Diameter Measurements for Identification of the First and Second Annulus on Dorsal Fin Ray Sections from Lingcod (*Ophiodon elongatus*)

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DIAMETER MEASUREMENTS FOR IDENTIFICATION OF THE FIRST AND SECOND ANNULUS ON DORSAL FIN RAY SECTIONS FROM LINGCOD (*Ophiodon elongatus*)

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ABSTRACT

Surry, A.M., and J.R. King. 2003. Diameter measurements for identification for the first and second annulus on dorsal fin ray sections from Lingcod (*Ophiodon elongatus*). Can. Tech. Rep. Fish. Aquat. Sci. 2490: 24 p.

We obtained dorsal fin ray samples from juvenile lingcod collected from Hecate Strait (Statistical Area 5CD) in May-June 2001, and from the west coast of Vancouver Island (Statistical Area 3C) and Queen Charlotte Sound (Statistical Area 5AB) in August-September 2001. We measured the diameters of the first and second annuli on cross sections of rays 4-8 from 207 second dorsal fin samples in order to obtain a range of measurements which can be used to identify the expected positions of the first two annuli on fin ray sections during the routine ageing of older lingcod. We recommend that lingcod age estimation by the fin ray method for samples from all statistical areas be conducted using the pooled mean first and second annular diameter measurements of 0.42 ± 0.08 mm and 0.70 ± 0.14 mm, respectively.

RÉSUMÉ

Surry, A.M., and J.R. King. 2003. Diameter measurements for identification for the first and second annulus on dorsal fin ray sections from Lingcod (*Ophiodon elongatus*). Can. Tech. Rep. Fish. Aquat. Sci. 2490: 24 p.

Nous avons obtenu des échantillons de rayons de nageoires dorsales de morues-lingues juvéniles pêchées dans le détroit d'Hécate (zone statistique 5CD) en mai et juin 2001 ainsi que sur la côte ouest de l'île de Vancouver (zone statistique 3C) et dans le bassin Reine-Charlotte (zone statistique 5AB) en août et septembre 2001. Nous avons mesuré les diamètres des premier et deuxième annuli sur des coupes transversales des rayons 4-8 de 207 échantillons de deuxième nageoire dorsale de façon à obtenir une fourchette de valeurs permettant de bien repérer les positions attendues des deux premiers annuli sur les coupes de rayons de nageoire durant les activités courantes d'âgeage des morues-lingues d'un certain âge. Ainsi, pour l'estimation par la méthode des rayons de nageoire de l'âge des morues-lingues des échantillons de toutes les zones statistiques couvertes dans la présente étude, nous recommandons d'utiliser les moyennes regroupées des diamètres des premier et deuxième annuli de 0,42 ± 0,08 mm et de 0,70 ± 0,14 mm, respectivement.

INTRODUCTION

Lingcod (*Ophiodon elongatus*) are found on the west coast of North America in the nearshore waters from Baja, California, to the Shumagin Islands, Alaska. They are an important component of both the recreational and commercial fishery off British Columbia, Canada. They are found on the bottom with most individuals occupying rocky areas at depths of 10-100 m. Growth during the first two years of life is rapid, and up to age 2 it is similar for males and females, with both reaching an average length of 45 cm by age 2. After age 2, females grow faster than males, and the growth of males tapers off at about age 8, whereas females continue to grow rapidly until about age 12-14. The maximum age recorded off the coast of British Columbia has been 14 years for males and 20 years for females. Females reach lengths in excess of 100 cm, whereas males rarely exceed lengths of 90 cm.

Lingcod are routinely aged at the Pacific Biological Station using thin sections of fin rays from the second dorsal fin, according to a method developed by Beamish and Chilton (1977) and Chilton and Beamish (1982). The method has been validated by two mark-recapture studies combined with injections of oxytetracycline (OTC) (Cass and Beamish, 1983; McFarlane and King, 2001). Over time, lingcod may resorb the central portion of their fin rays, or the first few annuli may become translucent, making the identification of the first few annuli difficult in older fish (Beamish and Chilton, 1977; Chilton and Beamish, 1982). In addition, the rapid growth of lingcod in the first two years of life results in the generation of numerous "checks" in the growth of the fin ray, which can be difficult to separate from annuli. Ages can be estimated using the expected positions of the first and second annuli, as determined by mean annular diameter measurements, in conjunction with counting the subsequent annual growth zones or annuli. Juveniles are used to obtain measurements of the first and second annuli because fish less than about 3 years of age are expected to have minimal resorption of the fin ray centres, and growth is sufficiently rapid that there should be virtually no overlap between the diameters of the first few annuli.

