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Use of Fin-Ray Sections to Age Walleye Pollock, Pacific Cod, and Albacore, and the Importance of this Method

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Abstract

Thin sections of fin rays were used to estimate the age of walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), and albacore (*Thunnus alalunga*). Because the number of methods of determining the age of fishes is limited, it is advisable that investigators develop a facility for the fin-ray method so that the best aging method for a stock of fish can be selected. Use of several methods also helps in estimating the accuracy of age determinations in the absence of a validation procedure that is applicable to all age-groups in a population.

It is the purpose of this paper, firstly, to illustrate how sections of fin rays can be used to determine the age of three species of fishes that cannot always be aged by traditional methods employing scales or otoliths, and secondly, to stress that this method should be used more often when the age composition of fish stocks is examined.

The method of aging fish with sections of fin rays is not new. Possibly the earliest reported use of fin rays was the determination of the age of sturgeon *Acipenser* sp. (Kler 1916). Boiko (1951) was the first to suggest that sections of the first few rays from the first dorsal fin may be an acceptable method of aging many species. Cuerrier (1951) showed that sections of other fins might be useful for age determination. Although the method still is not popular, some recent workers have used sections of fin rays to age Pacific salmon *Oncorhynchus* spp. (Bilton and Jenkinson 1969), brown trout *Salmo trutta* (Burnet 1969), white sucker *Catostomus commersoni* (Scidmore and Glass 1953; Ovchynnyk 1965; Beamish and Harvey 1969), lake whitefish *Coregonus clupeaformis* (Ovchynnyk 1962; Beamish et al. 1976; Mills and Beamish 1980), lingcod *Ophiodon elongatus* (Beamish and Chilton 1977), channel catfish *Ictalurus punctatus* (Sneed 1951), common carp *Cyprinus carpio* (English 1952), ide *Leuciscus idus* (Van Utrecht and Schenkkan 1972), tuna *Thunnus* spp. (Shadotiniets 1968), rudd *Scardinius erythropthalmus*, chub *Squalius cephalus*, roach *Rutilus rutilus*, bream *Abramis brama*, and perch *Perca fluviatilis* (Deelder and Willemse 1973). Application of the method appears to have been successful in most cases, and it is difficult to understand why greater use has not been made of it. Possibly the greatest difficulty has been the technical preparation of sections. Hand-operated jeweller's saws or motor-driven circular saw blades have been used, but they tended to be slow, required some skill, and could not be used on very thin and very thick fin rays without some modifications to the technique. However, high-speed, thin-sectioning machines (Beamish and Chilton 1977) allow sectioning of any structure at a rate almost as fast as preparation of other structures for age determination.

Fin-ray sections also appear to have been avoided because of the traditional use of scales (primarily for freshwater fish), and otoliths (primarily for saltwater fish). A popular attitude was (and still is) that if one tries hard enough, the secret of aging a particular fish from scales or otoliths can be found. While a person certainly should be given credit for trying, it would seem advisable at least to make sections of the various fins to determine if an annual pattern is more easily discernible on them.

There are three other reasons why fin rays should be considered before an aging method is decided upon. One obvious reason is that the use of fin rays does not require sacrificing the fish; rays can be removed without any apparent harm to the fish (Beamish and Harvey 1969; Mills and Beamish 1980). Secondly, because the annuli on scales result from a different process than those on bones (Simkiss 1974) there is no reason to assume that annuli on both structures will be equally prominent throughout the life of the fish. Fin-ray annuli can remain prominent for older fish when scale annuli are not identifiable (Beamish and Harvey 1969; Beamish and Chilton 1977). Finally, fin rays can be used to assess the credibility of ages assigned by some other methods.

Methods

Pectoral, pelvic, anal, and dorsal fins of walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), and albacore (*Thunnus alalunga*) were cut with scissors or surgical bone cutters as close to the body as possible. Fins were wiped clean of mucus and stored in heavy-weight kraft paper envelopes with the distal portion of the fin being inserted first. Care was taken to ensure that the base of the fin was at right angles to the length of a ray. Envelopes containing fins were either frozen or air-dried immediately. Frozen envelopes were thawed and air-dried when convenient. The heavier-weight envelope reduces the amount of adhesion of tissue to the paper; however, an optimum container for storing and drying fins has not been found.

Portions of fins were removed from frozen albacore with a "feather knife." The removal of fins in this manner did not alter the market value of the fish. The best sections were obtained 1–1.5 cm above the point where the ray base started to flare (Fig. 1). If rays are not dried such that the fin base is perpendicular to the longitudinal axis of each fin ray, then rays should be separated, by removing the skin, and mounted in epoxy so that sections are perpendicular to all fin rays. Sections should range between 0.5 and 1 mm in thickness. The large element of each ray should be selected in all cases.

The technique for sectioning fin rays and mounting sections was similar to the method described by Beamish and Chilton (1977). Our laboratory currently uses two sectioning machines. The high-speed machine (Beamish and Chilton 1977) is superior to the low-speed machine (Anonymous 1977) because less time is required in the preparation of sections. Sections were viewed through a microscope (Beamish and Chilton 1977) or on a microfiche reader (Dauble and Gray 1977). The reader can be equipped with a printer to facilitate discussion of interpretations. An important disadvantage of the microfiche reader is the poorer resolution and lighting compared to a research-quality microscope. A microscope should be used to confirm some of the age determinations made with the microfiche reader and to examine sections with less prominent annuli.

