A PRELIMINARY EVALUATION OF A METHOD TO DETERMINE THE AGE OF SABLEFISH (*Anoplopoma fimbria*)

by

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ABSTRACT

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The age of sablefish was estimated using broken and burnt otoliths. A partial validation of the method was achieved using fish of known age, oxytetracycline injected fish and results of tagging studies. Estimated ages indicated that most sablefish stocks contain a large number of fish that are much older than previously determined using the scale method of age determination. This new information on the age and growth of sablefish indicates that present strategies for the management of the sablefish fishery should be reconsidered.

Key words: Sablefish, age determination, age and growth, otoliths, age validation, fisheries management.

RÉSUMÉ

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INTRODUCTION

The sablefish or blackcod (<u>Anoplopoma fimbria</u>) is an important commercial species found in the Pacific Ocean off the coasts of North America from northern Mexico to the Bering Sea and off the Asian coast from Kamchatka to the northeastern coast of Japan. The centre of abundance appears to be in the northeastern Pacific between Vancouver Island and the Shumagin Islands.

Sablefish have been fished commercially by North Americans since the late 1800s (Ketchen and Forrester 1954), but it was not until Japanese fishermen entered the fishery in the early 1960s that stocks were subjected to intensive exploitation. In waters off the Canadian coast, early Japanese fishing (1968-76) occurred outside of Canada's fishery jurisdiction (beyond the 12-mile territorial limit) and as the domestic fishery was minimal there was little Canadian interest in developing a management strategy. After extension of fisheries jurisdiction to 200 miles in 1977, Canada assumed responsibility for management of the sablefish. By then participation by the foreign fishery had become intensive and participation by Canadian fishermen was increasing.

As part of the program to develop management strategies, it was essential that the age composition of the stocks be determined. There were only a few previous reports of age and growth of sablefish and most of these studies used scales for the identification of annuli (Pruter 1954; Heyamoto 1962; Shubnikov 1963; Kodolov 1967; Kennedy and Pletcher 1968; Webb and Lockner 1973). Results, though never validated suggested that sablefish is a relatively fast-growing, short-lived species, yet the results of recent tagging studies (Beamish et al. 1978, 1979, 1980) indicated that the annual growth of mature fish may be very small. More generally, there has been mounting support for the view that ages estimated from scales may not be reliable for long-lived species whose rates of growth become greatly reduced after attainment of maturity at a relatively young age (Aass 1972; Beamish 1973; Mills and Beamish 1980; Harrison and Hadley 1979).

This report describes preliminary results of studies designed to develop a reliable method of age determination for sablefish. Scales, sections of fin rays and otoliths were examined to determine which structure exhibited the clearest pattern of growth zone formation. At the same time experiments were initiated to verify that zones identified as annuli actually formed once a year. Because the results to date suggest that previous estimates of age are seriously in error and that consequences of this error to the management of sablefish are equally serious, we feel it is advisable to produce a report before the validation studies are completed in 5-10 yr.

MATERIALS AND METHODS

Otoliths, fin rays and scales were collected, stored and processed as described by Beamish and Chilton (1977) and Beamish (1979). Collections of juvenile sablefish were obtained for length frequency measurements from research cruises and from commercial trawl fishermen. Samples of sub-market sized juveniles obtained from commercial fishermen could be biased because of the codend mesh size selection. However, samples obtained during research cruises were caught by nets having a 2.5 cm stretched mesh codend liner and were considered to be unbiased.

As part of another study to identify stock units and to monitor growth of sablefish, large numbers (>60,000) of juvenile and adult sablefish captured in traps and trawls were tagged and released. A portion of the adult fish captured in traps was given an intraperitoneal injection of oxytetracycline to produce a "time" mark in the otolith. The procedures used for capture and tagging of sablefish and the injection of the oxytetracycline have been described in Beamish et al. (1978, 1979, 1980). When tagged fish were recovered they were remeasured and otoliths were removed and stored in 50% glycerin in darkened containers.

In 1972, Kennedy and Smith (1972) tagged 1,003 juvenile sablefish captured with baited barbless hooks. Some of these fish were recovered and sampled in 1979 and 1980 by Canadian observers on foreign and domestic fishing vessels.

Since most of the tagged fish were retrieved from frozen commercial catches, it was necessary to examine the change in size that occurrs when sablefish are frozen and then thawed. A sample of 50 freshly caught sablefish was selected to represent a wide range of sizes, and killed with anesthetic (MS 222). These fish were then measured for length and weight, tagged and frozen at sea. After 7 days the specimens were brought back to the laboratory, thawed, and remeasured.

An estimate of routine measurement error was made by comparing measurements before and after tagging. During tagging procedures, lengths were customarily recorded prior to applying the tag and the recorder routinely requested a second length measurement be made for about every 10th fish after tagging. A comparison of a series of 100 consecutive duplicate measurements from one cruise is included in this report.

RESULTS

A comparison of ages determined from scales and from the method recommended was not made. The alternating pattern of closely and widely spaced circuli was rarely observed and annuli (the zone of closely spaced circuli) is identified by Pruter (1954) were rarely observed beyond the first few years. Circuli were closely spaced, broken and formed irregularly. There also was a high percentage of regenerated scales. Because of the general absence of any recognizable pattern other structures were examined.

Sections of all fin rays and fin spines were unsatisfactory for age determination because growth zones were difficult to find. When zones could be detected only a few could be identified in fish that from their size had to be more than a few years old. Many fin rays had evidence of some form of internal bone resorption similar to the resorbing of bone that occurs in lingcod fin rays (Beamish and Chilton 1977). Fins were also very oily when dried and difficult to process.

Of the three structures examined, otoliths provided the best pattern of continuous growth zones. The pattern of growth on the external surface of the otolith was readily identified for the first few zones, just as with scales, but subsequent zones were poorly defined and obscured by irregularities in the growth pattern. A more distinct growth pattern was observed when the otolith was broken dorso-ventrally through the nucleus and the exposed surface was burnt and painted with cedar wood oil (Christensen 1964). Thin sections of otoliths (Beamish 1979) were also examined but the pattern of growth could not be identified as readily as from the broken and burnt surface. Therefore, the broken and burnt surface of the transverse section through the nucleus of the otolith was selected for estimating the age of sablefish. The annulus was defined as the translucent zone or the zone of slower growth.