In the late 1980's and early 1990's it became apparent that the original ageing criteria suggested for lingcod ageing by the fin ray method by Beamish and Chilton (1977) were no longer being followed, and the original diameter measurements for locating the first and second annulus were no longer available (McFarlane and King, 2001; McFarlane and Leaman 1993, 1994, 1995). The resulting ageing errors were sufficient to cause changes in estimates of life history parameters, which had implications for the development of management strategies for lingcod (McFarlane and King 2001), and it was necessary to re-age a large number of fin ray samples using new annular measurements (Leaman and McFarlane 1997). Annular measurements presently used for ageing lingcod are based on a sample of juvenile lingcod collected from the recreational fishery in the Strait of Georgia (statistical area 4B) in 1987 (McFarlane and King, 2001); however, while the annular measurements are available, the methodology used to obtain these measurements is not documented. In order to avoid future changes in or misunderstandings of the ageing criteria for lingcod, a standard approach to obtaining annular measurements needs to be documented and should be routinely employed when ageing lingcod. In addition, growth rates of lingcod may vary among different areas of the coast, though typically consequent to maturation (Cass et al., 1990). We provide annular measurements based on samples of lingcod from a range of areas, to ensure that ageing criteria may be applied to lingcod from all areas of the coast.

For this study, we measured the diameters of the first and second annuli of rays 4-8 from the second dorsal fin of juvenile lingcod collected in 2001, from a research survey and from the commercial fishery. Research samples were from Hecate Strait (statistical area 5CD), while commercial samples were from the southwest coast of Vancouver Island (statistical area 3C) and from Queen Charlotte Sound (statistical areas 5AB) (Figure 1).

From time to time samplers have collected rays from the first dorsal fin instead of the second. Therefore, the research sample included some fish for which we collected rays from both the first and second dorsal fins, in order to determine whether the first dorsal fin can also be used as an ageing structure, and to obtain annular measurements applicable to first dorsal fin rays.

METHODS

BIOLOGICAL SAMPLING

Opportunistic collection of juvenile lingcod was possible during the 2001 Hecate Strait research survey in May and June 2001 on board the CCGS *W.E. RICKER* (Choromanski et al., 2003). We designated fish < 600 mm as juvenile lingcod since Cass et al. (1990) estimated fish in this size range to be age-3 and younger. We recorded fork length to the nearest millimetre and sex. We collected rays 4-8 from the second dorsal fin (Figure 2a), as typically, lingcod age estimates are made using these fin rays (Beamish and Chilton 1977). In addition, we were interested in comparing the early growth recorded by the first dorsal fin rays, and therefore also collected rays 4-8 from the first dorsal fin (Figure 2a). We designated lingcod captured during this survey as the "research" sample.

We requested that the On-board Fisheries Observer Program collect samples of juvenile lingcod from the commercial trawl fishery in August and September 2001. We requested that the observers record sex and fork length to the nearest millimetre and collect rays 4-8 from the second dorsal fin (Figure 2a) from 50 juveniles from each of statistical areas 3C (south-west coast of Vancouver Island), 3D (north-west coast of Vancouver Island), and 5AB (Queen Charlotte Sound). If possible, the 50 fish were to be collected throughout each statistical area from a number of different tows. These fish were designated the "commercial" sample.

SPECIMEN PREPARATION

We placed lingcod fins from the research sample individually in labelled coin envelopes with the bases protruding, and froze them for return to the Pacific Biological Station. In the laboratory, we thawed the fins for several hours, trimmed any excess flesh, and spread out the fin rays (in their envelopes) and arranged them as perpendicular to the fin ray base as possible (Figure 2b). We placed the envelopes in wooden racks and left them for several weeks to air dry completely.

Lingcod fins from the commercial sample were submitted to us in either air dried or frozen form. We thawed and air dried the frozen fins in the same manner as for the research sample.

We mounted dried fins from both samples in Hysol 0151 Clear Epoxy to facilitate sectioning (Figure 2c). We first removed the fin ray bases, using heavy dissecting scissors for the larger fins, and fine dissecting scissors for the very small fins. We used fine dissecting scissors to cut the tissue between the rays so that they could be separated, and placed the rays from each fin on freezer paper in a bed of epoxy, arranged in order from left (anterior) to right, parallel to each other with the bases aligned. We covered the rays with a small amount of epoxy, so that they were embedded to about 2 cm from the base. We completely embedded the small fins. We left the epoxy to cure for approximately 36 hours before removing the mounted fins from the freezer paper, and returning them to their envelopes.

We made transverse sections of mounted fins by hand using a jeweller's saw (Figure 2d) fitted with an 8/0, 6/0, or 5/0 alloyed steel blade depending on the thickness of the rays, according to the method developed by Beamish and Harvey (1969). For an explanation of the blade designations, see Appendix Table 1. Sections were approximately 0.5 – 1.0 mm wide, with the first section transecting the fin ray base, or as close to the fin ray base as possible. The fourth section was therefore approximately 1.5 – 3.0 mm from the fin ray base. We briefly examined sections on both sides with a compound microscope at 40x magnification to ensure that measurable annuli were visible on at least one ray. We examined up to four sections from each fin ray until we obtained a section with measurable annuli on at least one ray, or until we determined that the fin ray was unusable (no visible or measurable annuli on any ray). We affixed sections to glass microscope slides using clear nail polish, arranging them in the order in which they were cut, oriented according to which side of the section afforded the best view of the annuli. After all diameters measurements were completed, we used ANOVA (Zar, 1999) to determine whether the choice of fin ray section influenced the measured annular diameters.