The width of the first two growth zones for walleye pollock was estimated on the third to sixth pectoral fin rays. Growth zones from sections of these pectoral fin rays in the area that produces the most readily identifiable annuli are approximately the same width. Growth-zone width was recorded as the maximum distance of each pair of hyaline and opaque zones (1 year's growth) measured at a right angle to the midline. The center had to be visible and the section had to be at right angles to the longitudinal axis of the ray or no measurement was made. If irregularities occurred, an estimate was made where the "average" maximum "width" occurred. Unquestionably, there is an undetermined variance associated with this measurement. However, if errors result from random variations, measurements that increase variance tend to reduce probability of significant differences between mean annulus widths of age-classes.

Results

Walleye Pollock

Walleye pollock samples were obtained from northern Hecate Strait, approximately 54°20′N, 131°20′W, and the Strait of Georgia, approximately 49°20′N and 123°45′W. Walleye pollock used for the annulus-width studies were captured at a standard fishing location in the Strait of Georgia. Sections of dorsal, pectoral, pelvic, and anal fin rays all appeared to be acceptable for age determination; however, sections of pectoral fin rays had the most distinct pattern of alternating opaque and translucent (hyaline) zones. The annulus was considered to be the narrow translucent or light zone when viewed in transmitted light (Fig. 2). The opaque or dark zone in transmitted light formed in the summer during the period of active growth. The pattern of annulus formation was similar in the two stocks studied up to age 3.

In the Strait of Georgia stock the third and subsequent annuli sometimes formed in close association with each other (Figs. 2, 3). In general, the fourth annulus could be separated

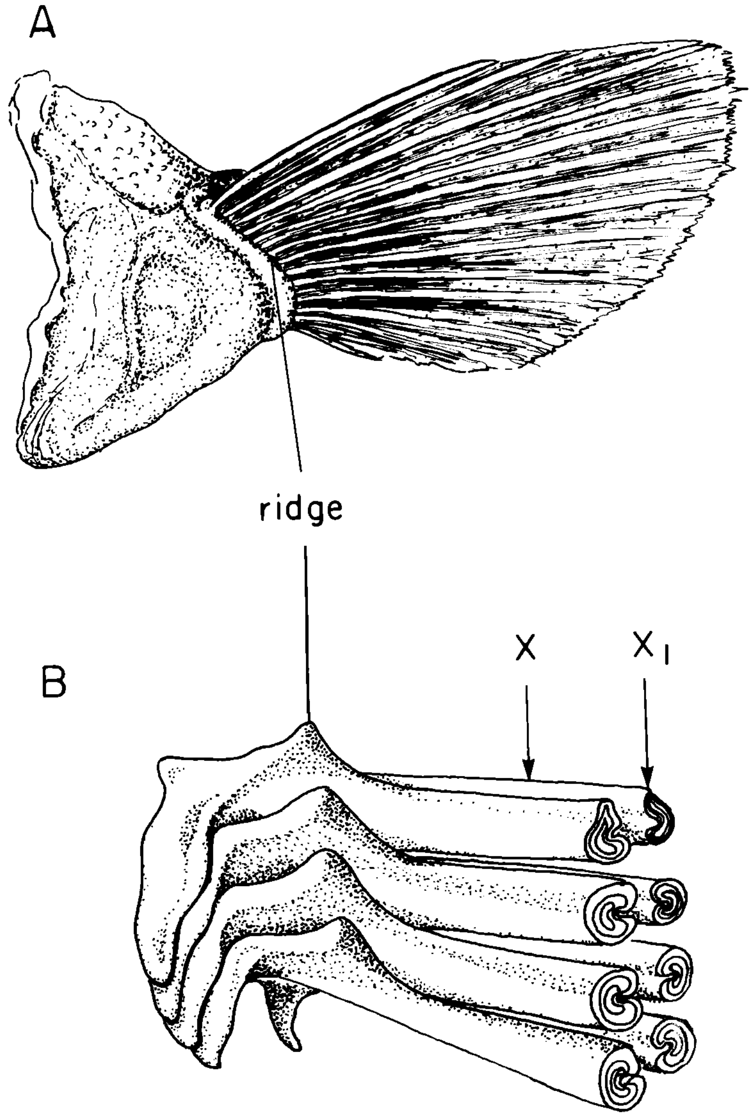

FIGURE 1.—*Left pectoral fin (A), and fin rays (B). (A) shows position of fin in the fish. Fin should be removed by cutting through or close to ridge. (B) shows the two fin-ray elements for each fin ray. The best sections are cut about 3 mm from the ridge (position X) to about 5 mm from the ridge (position X_1).*

from the third by the presence of a narrow opaque zone, but the separation of the annuli after age 3 in some sections was difficult. In such cases, the wide translucent area on the edge of the ray simply was identified as containing more than one annulus. The problem of annuli being close together in older fish was not as important for walleye pollock sampled from Hecate Strait. Presumably this clearer separation was related to the greater amount of growth after age 3, which resulted in larger sizes of older fish in the Hecate Strait stock.

The major problem with the application of the fin-ray method for walleye pollock is the determination of the first annulus. This annulus varies in prominence and in some sections is difficult to separate from the numerous checks that can appear during the first year of fin-ray growth. As an aid to identifying the position of the first annulus, the widths of the center, first, and second growth zones were compared to determine if significant overlap occurred. If there was no significant overlap, then a measurement could be made to estimate the position of the first annulus in cases where it was not distinct.

The length frequency of the fish in the sample showed two distinct modes (Fig. 4) and the separation of these two modes was maintained throughout the year (Beamish et al. 1978). The first mode represented 1-year-old fish almost exclusively; the second mode contained 2-year-olds and a small number of 3-year-olds.