METHOD OF AGE DETERMINATION

Burnt sections in Fig. 1 B-E are of better than average quality and clearly show a pattern of alternating growth zones. The annulus which appears as a dark zone when photographed using reflected light is readily visible in most sections. The first years of growth are usually difficult to identify because of the relatively rapid otolith growth and the indistinct annuli. In clearer sections (Fig. 1B) there are more definite changes in the growth zones that result in the formation of rather broad translucent zones. While these zones frequently contain numerous, narrow opaque zones or checks they do not obscure the annulus. However, in many sections (Fig. 1C), the first few annuli are not obvious except as ridges that appear on the edge of the transverse section.

The width of the annual growth zones during the first few years is quite large compared to widths of zones laid down in subsequent years. The relatively rapid growth in the first year is even more apparent from the otolith surface (Fig. 1A). This relatively large amount of growth suggests that the growth of the fish is quite rapid during the first year. An examination of the length frequencies of samples of sub-legal blackcod shows the dominance of a strong 1977 year class (Beamish et al. 1980). The relatively large size of the fish after the first years growth confirmed that fish growth is quite rapid and that the first annulus forms well outside of the center of the otolith (Fig. 1A, B). In many fish the relative positions of the first 3 annuli are similar and a comparison of the thickness of an otolith from a 3-yr old fish with the otolith of unknown age will indicate the approximate location of the 3rd annulus. As fish age, the pattern of alternating growth zones becomes more distinct and concentrated on the interior of the otolith.

Checks within the opaque zone were identified by their narrow width and the tendency to be present in only a portion of the opaque zone i.e. they rarely formed a continuous zone (Fig. 2A). Checks that form in the vicinity of the 3rd annulus sometimes are sufficiently distinct to make the identification of the 4th annulus difficult (Fig. 1D). However, the last check of the rather broad annulus of the 3rd zone can be quite faint, while the 4th and subsequent annuli are more distinct. This change in annulus formation occurs at about the same time changes were observed in the length frequency distribution of juveniles (Fig. 3A,B). The prominence of checks varied among samples.

Few otoliths have a pattern of alternating growth zones as prominent as those in Fig. 1D and E. While the thickness of the zones after age 3 is quite different in these two otoliths, the annuli form in a regular pattern and are not obscured by checks. It is noteworthy that the fish represented by Fig. 1D and E were both about the same age yet one was a slow growing male and the other was a fast growing female indicating that size of the fish or the thickness of otolith after age 3 or 4 is not necessarily an indicicator of age.

Figure 1C is about average in clarity and while the photograph is more difficult to interpret than the actual section, it is apparent that some annuli are difficult to identify because of the absence of prominent growth zones or because of the presence of checks within the annual pattern of growth. While these checks tend to be less apparent as the fish increases in age, in some individuals particularly from some areas, they dominate a portion or all of the pattern of zone formation making the recognition of annuli extremely difficult. Since most otoliths from older fish contained some areas where annuli were difficult to interpret, there was usually some doubt about the accuracy of the age determination. Despite this problem it appeared that the pattern of alternating translucent and opaque zones observed on the broken and burnt otoliths occurred annually. It remained to be demonstrated that the translucent zone identified as an annulus did form once a year for all age classes in the population.

VALIDATION OF METHOD

When validating a method of age determination it is essential that it be proven reliable for all or most age classes in a population and not just for the first few years of comparatively rapid growth. Traditional techniques using length frequency analysis or the examination of the edge of the otolith section are not satisfactory for older slower growing fishes because of the absence of modes and the narrow annuli. In this study tagged fish were used to validate the method. A sufficient number of fish have not been recovered to demonstrate conclusively that the growth zones identified as annuli do form once a year. However, the preliminary results do indicate that the method is valid.

VALIDATION WITH KNOWN AGE FISH

A partial validation of the method was possible when otoliths were collected from a small sample of "known age" sablefish. The juvenile sablefish tagged in 1972 by Kennedy and Smith (1972) had an average length of 38 cm (Fig. 4). A comparison of the length frequency of these fish with the length frequencies obtained for the 1977 year class from 1977-1980 (Fig. 3A,B) indicates that most of the fish tagged in Kennedy's study were age 1+.

Two fish which were 38 cm and 42 cm when tagged, were recovered in the commercial fishery in 1979 and measured 62-cm (male) and 68-cm (unknown sex). Unfortunately no otoliths were obtained. By June 1980, 4 more of these fish were recaptured and otoliths were obtained from a 60-cm male, a 63-cm male, a 64-cm female and a 68-cm male. Since these fish ranged from 34-37 cm when tagged and were probably age 1+ in 1972 they would be 9 or 9+ depending on whether or not the new year's growth was visible in mid-1980. When the reader was informed of the history of the fish, a second determination resulted in ages of 9, 9, 9, and 10 (Fig. 2). Ages were determined initially without any knowledge on the part of the reader of the history of the specimens and were 8+, 9+, 8+, and 10 yrs.

The annuli in two of the otoliths were very difficult to identify and the sections were difficult to photograph, thus only 2 of the 4 otoliths are included in Fig. 2. The 2 sections included in Fig. 2 show a definite pattern of alternating opaque and translucent zones and were considered to be of average clarity. As discussed, the positions of the first 3 annuli are difficult to identify. The approximate position of the 3rd annulus can be identified by comparing the thickness of the section with the thickness of the age-3 section in Fig. 1. The last 5 annuli in Fig. 2A are quite clear and a comparison of the thickness and pattern of these zones with some of the older sections in Fig. 1 clearly shows that older fish simply have added more zones to the otolith.