SPECIMEN SELECTION

For the research sample, we initially selected 40 fish with both first and second dorsal fin rays, attempting to get an even representation over the full juvenile size range. We later added 21 additional fish with second dorsal fin rays to increase the sample size in the smaller range (< 400 mm), and 12 in the larger range (> 400 mm) so that we could improve the sample size of two and three year old fish. For the commercial sample, we used all the juvenile lingcod second dorsal fin specimens available (134 fish).

MEASUREMENTS

The annular growth zone is defined as all the growth on a structure which forms in one year, and is made up of a summer zone, formed during the period of faster growth in the summer months, and a winter zone, formed during the period of no growth, or slow growth, in the winter months (Chilton and Beamish 1982). Under transmitted light, the summer zone on juvenile lingcod fin rays sections appears as an opaque (dark), usually wide band, while the winter zone is a translucent (bright), usually narrow band. We defined the annulus as the translucent, winter zone.

We examined sections from the fin ray samples under transmitted light with a compound microscope at 100x or 40x magnification, depending on the size of the fin ray section. The light source was fitted with a green filter to improve resolution. We made annular measurements using an ocular micrometer (100 units = 1 mm at 100x magnification; 40 units = 1 mm at 40x magnification). We measured annular diameters along axes perpendicular to the inner groove of the fin ray, between the widest points on the annulus (Figure 3), as is clearly illustrated in Fig. 28A of the Groundfish age determination manual (Chilton and Beamish 1982), and as described by McFarlane and King (2001). This method maximizes the difference between measurements of the first and second annulus, and reduces the chances of obtaining overlapping ranges of diameter measurements for each annulus. If an annulus appeared as a thick translucent zone, or as multiple narrow translucent bands, the diameter measurement was to the middle of the translucent zone, as described by McFarlane and King (2001). This is in contrast to the illustration in Chilton and Beamish (1982) which shows the measurements extended to the edge of the translucent zone, but does provide a consistent means of estimating the diameter when the edge of the annulus is less distinct or confused by the presence of numerous narrow translucent bands, as is often the case.

We examined some initial sections from the second dorsal fin rays for a number of the smallest fish from the research sample (< 400 mm fork length; expected age < 2 years) in order to study the structure of the center of the fin ray, so that the first annulus could be accurately identified on larger fin rays from fish in the 400-600 mm size range (expected age > 1 year).

For some lingcod, the position of the first annulus was difficult to determine. A number of very small lingcod (<250 mm) had fin rays with no visible annulus, but based on their size we expected them to be no more than one year old (Cass et al. 1990), and we therefore measured to the edge of the fin ray and called that the first annulus. For some additional lingcod, the fin rays exhibited a distinct, continuous translucent zone located at a diameter much smaller than we observed for the first annulus for other lingcod. This was followed by a second translucent zone at approximately the same diameter that we observed for the first annulus for other lingcod. As most of the lingcod exhibiting this pattern on their fin rays were in the <400 mm size range and would therefore be expected to be less than two years old (Cass et al. 1990), we identified the first, small translucent zone as a "check," and called the second translucent zone the first annulus. "Checks" are translucent zones visible on fin ray sections that may resemble annuli, but which do not represent a full years growth. They are often identifiable by being discontinuous around the ray, and are usually, but not always, less distinct than annuli, and are often not present in all fin rays from an individual (Chilton and Beamish 1982). The rapid growth of lingcod in the first two years of life results in the generation of numerous "checks," and we observed them on many fin ray sections, but most were easily identifiable by being discontinuous around the fin ray, or less distinct than the annuli.

ANALYSIS

We used the variance associated with the mean annular measurement from the statistical area with the largest sample size (statistical area 5AB) to determine the sample size necessary to detect a difference between the first and second annulus at the $\alpha = 0.05$, $\beta = 0.10$ significance level (Zar, 1999). We then compared this to the actual sample size achieved for each area and fin type to ensure that the sample sizes were sufficient.

For each statistical area (5CD, 3C, 5AB), we performed paired two-sample t-tests (Zar, 1999) to test whether the mean diameters of the first and second annuli were significantly different from each other for each fin type (first and second dorsal). For second dorsal fin samples, we used ANOVA (Zar, 1999) to test whether the statistical area mean diameters were significantly different from each other. For the research sample (statistical area 5CD), we used paired two-sample t-tests (Zar, 1999) to test whether the annular diameters measured on the second dorsal fin rays were significantly different from the corresponding annular diameters measured on the first dorsal fin rays.