The distribution of widths of the center, first, and second growth zones in Fig. 4 are significantly different from each other (t-test, $P < 0.01$). The modal width for the first growth zone for the 1977 year class was similar to that for the 1975 year class, but smaller than that of the 1976 year class. A small sample of 1-year-olds sampled in April 1977 (1976 year class) indicated that they averaged 2 cm larger than the 1977 year class measured in April, suggesting that the wider annuli resulted from the increased growth of the 1976 year class.

First-year growth-zone width and fork length of the 1977 year class were weakly correlated ($r = 0.6$), as were the width of the first two growth zones and fish length for the 2-year-old 1976 year class. Although the relationships are not strong, they suggest that the widths of the growth zones are related to the size of the fish at the time of annulus formation.

There was a small age-3 distribution within the larger age-2 distribution (Fig. 4). Although some of these age-3 fish displayed three clear annuli (Fig. 3), others had two prominent annuli and one annulus that appeared to be part of the center. The distinct annulus close to the center was within the width range for age-1 fish, whereas the second annulus was either in or just outside the range of overlapping widths. In such cases, the fish had to be aged as 3-year-olds because width measurements were used as an aid only when an annulus was not prominent and never to reject a prominent annulus.

The need to measure the growth-zone width is especially important for the novice reader as the first obvious translucent zone outside of the center may be the second annulus (Figs. 2, 3). In this case, the width of the apparent second growth zone usually will be well outside the range observed for the first annulus and then can be considered to be the second annulus.

The identification of annuli after age 1 often is routine, provided there are no technical problems in preparing the sections (Fig. 2). The main technical problems result from cutting the

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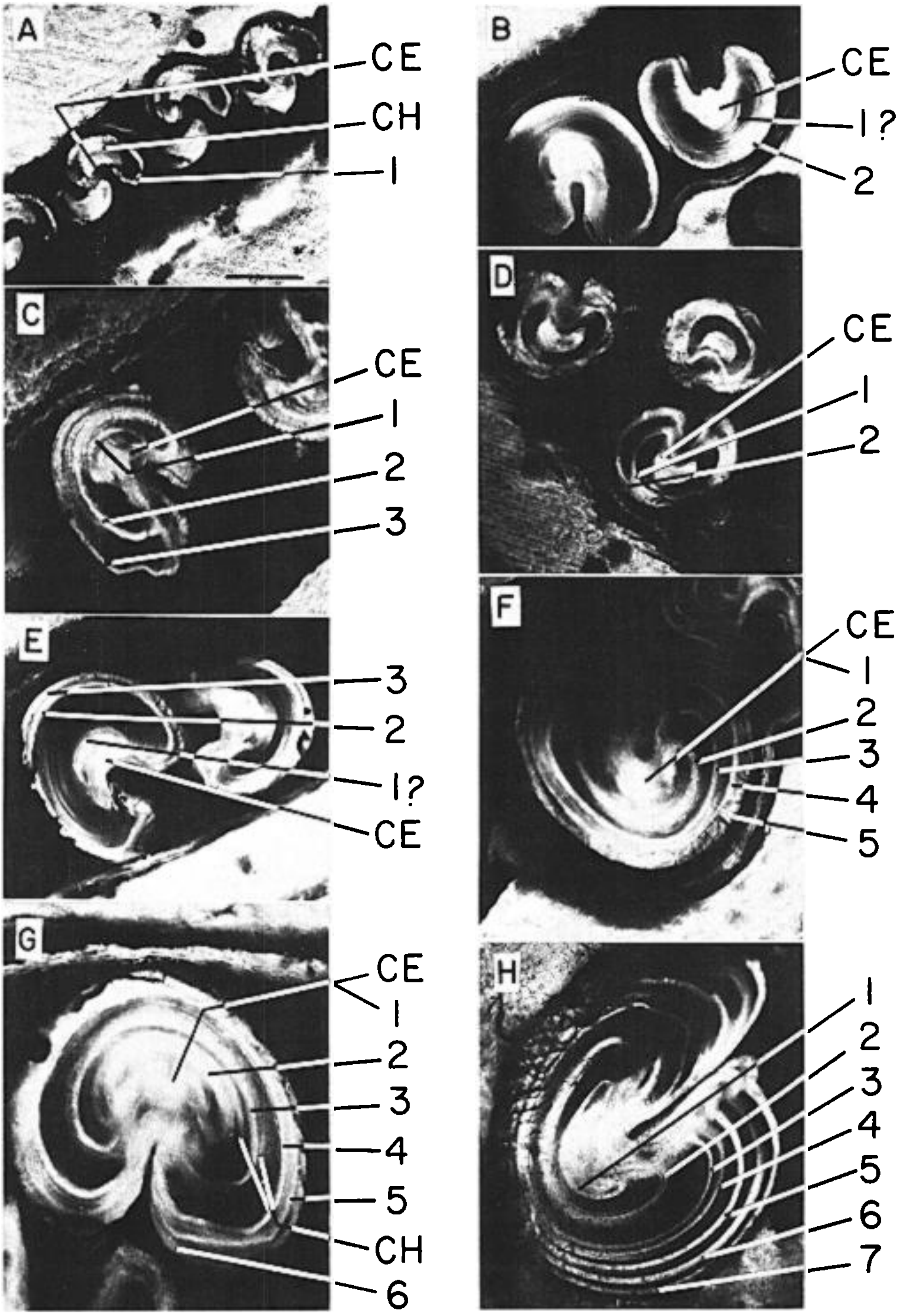
FIGURE 2.—*Sections of pectoral fins of walleye pollock from a difficult-to-age stock in the Strait of Georgia. Difficult-to-interpret sections are included. The photographs are more difficult to interpret than sections viewed with a microscope. The bar in A is equivalent to 0.2 mm and all photographs are the same magnification. Center = CE; check = CH; annulus age = 1–7.*