VALIDATION FROM OXYTETRACYCLINE INJECTIONS

During 1979, 53 tagged fish were recovered that had been injected with oxytetracyclinic (OTC) and released in the fall of 1977, and 306 were recovered that had been similarly treated in 1978. Not all otoliths recovered from these fish have been examined, but some form of an OTC mark was present on those that have. The OTC mark was visible on the interior surface when viewed in cross-section while occasionally being absent from the exterior surface of the otolith. Because most fish had grown very little during the release period, the mark was frequently near the edge of the otolith. A few fish such as a 62-cm male, marked and released off the west coast of Vancouver Island in September 1977 and recovered September 1979 at a length of 69 cm and an age of 7+ yr did show that 2 opaque and 2 translucent zones had formed in the 2 years prior to recapture. Another

53-cm male, released in September 1977 off the west coast of Vancouver Island and recovered at a length of 53 cm in September 1979, was aged as 16 yr when recaptured and while no apparent change in length occurred, 2 closely spaced opaque zones could be identified as having formed after the OTC mark was deposited. This preliminary information from the OTC experiment confirms that only one opaque and one translucent zone form in one year. However, many more otoliths must be examined over a number of years before it can be concluded that the zone identified as an annulus does in fact form once a year for all age classes in the population.

VALIDATION BY GROWTH ANALYSIS

Mean annual growth of mature sablefish as estimated from age determinations is small. The growth curves in Fig. 5 indicate that while there is variation among areas between ages of 5 and 40, the annual growth increment ranges from 0.17-0.26 cm for males and 0.55-0.66 cm for females. There also was little mean positive growth of the 1,911 tagged fish that were recovered between August 1977 and December 1979 (Table 1). If fish measured within several hours of recapture and prior to freezing or storing are treated separately from those that had been frozen or stored in ice or brine, a mean annual growth increment for all fish of 0.3 mm per year or 3.3 mm for fish recovered after 1 year or more was observed (Table 1).

There was no significant difference in the growth increments of males and females.

Measurement errors at time of tagging and recapture do not appear to have been a contributing factor to the observed small growth increments. There was no difference in the mean lengths of the sample of 100 fish that received a second measurement prior to release after tagging or when a sample of 50 dead fish were measured, tagged and remeasured. If measurement errors do occur, their frequency is probably equally distributed on either side of the true length, indicating that in large samples the net measurement error is negligible. There was a net average decrease of 0.5 cm when fish were measured after freezing and thawing indicating that freezing and handling contributed to the discrepancy in mean average growth recorded from the combined recoveries and the recoveries that were measured prior to freezing (Table 1). Because a large number of recoveries were examined and errors in measurements appear small, the slow growth indicated from the tagging study appears real and corroborates the slow rate of growth determined from the age estimates.

Sablefish in the Canadian fishery vary in average size depending on their sex and the capture location. Females grow to larger average sizes than males (Fig. 5) and in many areas less than 1% of the males are larger than 70 cm compared with 58% for females (Beamish et al. 1978, 1979, 1980). The rate of annual growth of males was reduced before females (Fig. 5) and males and females continued to live for long periods during which little growth in length occurs.

While most of the larger fish are females, there are substantial numbers of fish of both sexes in the Canadian zone that are larger than the sizes of the recovered fish of known age (ie. those tagged at age 1^+ years). Because of the reduced rate of annual growth that was apparent from the tagging studies, it is probable that these larger fish are considerably older than the known age 8 and 9 yr old fish recovered in 1979 and 1980. Thus, ages ranging from 20-40 yr, as estimted from otolith readings (Fig. 5) do not appear unreasonable.

While the general assumption that large fish of either sex are older fish appears applicable, there are many individuals within some areas that are small and very old making it difficult to apply any form of age length key to the whole population.

DISCUSSION

The most reliable method fishery biologists have for estimating the age of fishes requires that a pattern of growth be identified on some structure. The pattern must then be related to the annual growth history of the structure and if separately identifiable growth zones within the pattern form only once a year, one zone can be considered an annulus. However, it is essential that the pattern be shown to form throughout the life of the individual. For example, it is known that the pattern of circuli growth observed on scales of some fish can change abruptly (Beamish 1973). Since scales grow to protect the fish it is not unreasonable that scale growth should become retarded once growth of the fish is reduced. It is also known that as otliths grow the area of growth may change from on all surfaces to on the interior surface only (Irie 1960; Mugiya 1974). Such a change in otolith growth could obviously alter the growth pattern if viewed from the external surface. Thus, a particular structure is only important if a pattern of growth zones can be recognized. It is a mistake to choose a structure simply because it has been useful for some other species or stock.

While we did not examine a large number of fish and structures we were able to identify a pattern of growth zones that appeared useful for age determination. We rejected the use of scales because we could not consistantly recognize any pattern of circuli formation. A week pattern was observed on some sections of fin rays but only a few growth zones could be counted and it was not possible to relate these zones to the annual growth history of the fin or the fish. There were zones that appeared on the external surface of the otolith but it was rarely possible to identify a pattern of zone information. Only on the transverse section of the otolith was there an obvious pattern of growth zone development. Because the pattern appears to form throughout the life of the fish, the age of sablefish was estimated from broken sections of otoliths. Burning and treating with cedarwood oil enhanced the contrast between growth zones.

The method developed for estimating the age of sablefish indicates that sablefish are much older than formerly thought. While the interpretation of the growth pattern on otolith sections may be questioned because it has not been validated for all age classes within the population, it is valid for the few examples tested. Evidence of a low rate of growth beyond the first few years is corroborated by the results of tagging. In contrast, the ages determined from scales (Pruter 1954 and others) indicates that the rate of growth is much faster and that most sablefish in the commercial size range are 5-10 yr rather than 8-45 yr as indicated from the otolith sections. We can accept that there are some difficulties with our method of age determination, but because the scale method has not been validated for adult fish and because it has been demonstrated to be unreliable for other slow-growing, long-lived fishes (Aass 1972; Beamish 1973; Mills and Beamish 1980) there is no reason to reject the ages determined using the growth pattern on the broken and burnt section of the otolith simply because they do not agree with ages estimated from scales or because we have some anthropomorphic difficulties accepting that some fishes have longevities approaching that of man.