RESULTS

BIOLOGICAL SAMPLING

Research Sample

From May 31 to June 11, 2001, we sampled 131 juvenile lingcod with fork lengths ranging from 236 mm to 598 mm (Appendix Table 2, Figure 4). Length modes are clearly visible at 300 mm, 450 mm, and 600 mm and should correspond to the one-, two-, and three-year-old age classes (Figure 4). We collected second dorsal fin ray samples from all fish, and first dorsal fin ray samples from 77 fish (Table 1).

Commercial Sample

From August 13 to September 24, 2001, fisheries observers sampled 134 lingcod during 14 different trips on commercial groundfish trawl vessels. Observers sampled 27 juvenile lingcod from the south west coast of Vancouver Island (Area 3C, Table 2) and 107 from Queen Charlotte Sound (Area 5AB, Table 3). Fork lengths ranged from 449 to 599 mm (Appendix Table 2, Figure 4). While the length modes at 500 mm and 600 mm for both areas are not as distinct as for the research sample, they should correspond to the two- and three-year-old age classes (Figure 4). Only second dorsal fin ray samples were collected.

STRUCTURE OF FIN RAYS

Lingcod second dorsal fin rays each have two roughly semi-circular bony elements situated opposite each other within the ray (Figure 3a, Appendix Figure 1a-d). Both elements are potentially usable for annular measurements. The fin ray elements in each first dorsal fin ray that we examined appeared fused into a single roughly circular structure with a groove in one side, and for the purpose of obtaining annular measurements, we treated this structure as a single element (Figure 3b, Appendix Figure 2a-c). Both fin ray types exhibited clear annuli, and we noticed that the patterns of annuli tended to be similar between first and second dorsal fins from the same fish. In general, the annuli on second dorsal fin ray sections tended to be more distinct than on first dorsal sections from the same fish, but about the same proportion of sections were usable from both fin types (>85%).

Although we expected that fish in the <600 mm size class (expected age < 3 years) would show little or no resorption on their dorsal fin rays, we found that for some fish, resorption was extensive, making measurement of the first and second annulus impossible. The presence and amount of resorption was very variable, with resorption present in some fish from age-1 upwards, and some four-year-olds showing no resorption (Appendix Figure 1 and Appendix Figure 2). Resorption was observed on both first and second dorsal fin rays.

ANNULAR MEASUREMENTS

Diameter measurements were taken from one of up to four sections from each fin ray, with the fourth section approximately 1.5-3.0 mm from the fin ray base. We found that the mean annular diameter did not vary with section choice for any statistical area (ANOVA, $p>0.05$) (Figure 5).

As the number of second dorsal fin specimens with both first and second annular diameters was largest for area 5AB (n=93), we used the variance associated with this area to calculate the sample size necessary to detect a difference between the first and second annular diameters (Zar, 1999). We found that all areas had samples sizes sufficient to detect at least a 0.06 mm (6 eye piece units at 100 x) difference ($S^2 = 0.005$, n=13, $\alpha = 0.05$, $\beta = 0.10$).

<u>Research Sample</u>

A total of 66 second dorsal fin specimens and 36 first dorsal fin specimens were usable out of 73 and 39 specimens examined, respectively (Table 1). Annular measurements for both the first and second dorsal fin and the associated fork length for each fish are tabulated in Appendix Table 3. Diameter data are summarized in Table 4. Photographs of representative fin ray sections are presented in Appendix Figure 1 and Appendix Figure 2.

For the first dorsal fin research sample from area 5CD, the mean first annular diameter was 0.39 mm (SD=0.05), and the mean second annular diameter was 0.71 mm (SD=0.08) (Table 4). There was no overlap between the measured diameters for the first annulus and those for the second annulus, and the two means were significantly different from each other (paired t-test, t=14.31, df=19, $P<0.0001$). The mean annular diameter did not vary across the range of fork lengths observed (Figure 5).

For the second dorsal fin research sample from area 5CD, the mean first annular diameter was 0.41 mm (SD=0.04), and the mean second annular diameter was 0.71 mm (SD=0.05) (Table 4). There was no overlap between the measured diameters for the first annulus and those for the second annulus, and the two means were significantly different from each other (paired t-test, t=26.09, df=30, P<0.0001). The mean annular diameter did not vary across the range of fork lengths observed (Figure 5).

Commercial Sample

For area 3C, 22 second dorsal fin specimens out of 27 examined were usable (Table 2). For area 5AB, 96 second dorsal fin specimens out of 107 examined were usable (Table 3). Annular measurements for both the second dorsal fin and the associated fork length for each fish are tabulated in Appendix Table 4 and Appendix Table 5. Diameter data are summarized in Table 4. Photographs of representative fin ray sections are presented in Appendix Figure 1.

For area 3C fins, the mean first annular diameter was 0.44 mm (SD = 0.04), and the mean second annular diameter was 0.68 (SD = 0.06) (Table 4). There was no overlap between the measured diameters for the first annulus and those for the second annulus, and the two means were significantly different from each other (paired t-test, t=14.69, df=16, P<0.0001). The mean annular diameter did not vary across the range of fork lengths observed (Figure 5).