(A) One-year-old, 14 cm, captured April 1978. The center and first annulus are clearly visible. Note the smaller second element at the bottom left of each ray. This is a better-than-average-quality section taken from a slightly smaller-than-average-sized (Fig. 4A) walleye pollock from the 1977 year class. (B) Two-year-old, 33 cm, April 1978. The first annulus is difficult to identify because there is almost no overlap in the widths of the first and second annuli, and the first clear annulus is within the width range for the second annulus. It is assumed that the first clear annulus in this section is the second annulus. (C) Three-year-old, 38 cm, April 1978. The section is very easy to interpret as all annuli and the center are distinct. Note that the first annulus is close to the center. (D) Two-year-old, 27 cm, April 1978. The first annulus is unusually wide and prominent. (E) Three-year-old, 31 cm, April 1978. The position of the first annulus is uncertain. The first prominent annulus is too wide to be the first annulus and was identified as the second annulus. The third annulus meets all the criteria of an annulus even though it is close to the second. (F) Five-year-old, 40 cm, April 1979. Despite the prominent annuli, the interpretation of this section is difficult. The first annulus is assumed to be confluent with the center. The second annulus is prominent and its width is outside of the range of widths for the first annuli determined from 1- and 2-year-old fish (Fig. 4). This section could be interpreted as from a 4-year-old; however, the best estimate was a 5-year-old. Note check between third and fourth annuli and beginning of new growth. (G) Six-year-old, 50 cm, April 1978. This is a very typical section. The first annulus is weakly prominent and is difficult to identify because the center is not prominent. The second and third annuli have rather prominent checks that were not counted as annuli because they were not continuous around the section and were not present on all sections. The sixth annulus is on the edge of the section. (H) Seven-year-old, 66 cm, February 1975. This is a better-than-average section. Note the prominence of the first annulus and the narrow checks between the fourth and fifth, and fifth and sixth annuli.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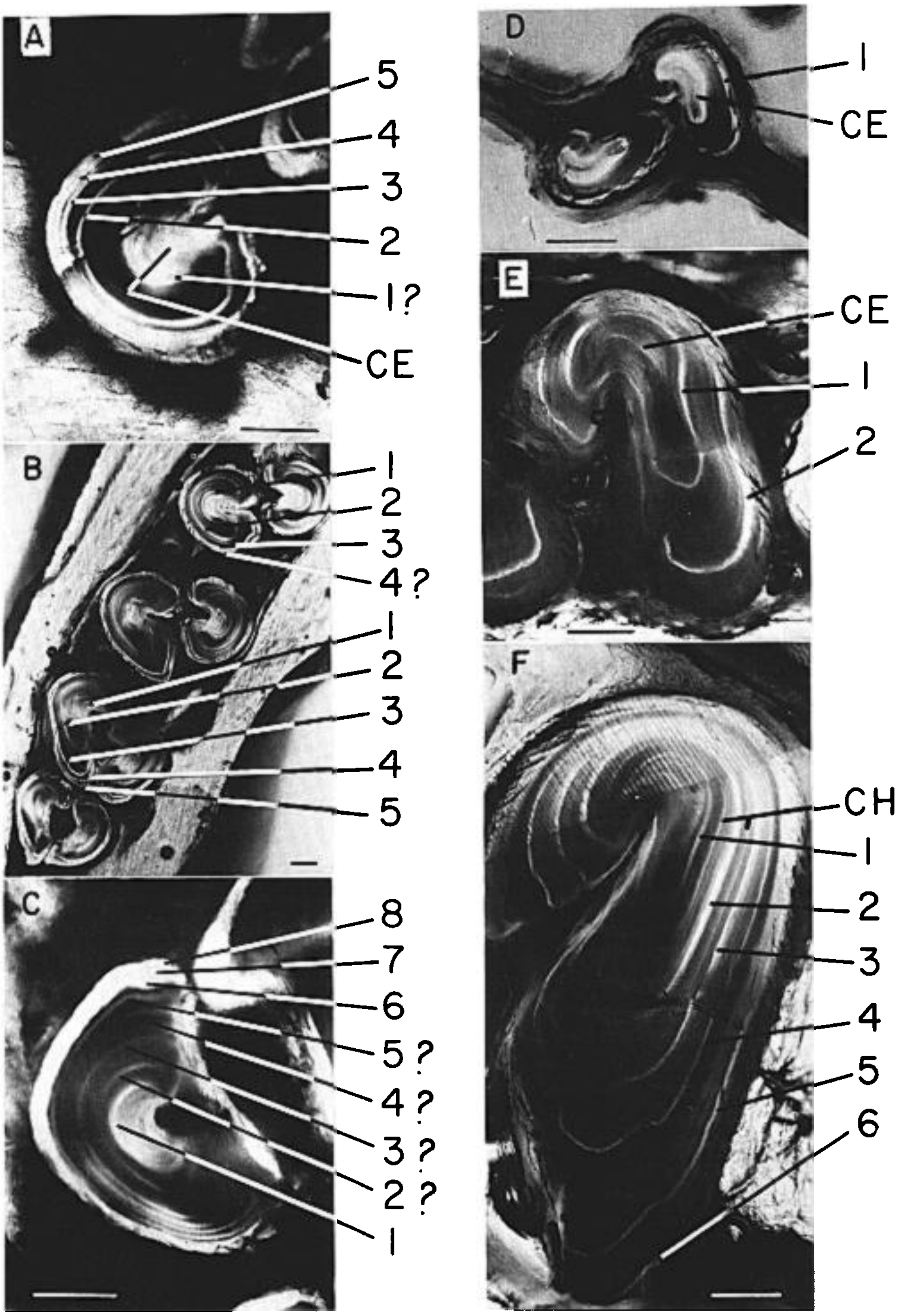
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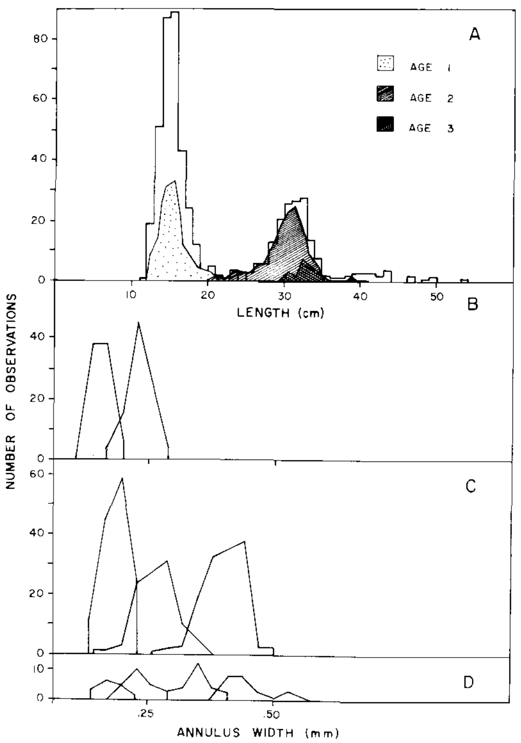

