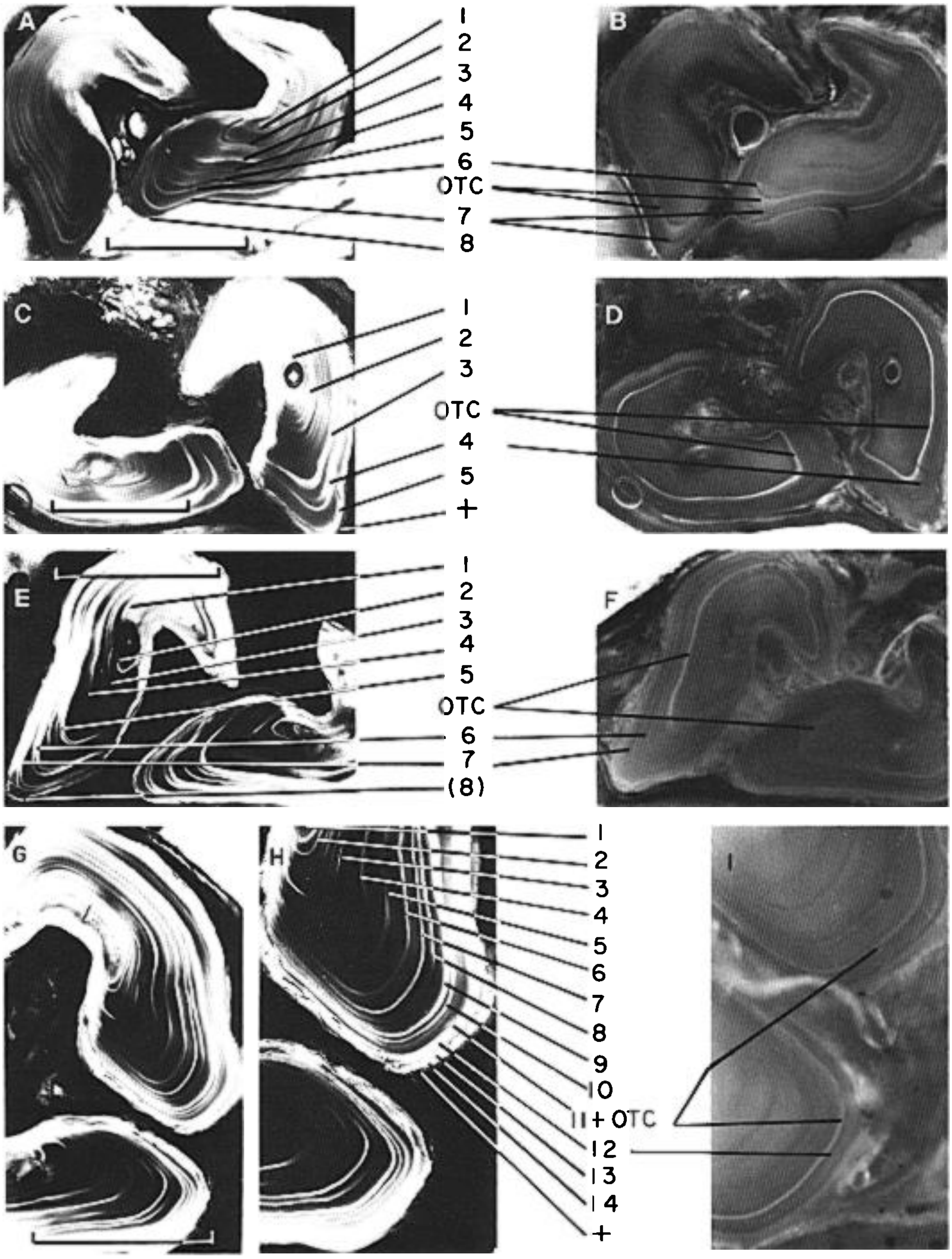
Figure 1. Cross sections of fin rays from lingcod that were tagged, injected with oxytetracycline, and recovered after more than 1 year at liberty. The oxytetracycline mark was photographed using reflected UV light (Fig. 1B, D, F, I), and the annulus pattern of opaque and translucent zones