For area 5AB fins, the mean first annular diameter was 0.42 mm (SD = 0.04), and the mean second annular diameter was 0.70 mm (SD = 0.08) (Table 4). There was no overlap between the measured diameters for the first annulus and those for the second annulus, and the two means were significantly different from each other (paired t-test, t=39.21, df=92, P<0.0001). The mean annular diameter did not vary across the range of fork lengths observed (Figure 5).

COMPARISON OF STATISTICAL AREAS

For fish from the three statistical areas (5CD, 3C, 5AB), we compared the mean annular diameter measurements from the second dorsal fin, and found no significant differences among the areas (ANOVA, p>0.05) for either the first or second annulus. We therefore calculated that the pooled mean first and second annular diameters were 0.42 mm (SD = 0.04) and 0.70 mm (SD = 0.07), respectively (Table 4).

COMPARISON OF FIRST AND SECOND DORSAL FINS

For fish from the research sample where we had samples from both the first and second dorsal fins, we compared the diameter measurements for both annuli (Figure 6). We found no significant difference between the fin types for either the first annulus (paired t-test, t=1.66, df=32, p=0.106) or the second annulus (paired t-test, t=0.57, df=16, p=0.576).

DISCUSSION

We found no overlap between the first and second annular diameters measured on fin ray sections from rays 4-8 of the second dorsal fin of juvenile lingcod captured in 2001 in Hecate Strait (statistical area 5C), off the southwest coast of Vancouver Island (statistical area 3C), and in Queen Charlotte Sound (statistical area 5AB). It is therefore a useful criterion for identifying the expected position of the first and second annulus on older lingcod where the central portion of the fin ray may have been resorbed or become indistinct.

First and second annular diameters did not appear to differ significantly among juvenile lingcod collected in 2001 from the south west coast of Vancouver Island (statistical area 3C), Queen Charlotte Sound (statistical area 5AB), or Hecate Strait (statistical area 5CD).

We recommend that lingcod age estimation by the fin ray method, using second dorsal fin rays, for samples from all statistical areas be conducted using the pooled mean first and second annular diameter measurements obtained in this study ± two standard deviations, in order to allow for the expected variance in measurements. The first and second annuli can therefore be identified at 0.42 ± 0.08 mm and 0.70 ± 0.14 mm diameter, respectively (Table 4). As the annular diameters from the first and second dorsal fin of the same fish were not significantly different from each other, if first dorsal fin rays are collected by mistake, the same criteria for identification of the first and second annuli may be utilized.

While the annular measurements documented in this study differ slightly from those which were reported in McFarlane and King (2001) and which are currently in use by the Fish Ageing Laboratory (0.40 ± 0.07 mm and 0.63 ± 0.22 mm , respectively), it is important to note that the difference is much less than the average difference between the two annular diameters, and adopting the new criteria proposed in this study will not require the re-aging of historical fin rays samples for lingcod. However, it is important that future fin ray samples be aged using the diameter measurements documented in this study to identify the first and second annulus. A standard and documented approach to annular diameter measurements for lingcod, as described in this report (Figure 3) and in previous publications (Chilton and Beamish 1982, McFarlane and King 2001) is essential in order to avoid changes and misunderstandings in the application of ageing criteria, such as has occurred in the past, and which could occur in the future as staff and priorities change. Accurate and consistent age determination is critical for the estimation of life history parameters, and can have significant implications for the development of future management strategies for lingcod.

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REFERENCES

Beamish, R.J., and D.E. Chilton. 1977. Age determination of lingcod (*Ophiodon elongatus*) using dorsal fin-rays and scales. J. Fish. Res. Board Can. 34: 1305-1313.

Beamish, R.J., and H.H. Harvey. 1969. Age determination in the white sucker. J. Fish. Res. Board Can. 26: 633-638.

Cass, A.J., and R.J. Beamish. 1983. First evidence of validity of the fin-ray method of age determination for marine fishes. N. Am. J. Fish. Man. 3: 182-188.

Cass, A.J., R.J. Beamish, and G.A. McFarlane. 1990. Lingcod (*Ophiodon elongatus*). Can. Spec. Pub. Fish. Aquat. Sci. 109: 40 p.

Chilton, D.E., and R.J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Pub. Fish. Aquat. Sci. 60: 102 p.

Choromanski, E.M., J. Fargo, and A.R. Kronlund. 2003. Flatfish demographic survey of Hecate Strait, CCGS *W.E. RICKER*, May 28 - June 12, 2001. Can. Data Rep. Fish. Aquat. Sci. XXXX. X p.

Leaman, B.M., and G.A. McFarlane. 1997. Offshore lingcod stock assessment and recommended yield options for 1998. Canadian Stock Assessment Secretariat Research Document 97/131. 42 p.