FIGURE 4.—*(A) Length and age frequencies of a walleye pollock sample. (B) Width frequencies of the center and first growth zone for the 1977 year class of walleye pollock from (A). (C) Center, first, and second growth zones from the 1976 year class from (A). (D) The center, first, second, and third growth zones from the 1975 year class from (A).*

sections too thick or too thin, resulting in reduced contrast between zones, or from making oblique cuts, causing variable spacing between annuli. The distance that the section is taken from the fin base is important and clarity often can be improved by more sections taken at a greater distance from the base.

Growth checks may create interpretation difficulties, but usually can be identified because they are less prominent than annuli, do not form completely around the ray, often are close to annuli, and (most important) are not present in all ray sections.

Preliminary (unpublished) observations indicate that in younger fish opaque material found between the ray center and the first annulus may gradually become more translucent with age. Thus, in older fish the first annulus is not always distinguishable from the center (Fig. 2). Measurement of the width of the first prominent annulus, in addition to the large translucent center area, and comparison with the center area of 1-year-olds (Fig. 2) usually confirms that the first annulus is confluent with the center.

One of the advantages of the fin-ray method is the facility with which annuli can be identified in older fish (Fig. 2). Even when annuli form close together, it usually is possible to count translucent zones or at least to establish that the fish is old and accumulating annuli on the edge of the ray (Fig. 3).

Pacific Cod

All adult Pacific cod were obtained from off the west coast of Vancouver Island. It was possible to find distinct annuli on sections of fin rays from the first dorsal fin, particularly for older fish. The fin-ray annuli and checks were similar to those of walleye pollock, but because of the rapid growth of Pacific cod the first an-