The slow growth rate suggests that there is a large number of age groups in the commercial catch and the instantaneous natural mortality rates are much lower than formerly thought (Low et al. 1976). A management strategy that assumes fast growth and few age groups and encourages heavy fishing clearly could result in overfishing and a drastic reduction in the number of age groups available to the fishery. If the need for a large number of age groups in blackcod populations is in response to long periods of poor environmental conditions, then an error in management strategies, coupled with a number of consecutive years of poor environmental conditions could result in a major recruitment failure and a collapse of a commercial fishery.

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Table 1. Average growth of recovered sablefish.

	All recovered sablefish			Only sablefish measured by fisheries staff within one hour of recapture		
Years after tagging[1]	Average growth (cm)	S.D.	n	Average growth (cm)	S.D.	n
0	-0.6	1.3	187	-0.1	0.9	15
0.5	-0.5	1.1	734	-0.2	0.9	112
1	-0.5	1.4	589	+0.3	1.6	77
1.5	-0.6	1.5	334	+0.2	1.5	16
2	-0.3	1.4	51	+0.7	1.6	9
2.5	-0.7	1.1	16	+0.0	1.4	2

[1]One growing season is arbitrarily assumed to be from May 1 to September 30. A tagged fish has completed 0.5 of a growing season after any 2.5 month period between May 1 and September 30.

Fig. 1. (A) Surface of an otolith from a juvenile male sablefish; 49 cm, age 3, sampled in May. The highlighting in some areas of the annulus is a result of the lighting used for the photograph. (B) Section of the above otolith. Note that annuli are difficult to identify but that ridges appear in the outline of the section at the approximate position of each annulus as observed in 1A. (C) Example of an average section of a very old sablefish; 77 cm female, age approximately 34 yr, sampled in May. (D) Example of a slow-growing, old fish; 51 cm male age 17 yr, sampled in May. (E) Example of an easily aged fast-growing blackcod; 96 cm female age 19, sampled in May.

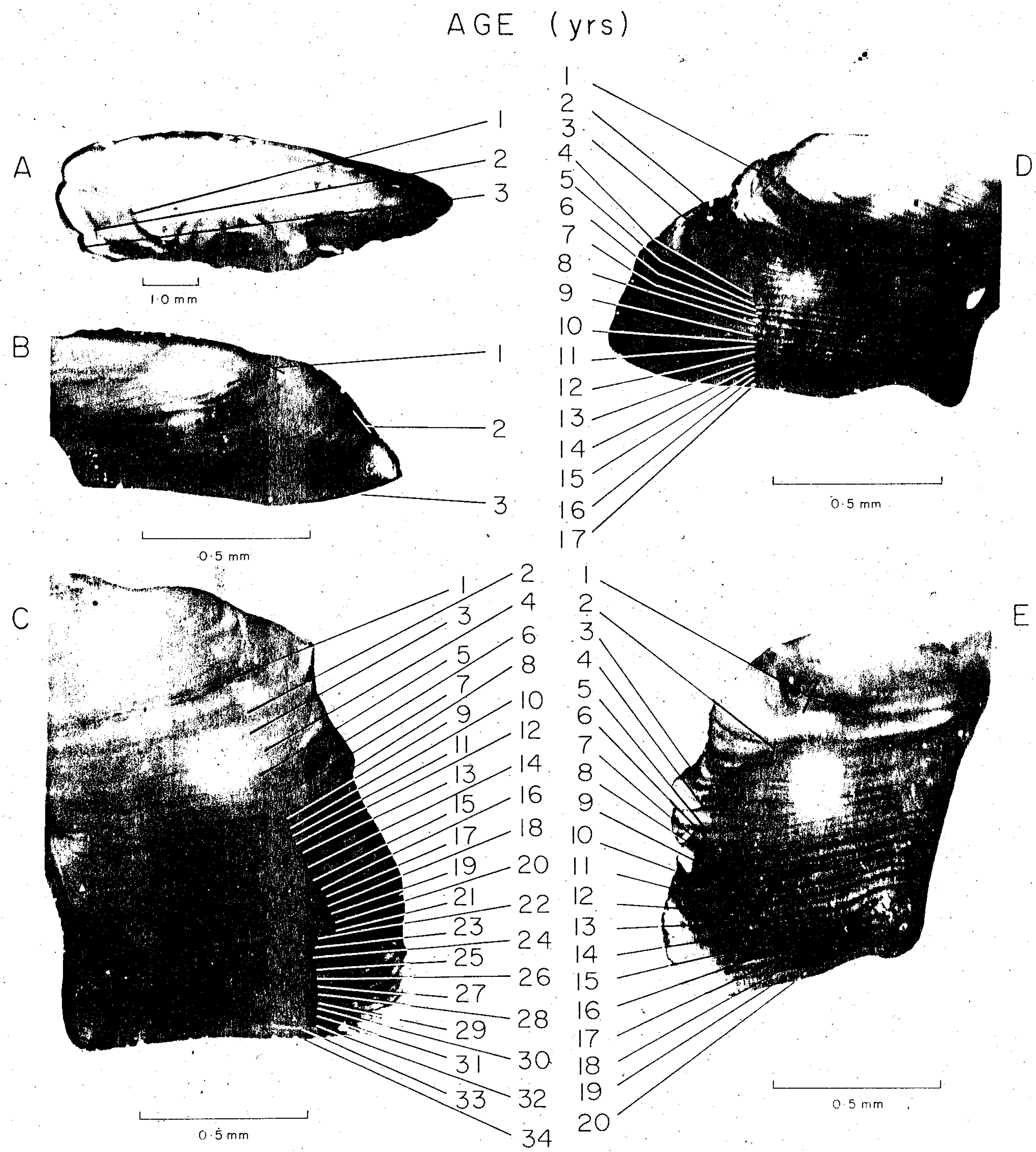

AGE (yrs)
A
1
2
3
1·0 mm
B
1
2
3
0·5 mm
C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
0·5 mm
D
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
0·5 mm
E
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0·5 mm

Fig. 1.