McFarlane, G.A., and J.R. King. 2001. The validity of the fin-ray method of age determination for lingcod (*Ophiodon elongatus*). Fish. Bull. 99: 459-464.

McFarlane, G.A., and B.M. Leaman. 1993. Offshore Lingcod. pp. 33-48 *In* Leaman, B.M. and M. Stocker (eds.). Groundfish stock assessments for the west coast of Canada in 1992 and recommended yield options for 1993. Can. Tech. Rep. Fish. Aquat. Sci. 1919: 407 p.

McFarlane, G.A., and B.M. Leaman. 1994. Offshore Lingcod. pp. 33-49 *In* Stocker, M. (ed.). Groundfish stock assessments for the west coast of Canada in 1993 and recommended yield options for 1994. Can. Tech. Rep. Fish. Aquat. Sci. 1975: 352 p.

McFarlane, G.A., and B.M. Leaman. 1995. Offshore Lingcod. pp. 97-114 *In* Fargo, J. and M. Stocker (eds.). Groundfish stock assessments for the west coast of Canada in 1994 and recommended yield options for 1995. Can. Tech. Rep. Fish. Aquat. Sci. 2069: 440 p.

MacLellan, S.E. 1999. Guide for sampling structures used in age determination of Pacific Salmon. Fisheries and Oceans Canada, Stock Assessment Branch, Pacific Biological Station, Nanaimo, BC. 26 p.

Zar, J.H. 1999. Biostatistical Analysis. 4th ed. Prentice Hall, Inc., New Jersey. 663 p.

Table 1. Summary of fin samples collected from juvenile lingcod captured in Hecate Strait (Area 5CD) during the 2001 Hecate Strait research survey, May 28 – June 12, 2001, aboard the *CCGS W.E. RICKER*.

Area	Set	Date	No. Juveniles (< 600 mm)			1st Dorsal Fin		2nd Dorsal Fin	
			Males	Females	Total	No. Examined	No. Usable	No. Examined	No. Usable
5C	58	11-Jun							
5C	59	11-Jun	38	45	83	16	16	37	34
5C	60	11-Jun		1	1			1	1
5D	3	31-May	1	1	2			1	1
5D	5	31-May	2		2			2	2
5D	6	01-Jun							
5D	7	01-Jun	4		4	4	4	4	4
5D	10	01-Jun		3	3	3	3	3	3
5D	11	02-Jun	1	1	2	2	2	2	2
5D	12	02-Jun		3	3	2	2	3	3
5D	17	03-Jun	1	1	2	1	1	1	
5D	21	04-Jun	4	9	13	5	3	9	7
5D	22	04-Jun							
5D	23	04-Jun		3	3				
5D	25	04-Jun	1	2	3			2	2
5D	29	05-Jun							
5D	32	05-Jun	1		1	1	1	1	1
5D	34	05-Jun		1	1				
5D	35	06-Jun		1	1	1	1	1	1
5D	36	06-Jun	2		2			1	0
5D	38	07-Jun		3	3	3	3	3	3
5D	40	07-Jun	1		1	1		1	1
5D	43	07-Jun		1	1			1	1
	Total for Area 5CD		56	75	131	39	36	73	66

Table 2. Summary of fin samples collected from juvenile lingcod captured in the commercial fishery off the south west coast of Vancouver Island (Area 3C) in August and September 2001.

Area	Trip	Set	Date	No. Juveniles (< 600 mm)				2nd Dorsal Fin	
				Males	Females	Unknown	Total	No. Examined	No. Usable
3C	C	5	25-Aug			2	2	2	1
3C	D	7	24-Aug	1			1	1	1
3C	D	16	26-Aug	2	2		4	4	3
3C	H	4	02-Sep	4	6		10	10	8
3C	O	17	21-Sep			10	10	10	9
		Total for Area 3C		7	8	12	27	27	22

Table 3. Summary of fin samples collected from juvenile lingcod captured in the commercial fishery in Queen Charlotte Sound (Area 5AB) in August and September 2001.

Area	Trip	Set	Date	No. Juveniles (< 600 mm)				2nd Dorsal Fin	
				Males	Females	Unknown	Total	No. Examined	No. Usable
5A	B	14	19-Aug	2			2	2	2
5A	B	18	19-Aug	1	1		2	2	2
5A	E	16	31-Aug	1	1		2	2	1
5A	F	1	29-Aug	1	2		3	3	3
5A	I	20	09-Sep	4	3		7	7	7
5A	J	14	14-Sep	3	4		7	7	6
5B	A	24	13-Aug	5	5		10	10	10
5B	B	3	17-Aug	1	1		2	2	2
5B	G	2	04-Sep	5	5		10	10	8
5B	I	12	08-Sep	2	9		11	11	10
5B	J	2	13-Sep	5	3		8	8	7
5B	J	7	13-Sep	4	6		10	10	10
5B	K	1	10-Sep	3	3	4	10	10	7
5B	L	10	14-Sep		1		1	1	1
5B	O	3	18-Sep			10	10	10	9
5B	P	6	24-Sep	2	5		7	7	7
		Total for Area 5AB		43	50	14	107	107	96

Table 4. Summary of annular measurements for first and second dorsal fin rays for juvenile lingcod collected from a research survey in Hecate Strait (Area 5CD) in May-June, 2001, and from the commercial fishery off the west coast of Vancouver Island (Area 3C) and in Queen Charlotte Sound (Area 5AB) in August and September 2001. Highlighted area indicates the pooled mean annular diameters for the second dorsal fin ray samples.