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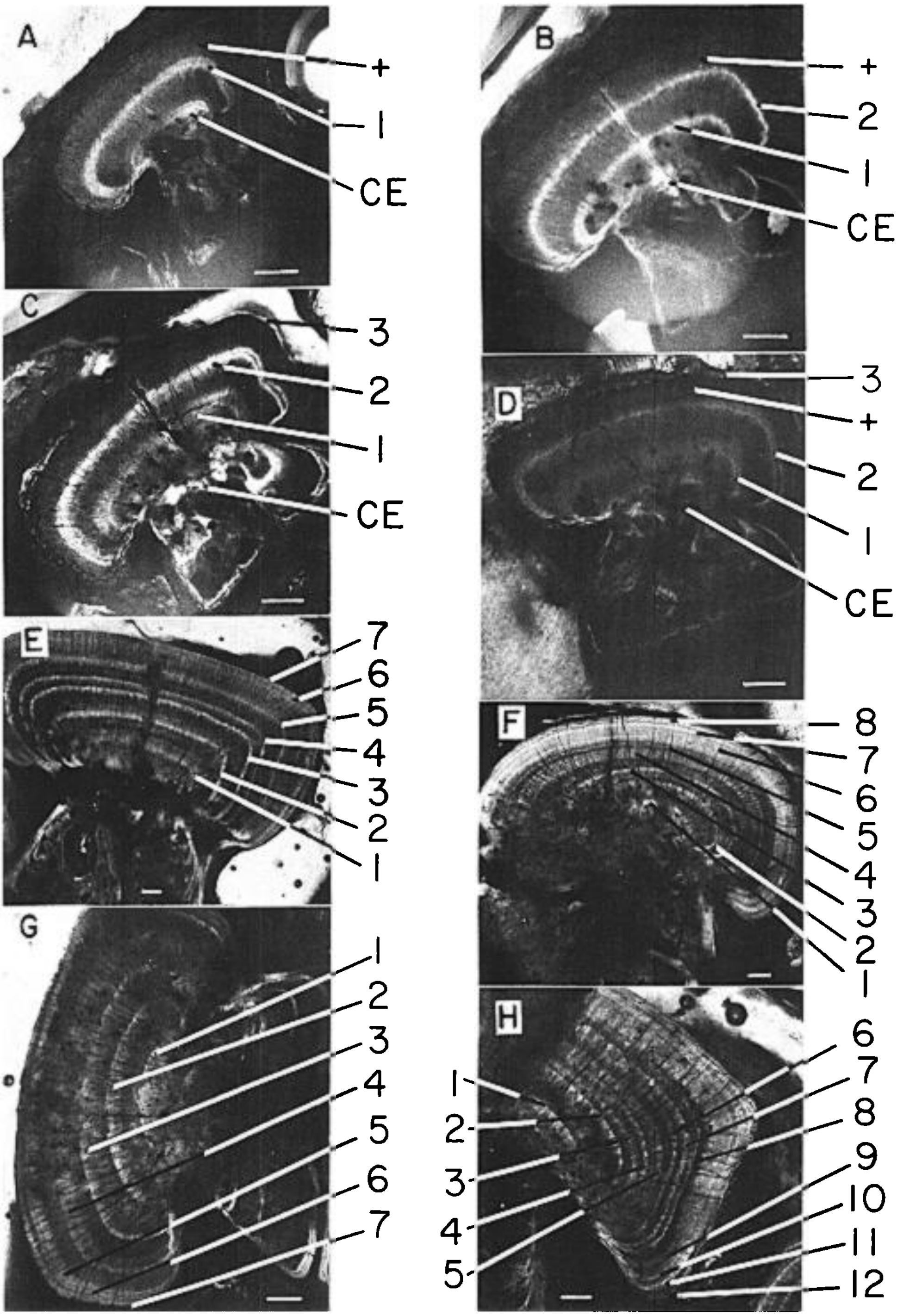
FIGURE 3.—*Pectoral fin sections from walleye pollock from the difficult-to-age stock in the Strait of Georgia (A–C) and dorsal fin-ray sections of Pacific cod (D–F). All pollock sections indicate interpretation difficulties. The bar in each photograph represent 0.2 mm.*

Walleye pollock. *(A) Five-year-old, 46 cm, captured February 1975. The first annulus is difficult to identify but the second annulus is too wide to be the first annulus. The third, fourth, and fifth annuli are close together at the edge of the ray. (B) Five-year-old, 47 cm, April 1978. This illustrates the desirability of examining more than one section. The top section shows four annuli. However, a better definition of edge annuli occurs two sections below. (C) Seven-year-old, 44 cm, February 1975. This section shows the wide outside translucent zone that is interpreted as containing three annuli. A wide translucent zone on the edge of fin sections from larger fish characteristically contains several annuli. This particular section shows the annuli on the edge but the second, third, and fourth annuli had to be identified from another section. If only this section were available, no age would be assigned because of the poor quality.*

Pacific cod. *All sections are better than average quality. (D) One-year-old, 22 cm, captured February 1978. The section clearly shows the center and first annulus. (E) Two-year-old, 45 cm, October 1977. Both annuli are clearly visible. Note the band of opaque or summer growth on the outside of the section. (F) Six-year-old, 70 cm, October 1977. All annuli are clearly visible. Note the annulus on edge and two rather prominent checks.*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nulus was not as difficult to identify (Fig. 3). In a comparison of ages determined from scales and fin-ray sections for a sample that was selected because it contained larger fish, 61% of the fin-ray sections and scales gave identical ages, 21% were aged older from fin rays, and 18% were aged younger. In one instance, the fin ray of a 75-cm fish was aged 4 years older than the corresponding scale age. Annuli that were clearly visible on fin rays of larger fish often were partially or entirely missing from scales; when present, they usually were crowded on the edge, making the separation of annuli extremely difficult.

In general, ages obtained from the scale method agreed with ages obtained from fin-ray sections in the sample of fish that was examined. It was only the larger fish in which ages determined from fin-ray sections appeared to provide higher and possibly more accurate ages. The use of fin-ray sections in this species, therefore, served as a check for scale ages and a method for aging larger fish.

Albacore

All albacore sampled were from commercial holdings; 20 fish (61–77 cm) were caught off the west coast of Vancouver Island, and 75 fish (95–118 cm) were imported into the United States reportedly from Singapore. Often the fins were severely damaged with only small portions of their bases remaining. These were sufficient although as many as 10 sections often were necessary. All except caudal fin rays were sectioned and a growth pattern was visible on all sections. However, the sections from the second dorsal or anal fins were most suitable because of the prominence of zones and absence of bone resorption from the centers of the rays.

An alternating pattern of opaque and translucent zones was visible on 59 of the 75 fish sampled. The remaining fish could not be aged because the pattern of growth zones was unclear (Fig. 5) or because it was not possible to obtain a section from a shattered ray. Growth patterns were similar to those of walleye pollock and Pacific cod.