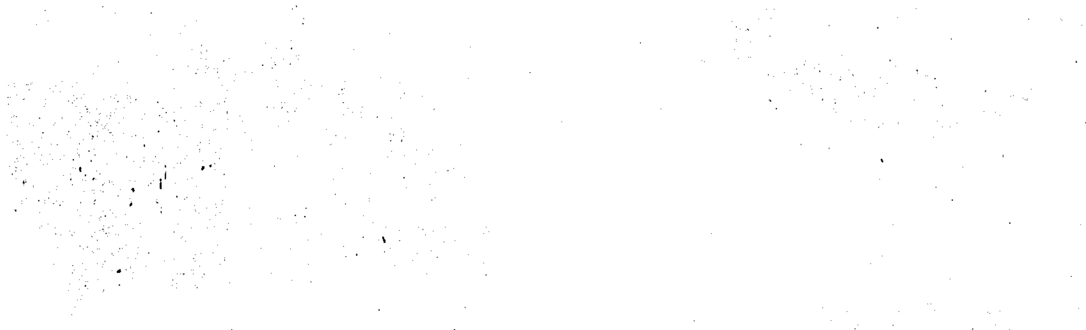


Fig. 2. Sections of otoliths from known age sablefish. (A) A 68 cm male recaptured in May 1980 and aged 9 yr. Arrows point to checks. (B) A 60 cm male recaptured in February 1980 and aged 10 yr.

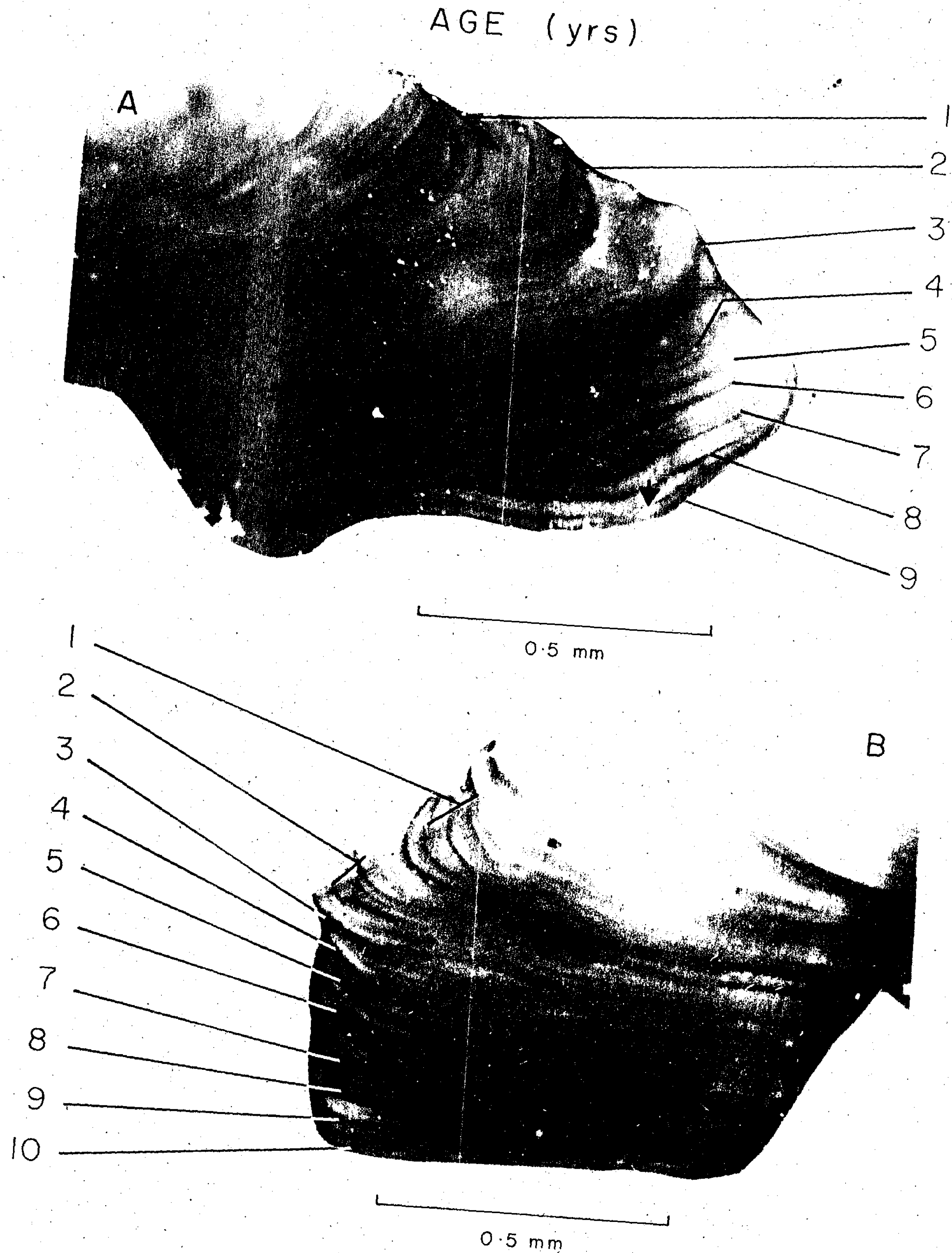


Fig. 2

Fig. 3A. Length frequencies of total or random samples of juveniles of the 1977 year class obtained off the west coast of Canada from August 1977 until February 1980.