(Fig. 1A, C, E, G, H) was photographed using transmitted tungsten light. The bar represents 1 mm. OTC = oxytetracycline. (A, B) Fish number B7735003; (C, D) number B7738057; (E, F) number B7735931. Age in parenthesis indicates that a new annulus appears to be forming on the edge, but the fish was recaptured prior to January 1. (G-I) is fish number B7736519; H and I are enlargements of G.

Table 3. Mean length at age of lingcod in samples from the commercial trawl fishery off the southwest coast of Vancouver Island, May-July 1979.

	Males			Females		
Age	Mean length	SE	Number of fish	Mean length	SE	Number of fish
3	61		1	58.0	6.00	3
4	63.8	1.13	20	65.5	2.01	13
5	66.9	0.68	58	70.5	1.25	17
6	70.9	0.71	62	70.3	1.03	54
7	75.1	0.64	60	81.7	0.78	61
8	77.8	0.68	50	86.7	0.90	41
9	80.3	0.65	40	91.5	0.85	32
10	80.7	0.99	25	89.9	2.55	11
11	81.2	1.85	5	95.1	0.87	8
12	83.8	3.29	4	93.3	3.90	3
13			0	101.7	4.50	3
14	87.3	0.88	3	106		1
Totals			328			247

to determine from the photograph, it is possible to determine that the OTC mark was deposited just beyond the annulus, again indicating that the annulus was present before June.

Number B7735931 was a female that was 60 cm long when tagged in September 1978 and 77 cm long when recovered in August 1981. The fish was aged as 5+ at the time of marking and 7+ when recaptured (Fig. 1E). The position of the OTC mark corresponds to the position of the fifth annulus (Fig. 1F). Two very distinct annuli formed beyond the OTC mark and each annulus shows some "splitting" in the faster growing portion of the ray. In the year following its tagging, several checks appear in the opaque zone. These checks are narrow and do not form completely around the ray. This was the definition of a check previously adopted by Beamish (1981). There is a translucent zone forming on the edge of the ray, suggesting that growth of the opaque zone was complete prior to recapture in August 1981. This translcent zone would not be counted as an annulus until January 1 of the following year. It is not uncommon to find an annulus or a portion of an annulus beginning to form late in the year. We recorded this as "7+ (8)", indicating the age is 7+ but eight translucent zones are visible. It is possible that the "split" in the two preceding annuli resulted from a similar growth pattern, indicating that there might have been a brief period of opaque growth followed by another period of translucent zone formation. These short periods of alternating growth pattern may be related to spawning behaviour.

This fish was recaptured approximately 3 years (1,053–1,084 days) after marking, during which time three opaque zones and two distinct translucent zones formed, with the third translucent zone beginning to form on the edge of the ray. Again, the interpretation of the annulus proved to be valid.

The final recovery (Number B7736519) was a male tagged at a length of 77 cm on September 13, 1978 and recovered in September 1981. Unfortunately, the head was removed when recovered but the dressed length was 65 cm. The calculated fork length was approximately 80 cm (Wendler 1953).

It is evident from the position of the OTC mark (Fig. 1G) that the pattern of fin-ray growth was not the same as in the other fin rays in Fig. 1. The fish was estimated to be 11 years old when tagged, and the initial examination suggested that after 3 years it appeared to have added only two opaque zones and one transulent zone (Fig. 1G, H).

After closer examination and knowing that the fish had been at liberty for 3 years, it was possible to locate the appropriate number of annuli corresponding to the years at liberty. The 11th and 12th annuli have formed in close association to each other. The position of the OTC mark appears to be in the same location as the 11th annulus, although it was very difficult to determine the exact location (Fig. 1I). The 13th and 14th annuli also have formed in close association and there is a small band of opaque growth on the edge of the fin-ray section. If this interpretation is correct, then the number of translucent zones that formed after tagging is equal to the years at liberty.