Survey Year	Fin Type	Area	1st Annular Diameter (mm)			2nd Annular Diameter (mm)		
			Mean (SD)	n	Range	Mean (SD)	n	Range
2001	2nd Dorsal	5CD	0.41 (0.035)	66	0.35 – 0.50	0.71 (0.051)	31	0.64 – 0.83
		3C	0.44 (0.042)	21	0.39 – 0.52	0.68 (0.059)	18	0.57 – 0.78
		5AB	0.42 (0.042)	94	0.33 – 0.53	0.70 (0.079)	95	0.55 – 0.97
		All Areas	**0.42 (0.040)**	**181**	**0.33 – 0.53**	**0.70 (0.072)**	**144**	**0.55 – 0.97**
2001	1st Dorsal	5CD	0.39 (0.047)	36	0.27 – 0.49	0.71 (0.080)	20	0.60 – 0.86

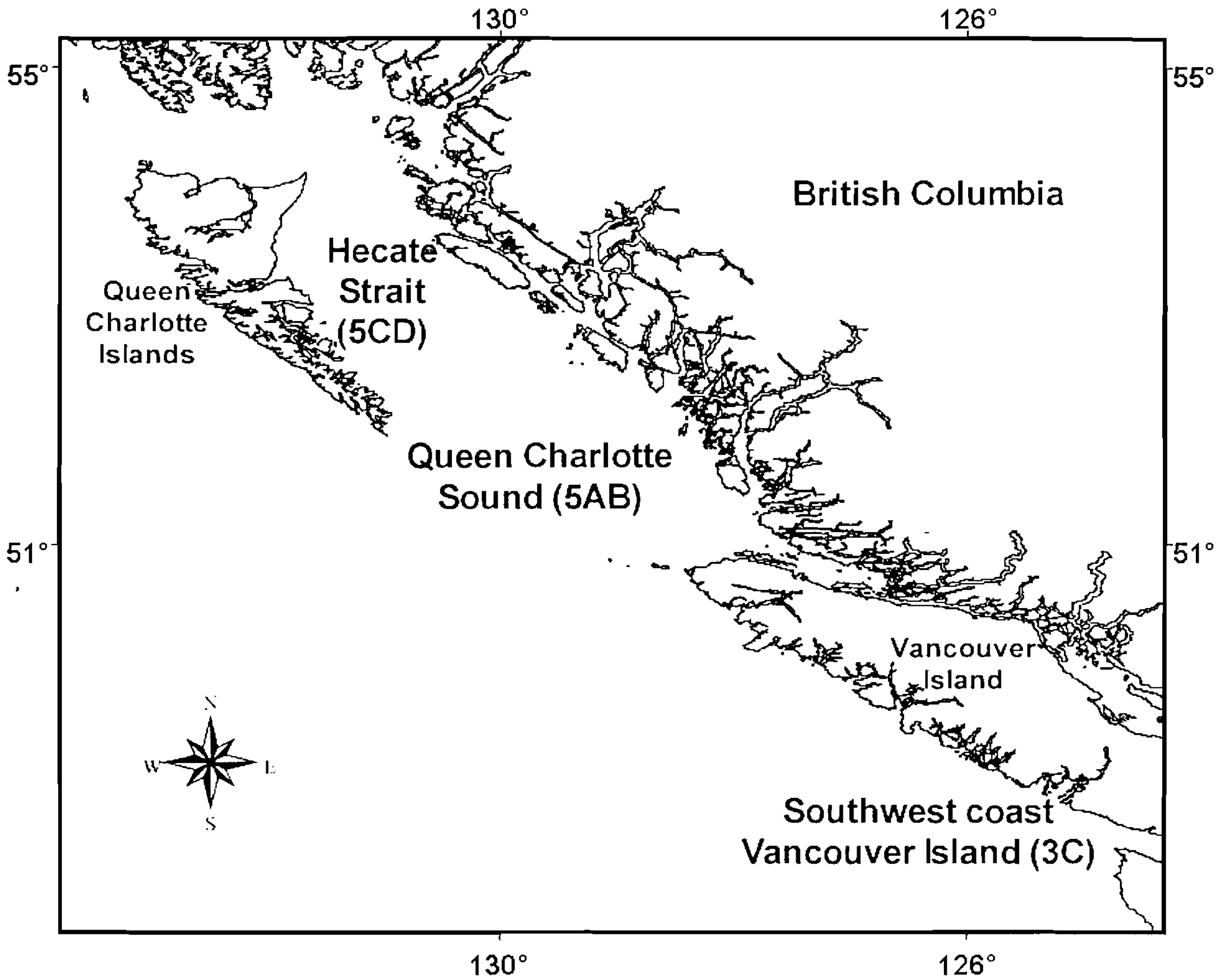


Figure 1. Sampling locations for lingcod collected from a research survey in Hecate Strait (Area 5CD) in May-June, 2001, and from the commercial fishery off the west coast of Vancouver Island (Area 3C) and in Queen Charlotte Sound (Area 5AB) in August and September 2001.