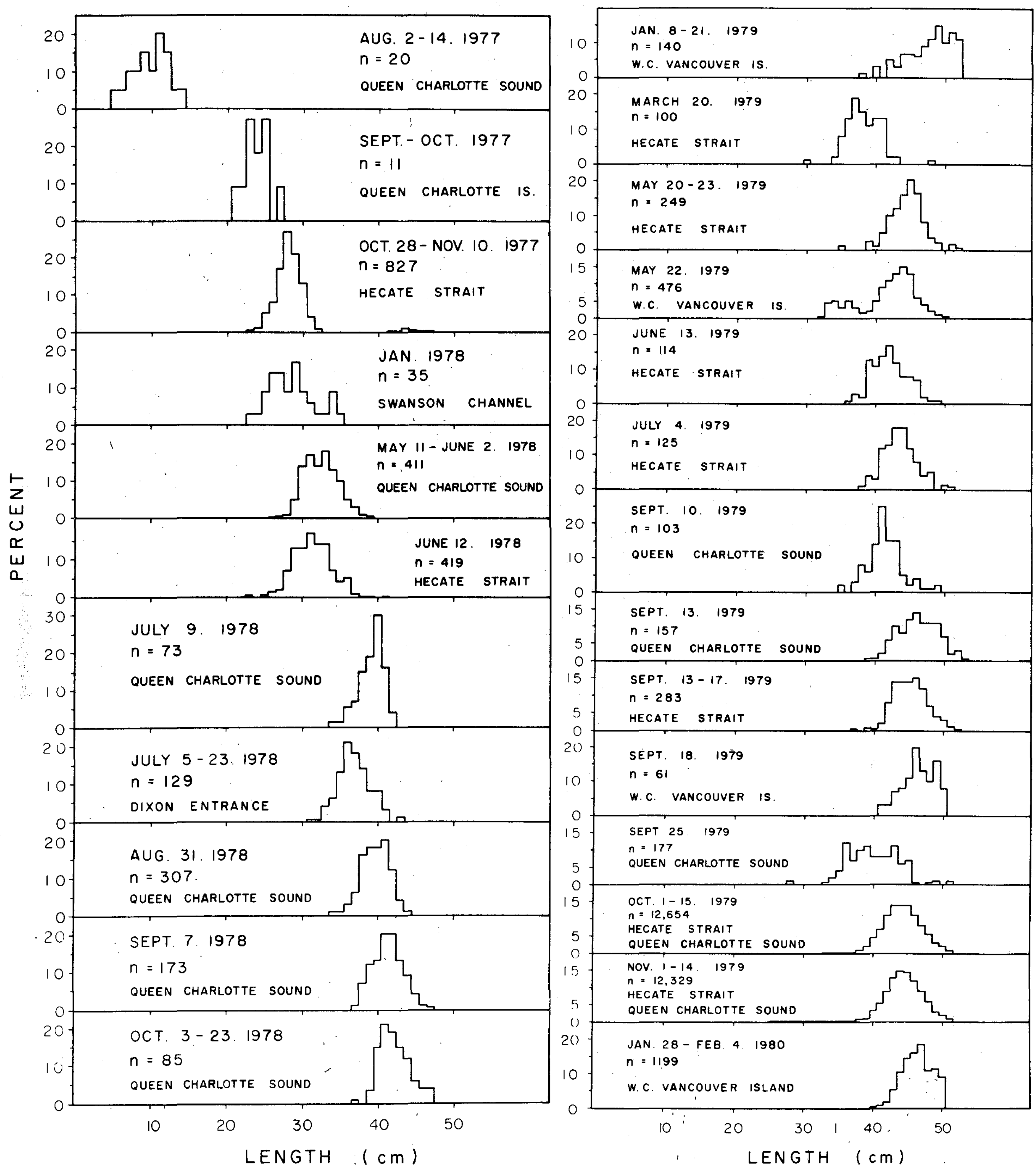

AUG. 2-14. 1977
n = 20
QUEEN CHARLOTTE SOUND
SEPT.- OCT. 1977
n = 11
QUEEN CHARLOTTE IS.
OCT. 28- NOV. 10. 1977
n = 827
HECATE STRAIT
JAN. 1978
n = 35
SWANSON CHANNEL
MAY 11 - JUNE 2. 1978
n = 411
QUEEN CHARLOTTE SOUND
JUNE 12. 1978
n = 419
HECATE STRAIT
JULY 9. 1978
n = 73
QUEEN CHARLOTTE SOUND
JULY 5-23. 1978
n = 129
DIXON ENTRANCE
AUG. 31. 1978
n = 307
QUEEN CHARLOTTE SOUND
SEPT. 7. 1978
n = 173
QUEEN CHARLOTTE SOUND
OCT. 3-23. 1978
n = 85
QUEEN CHARLOTTE SOUND
PERCENT
LENGTH (cm)
JAN. 8-21. 1979
n = 140
W.C. VANCOUVER IS.
MARCH 20. 1979
n = 100
HECATE STRAIT
MAY 20-23. 1979
n = 249
HECATE STRAIT
MAY 22. 1979
n = 476
W.C. VANCOUVER IS.
JUNE 13. 1979
n = 114
HECATE STRAIT
JULY 4. 1979
n = 125
HECATE STRAIT
SEPT. 10. 1979
n = 103
QUEEN CHARLOTTE SOUND
SEPT. 13. 1979
n = 157
QUEEN CHARLOTTE SOUND
SEPT. 13-17. 1979
n = 283
HECATE STRAIT
SEPT. 18. 1979
n = 61
W.C. VANCOUVER IS.
SEPT 25. 1979
n = 177
QUEEN CHARLOTTE SOUND
OCT. 1-15. 1979
n = 12,654
HECATE STRAIT
QUEEN CHARLOTTE SOUND
NOV. 1-14. 1979
n = 12,329
HECATE STRAIT
QUEEN CHARLOTTE SOUND
JAN. 28 - FEB. 4 1980
n = 1199
W.C. VANCOUVER ISLAND
LENGTH (cm)

Fig. 3A.

Fig. 3B. A von Bertalanffy growth curve (dashed line) and a growth curve fitted by eye (solid line) for the mean sizes of each of the frequency distributions in Fig. 3A. Length at time zero was estimated to be 1 cm.