There was some difficulty determining the position of the first annulus for some specimens. Growth during the first 12 months of life has been reported by many authors to be quite rapid (Bell 1962), and it was assumed that opaque material (laid down during periods of rapid growth) would be visible around the translucent larval center. Thus, the first annulus was considered to be the first translucent zone surrounding the first opaque zone. This assumption probably is satisfactory for the present but must be verified by examining samples of age-1, and possibly age-2, fish as estimated from length frequencies. Until more is known about the early development of growth zones in fin rays of young albacore, it is possible that some fish may be underaged by 1 year in this study. A second problem resulted from the presence of checks. In most cases checks could be separated from annuli because they were less prominent, that is, not as thick and not continuous around the ray. Also, because some rays have a larger diameter, it was assumed they grow more rapidly or longer each year or both, and checks often are more apparent in such rays. When sections of the slower-growing rays are examined the check often is not visible or at least is less prominent. Spacing also can be used to identify a check, which often forms very close to the annulus. The width of the opaque growth zones between the check and the annulus is much narrower than between the adjacent annuli. There were a few cases when it was difficult to age a section because the mixture of checks and suspected annuli could not

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FIGURE 5.—*Fin sections from albacore. The bar in each photograph represents 0.2 mm. (A) One-year-old fish, 63 cm. Most of the growth appears to have been completed. The section is from the anal fin. (B) Two-year-old, 71 cm. Most of the third-year growth is complete. The section is from the anal fin. (C), (D) Three-year-old fish, 76 cm. The sections are from the second dorsal (C) and anal fins (D). The third annulus has just formed on the edge (C). The first and second annuli each contain two closely spaced translucent zones. (E) Seven-year-old fish, 117 cm. The section is from the second dorsal fin. A faint translucent zone appears between the fifth and sixth annuli that would be counted as an annulus if it were more prominent. (F) Eight-year-old fish, 111 cm. The section is from the anal fin and difficult to interpret because of the diffuse nature of some translucent zones. (G) Seven-year-old fish, 99 cm. The section is from the anal fin. Three annuli are close to the edge of the ray. (H) Section of an anal fin that was not aged, 110-cm fish. Twelve translucent zones are evident but zones could not be separated around the whole circumference.*

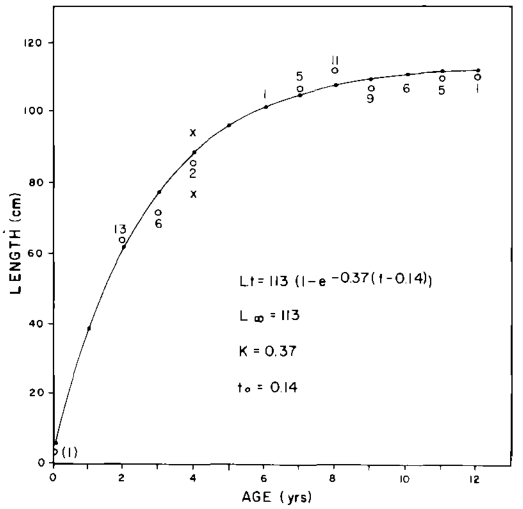

FIGURE 6.—*Growth curve and Von Bertalanffy growth parameters for albacore aged in this study. When considerable growth beyond the last annulus was visible the fish was considered to have completed that year's growth; that is, a fish aged 1+ was considered to be age 2. A size at hatching of 0.3 cm was obtained from Sanzo (1933). Sample sizes are indicated opposite the mean lengths (circles) for each age-group. Dots indicate the calculated mean lengths. The lengths of the two age-3 fish from two different samples are indicated separately (×). The curve is the calculated Von Bertalanffy growth curve.* Lt = *length (cm) at time* t *(years);* L_∞ = *asymptotic maximum length;* K = *growth coefficient.*

be separated. In older fish annuli were crowded at the periphery of the fin section. There was little doubt these translucent zones were annuli and ages estimated from the combined sample indicated growth in length is reduced in older albacore (Fig. 6).

The ages that were assigned for younger albacore (Fig. 6) were similar to ages assigned from scales (Bell 1962) and tags (Clemens 1961). However, because of variation in published age-and-growth data, an independent mark and release study would be necessary to validate the results of this study. When the sample from the catches made off Vancouver Island was considered separately there was some suggestion that these fish might be smaller than fish of similar age from the second sample.

Discussion

Walleye pollock apparently have been successfully aged from scales (Ogata 1956) and otoliths (Mosher 1954; LaLanne 1975), although the methods have not been validated for all age-groups in the population. However, Ishida (1954) claimed that walleye pollock larger than 35 cm cannot be aged by otoliths because of calcium deposits. Ogata (1956) acknowledged that age determination from scales were difficult for older walleye pollock and not possible for at least one stock. Age studies of walleye pollock found off the west coast of Canada showed that ages estimated from sections of fin rays from most fins, and particularly the pectoral fin, were either similar to age estimates from other structures or the only method that produced a clear growth pattern. The fin-ray method was particularly useful for determining the age composition of stocks in which individuals increase minimally in length as adults. The accumulation of annuli was particularly evident on the edge of the fin-ray section for these slow-growing adults. Although sections of fin rays appeared to be the most suitable method for most stocks, there was some difficulty interpreting the position of the first annulus. This problem was partially solved by comparing growth-zone width for the first 2 years from immature fish with the length of the fish. Growth in length for the first few years was sufficiently rapid that there was almost no overlap in the length frequencies of the first two year classes and very little overlap in the estimated widths of the first two fin-ray growth zones. Thus, in the absence of a prominent first annulus a width measurement was taken to confirm an interpretation or establish the approximate position of the first annulus. Because of this difficulty of aging some young walleye pollock, the scale method may be more appropriate for heavily exploited stocks in which there are few larger or older fish.