We acknowledge that this interpretation may be questionable. However, the presence of thick, translucent zones on the edges of fin-ray sections from other species that exhibit reduced growth with age has been interpreted as containing several annuli (Beamish 1981). Thus, it is probable that the interpretation in Fig. 1H is correct and the reduced growth of the fish and the fin ray is reflected in the close spacing of the last six annuli.

It is doubtful if this fish would be aged accurately without prior knowledge of its growth history; i.e., without validating the method for all age groups in the population. Certainly the three annual growth zones that formed after marking would be difficult to identify without prior knowledge of its growth history. However, there is no evidence that the age of the fish would be overestimated and an experienced reader could determine that the very wide translucent material at the edge of the fin ray indicated there was a compression of annuli.

DISCUSSION

It is unfortunate that the sample size is so small but it is unlikely that many more fish will be recovered and sampled for fin rays. The validation study was repeated in 1982 but it will be 2–4 years before the results of this second study will be known. Thus, even though the sample size is limited, we believe it is useful to report that our results indicated that the method of age determination developed for lingcod by Beamish and Chilton (1977) appears to be valid.

In three of the four fish, there was a clearly defined pattern of annual growth on the fin ray. The translucent zone (considered to be the annulus) was narrow and had formed sometime during the fall or winter months between September and June. The opaque zone was wider and was formed during the summer (June–September). Only one opaque and one translucent zone was formed each year. There was some indication of "splitting" of the translucent zone in the faster growing areas of the fin ray but the splitting was identifiable. When brief interruptions in a growth pattern occurred (checks) they were narrow, not continuous around the ray, and not present in all fin-ray sections. Fish estimated to be 3–6 years old when tagged were shown to have added the number of annuli (or annual growth zones) equivalent to the number of years they had been at liberty after tagging.

In one case, it was difficult to validate that the number of annual growth zones formed between tagging and recapture was equal to the number of years at liberty. It was evident that there was very little fin-ray growth during this period and it appeared that the length had increased very little, a common occurrence for older males (Table 3). The position of the OTC mark indicated that some annuli on the edge of the fin ray were either missing or were all present but closely spaced. Thus, while the exact age was difficult to assess, it was possible to determine that the fish was old and that obtaining an accurate age would be difficult using the fin-ray method.

The accumulation of annual growth zones on the edge of the fin-ray section occurs for older, slow-growing walleye pollock (*Theragra chalcogramma*) in the Strait of Georgia (Beamish 1981). Although ages are difficult to estimate, it is possible to determine that the fish have a number of annuli on the edge of the fin-ray section. In contrast, an accumulation of annual growth zones is not always identifiable on the edge of scales of older or slow-growing fish (Beamish and Harvey 1969). The failure to recognize an accumulation of annuli frequently results in the production of a growth curve that does not become asymptotic for the older ages and will result in an overestimate of the actual mortality rate.

It is important to note that, for all four fish, there was no indication that the application of the fin-ray method would result in an overestimate of age. There also was no indication that the previous interpretation of an annual growth pattern by Beamish and Chilton (1977) was incorrect. Also, the growth increments in length between marking and recapture (Table 2) were similar to the growth increments determined from the "fin-ray" ages of a sample of 575 lingcod collected from the commercial fishery (Table 3). The size of the fish at the estimated age at marking and recapture was similar to the mean size estimated in the commercial sample, indicating that the ages estimated from the commercial sample are at least close approximations of the true age.

In summary, it was shown that, from the small sample examined, the fin-ray method for estimating the age of lingcod is valid. Because there was a range of ages in this small sample, it also appears that the method is valid for most age classes with the possible exception of some older, slower-growing individuals (particularly older males) where the method may underestimate the true age.

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