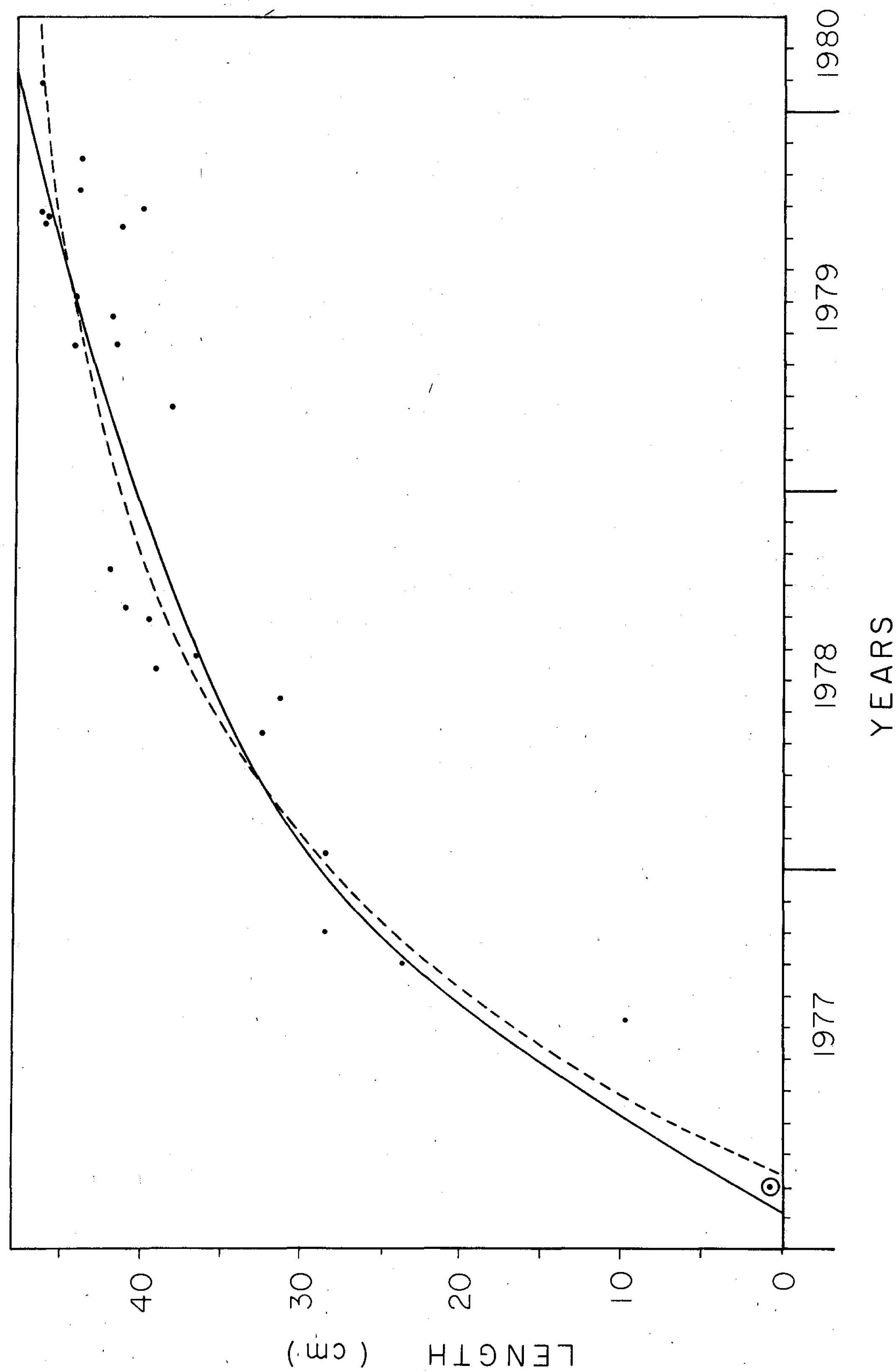


Fig. 3B.

Fig. 4. Length frequency of the sablefish tagged off the northeast coast of Vancouver Island in the summer of 1972 by Kennedy and Smith (1972).