Until recently the only methods available to determine the age of Pacific cod were length-frequency analysis or tagging studies (Ketchen 1961, 1964). Kennedy (1970) developed a technique for the interpretation of scale annuli and this method has been used routinely to examine the age composition of Pacific cod stocks off the west coast of Canada. However, there was difficulty interpreting annuli on scales from some of the larger (and presumably older) fish. Sections of dorsal fin rays showed prominent and easily discernible growth patterns, and yielded higher ages for large fish than scales. Because commercial catches of Pacific cod are thought to contain very few fish older than age 4, the problem of overestimating the age of older fish may not be critical. However, it is important that the management of any species be based on as firm an understanding of its biology as possible. Thus, the use of fin rays to age Pacific cod will help to confirm ages determined from scales and to assess the relative importance of older fish found in some stocks.

An inability to age albacore has caused management to depend on a production model that Rothschild and Suda (1977) acknowledge may not have a biological basis. Bell (1962) reviewed attempts to age albacore and concluded that the development of a successful aging method for this species was one of the most important problems facing fisheries scientists. At the time of his review, vertebrae, scales, length-frequency analysis, and tagging studies had been used to age albacore but no method had gained acceptance because of serious difficulty with each approach. Otsu and Uchida (1959) collected fin rays but apparently did not section them, and rejected their use for age determination after a "cursory examination." Shadotiniets (1968) applied the method of Boiko (1951) to Indian Ocean tuna and found that sections of the first dorsal ray did show a pattern of growth zones that could be interpreted as annuli. He concluded that the sections were equally suitable to vertebrae. My observations revealed that sections of the first dorsal ray usually were not suitable for age determination. Photographs produced by Shadotiniets indicated that a large area in the center of the fin-ray section was obscured by intrusions of porous material and blood vessels. This inability to see an intact ray confuses the interpretation as it cannot be determined if annuli have been lost from the center. Nevertheless, the report of Shadotiniets was an important advance. However, it seems to have been overlooked, and the need for a direct method of aging albacore remained.

The method described in this report satisfies previous requirements. Growth zones are prominent in sections of albacore fin rays, and can be interpreted with less problem than any of the other published age determination methods for this species. Large numbers of fish can be aged by this technique with about the same amount of effort expended for most other methods, and structures can be obtained without sacrificing the animal or damaging the retail value.

There is some indication that the method is valid, at least for young albacore, as age-and-growth information produced in this study is similar to that from some other studies (Partlo 1955; Bell 1962). It was beyond the scope of this study to validate the proposed method, but this could be done by marking, releasing, and recapturing fish and comparing fin rays sampled before and after the period of liberty. The major difficulty with the method may be the interpretation of checks. One of the criticisms of the use of vertebrae was that the growth pattern could not be related to an annual pattern or that the "rings" do not form annually (Otsu and Uchida 1959). No matter what structure is used for age determination, the interpretation of an annulus frequently is complicated by other zones that appear similar to the annulus. Some qualitative interpretation always is involved, and this is why aging fishes is neither simple nor unequivocal.

There are at least two reports in which the authors have stated that the fin-ray method was either unsatisfactory or unnecessary. Before discussing these reports it should be made clear that in my studies sections of fin rays could not be used to age some species. In one of the reports (Everhart et al. 1975) it was stated that "Although some authors make certain claims for using spines and rays [for age determination] we can see no advantage over scales." This statement was not supported by any empirical information; as previously indicated there was prior evidence that sections of fin rays were better than scales for aging species such as sturgeon, catfish, white sucker, and ide. For white suckers, it was shown that total dependence on scales results in erroneous age determinations of older fish (Beamish 1973). Since the publication of this statement, other studies have demonstrated that ages determined from scales may be incorrect and that sections of fin rays or other bones may give more accurate determinations (Beamish and Chilton 1977; Power 1978; Mills and Beamish 1980).

A study by Gulland (1958) concluded that a direct application of the Boiko (1951) method underestimated the age of Arctic cod (*Gadus morhua*). This may not be the most suitable application of the fin-ray method as sections of the first ray of the first dorsal fin frequently do not produce growth zones that are as clear as sections of other rays or rays from other fins. Gulland did not include photographs, so the quality and interpretations of the fin sections can not be assessed independently.

At present, four techniques commonly are used to validate an aging method: these are analyses of length frequencies; seasonal changes in the growth pattern of the structure used; progressive ages from a strong year class; and ages of marked and recaptured fish. The major difficulty with the first three methods is that convincing results only can be obtained for younger individuals. A strong year class soon becomes obscured by other year classes as the fish age. Older fish may exhibit little or no growth, or their patterns of structural growth may change. Unless such structural changes are recognized, older fish often will be assigned similar ages, resulting in an erroneous accumulation of fish within a narrow age range. Only the mark-and-recapture method can truly validate an aging method for all age-groups of fishes that attain older ages. When this approach cannot be applied to some species because of technical problems or resource limitations, the accuracy of ages must be assessed indirectly. One means of doing this is to compare ages determined from scales, otoliths, otolith sections, and fin rays. If the methods disagree significantly, the investigator must make a serious effort to validate the method in the age range where the discrepancies occur.

In summary, sections of fin rays for many species, properly prepared, display growth patterns that may be more easily discernible than those observed on other structures. The advantages of this method are in the clarity of the growth pattern, especially for older fish, and in the ability to determine age without sacrificing fish. The disadvantages of the method are the difficulties in determining the position of the first annulus and in identifying checks. Sections of fin rays represent a technique for the age determination of fishes at least equal in potential to the use of scales and otoliths. The suitability of fin rays can be determined quickly, and even if other methods are equally acceptable, an occasional comparison of ages obtained from fin rays may increase both the accuracy and precision of the determinations.

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