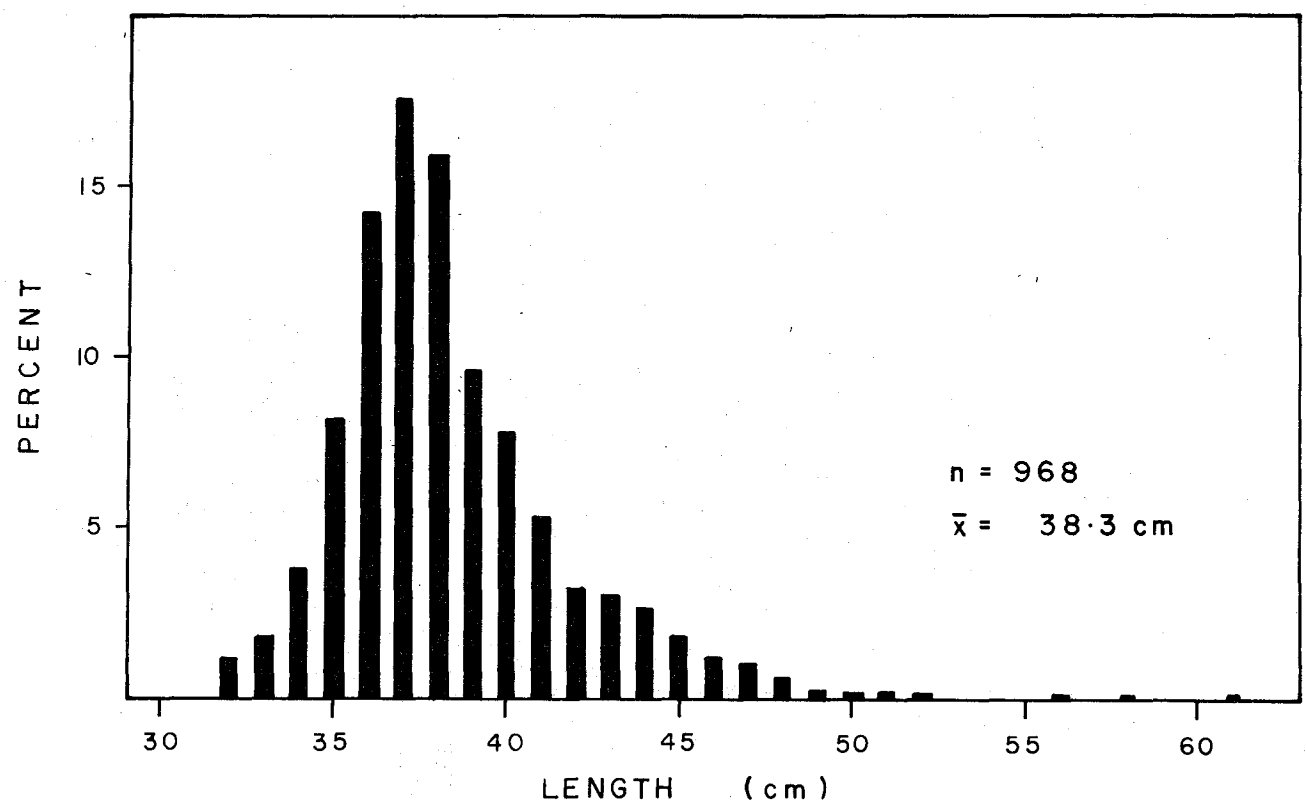
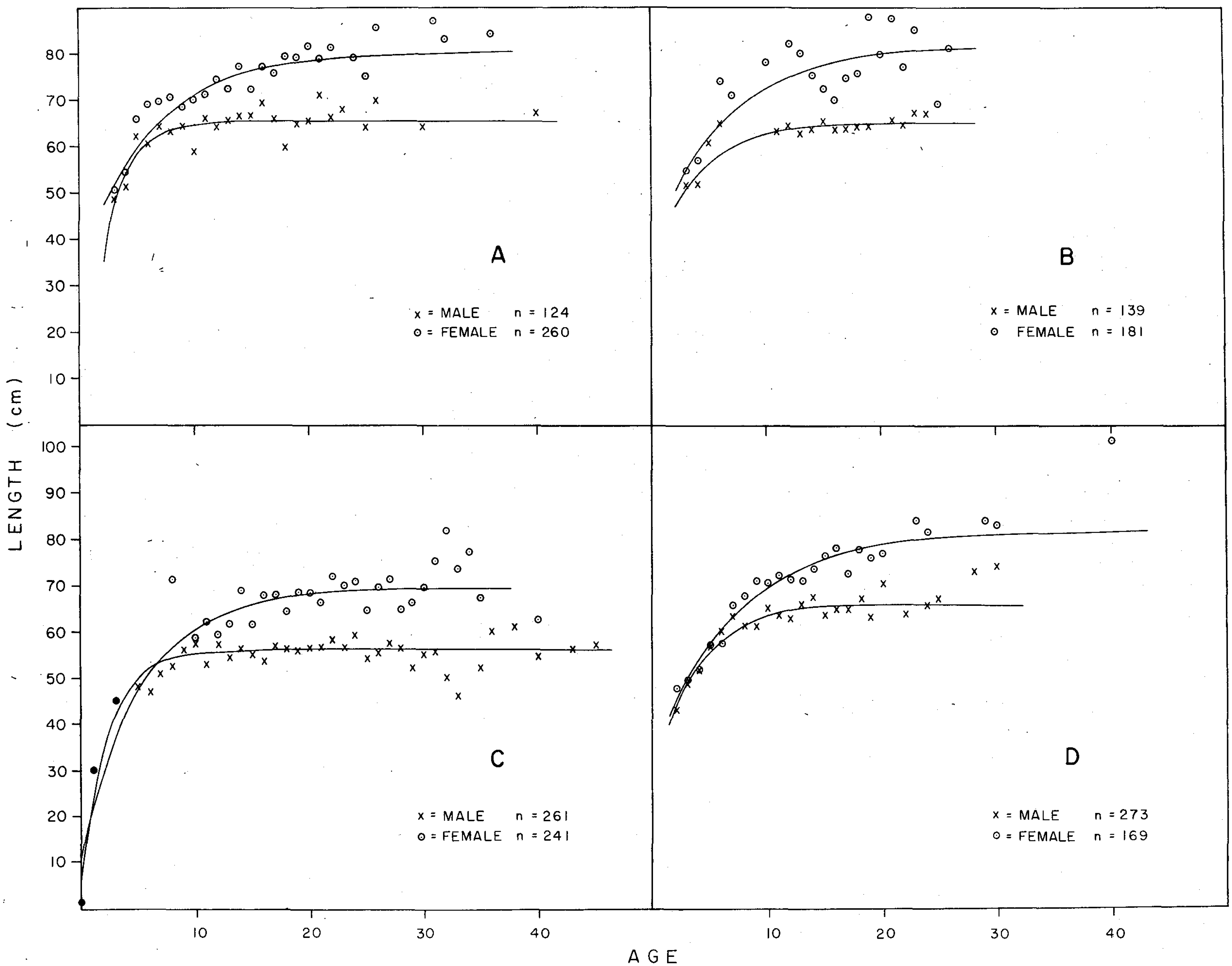


Fig. 4.

Fig. 5. Growth curves showing the variation in growth of some sablefish stocks sampled in 1979-80 off the west coast of British Columbia. Two samples from the west coast of Vancouver Island are included (C,D) to show the differences in size and age that can occur between samples collected in the same location. (A) West coast of the Queen Charlotte Islands: ♂ -- $K=0.47$, $L_\infty=65.5$, $t_0=0.14$; ♀ -- $K=0.16$, $L_\infty=80.8$, $t_0=-3.51$. (B) Inlets east of Queen Charlotte Sound: ♂ -- $K=0.26$, $L_\infty=64.6$, $t_0=-2.91$; ♀ -- $K=0.16$, $L_\infty=81.6$, $t_0=-3.96$. (C) West coast of Vancouver Island: ♂ -- $K=0.43$, $L_\infty=56.0$, $t_0=-0.22$; ♀ -- $K=0.19$, $L_\infty=69.5$, $t_0=-0.99$. (D) West coast of Vancouver Island: ♂ -- $K=0.29$, $L_\infty=65.7$, $t_0=-1.75$; ♀ -- $K=0.14$, $L_\infty=81.7$, $t_0=-3.93$.



A
x = MALE n = 124
o = FEMALE n = 260
B
x = MALE n = 139
o FEMALE n = 181
C
x = MALE n = 261
o = FEMALE n = 241
D
x = MALE n = 273
o = FEMALE n = 169
LENGTH (cm)
AGE

Fig. 5.