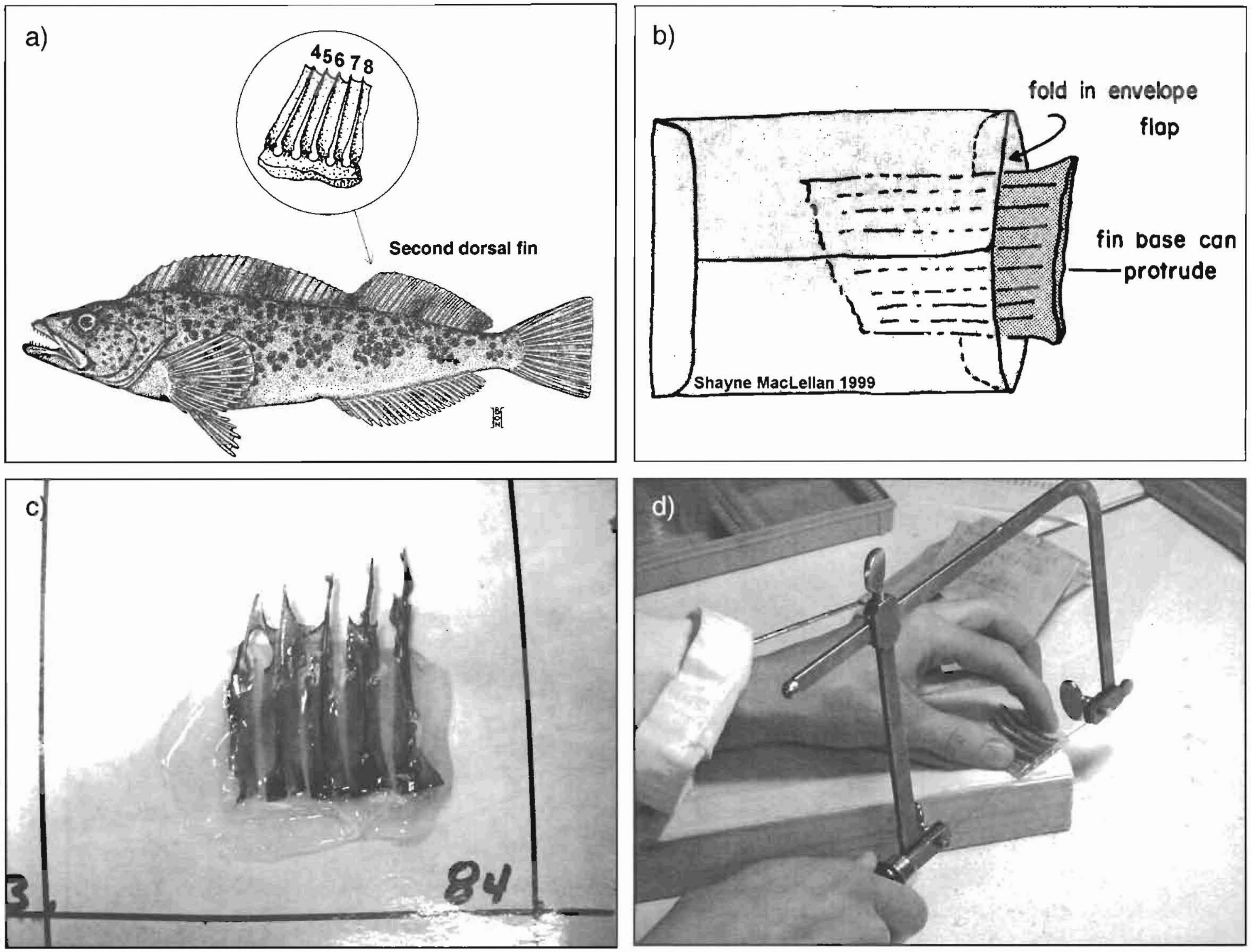


Figure 2. The process of collecting, and preparing dorsal fin rays from lingcod: a) samplers collect rays 4-8 from the first and second dorsal fins; b) fin rays are placed in envelopes with the bases protruding and rays arranged parallel to the fin ray base (MacLellan 1999); c) dried fins are mounted in epoxy on freezer paper; d) fins are sectioned by hand using a jeweller's saw.

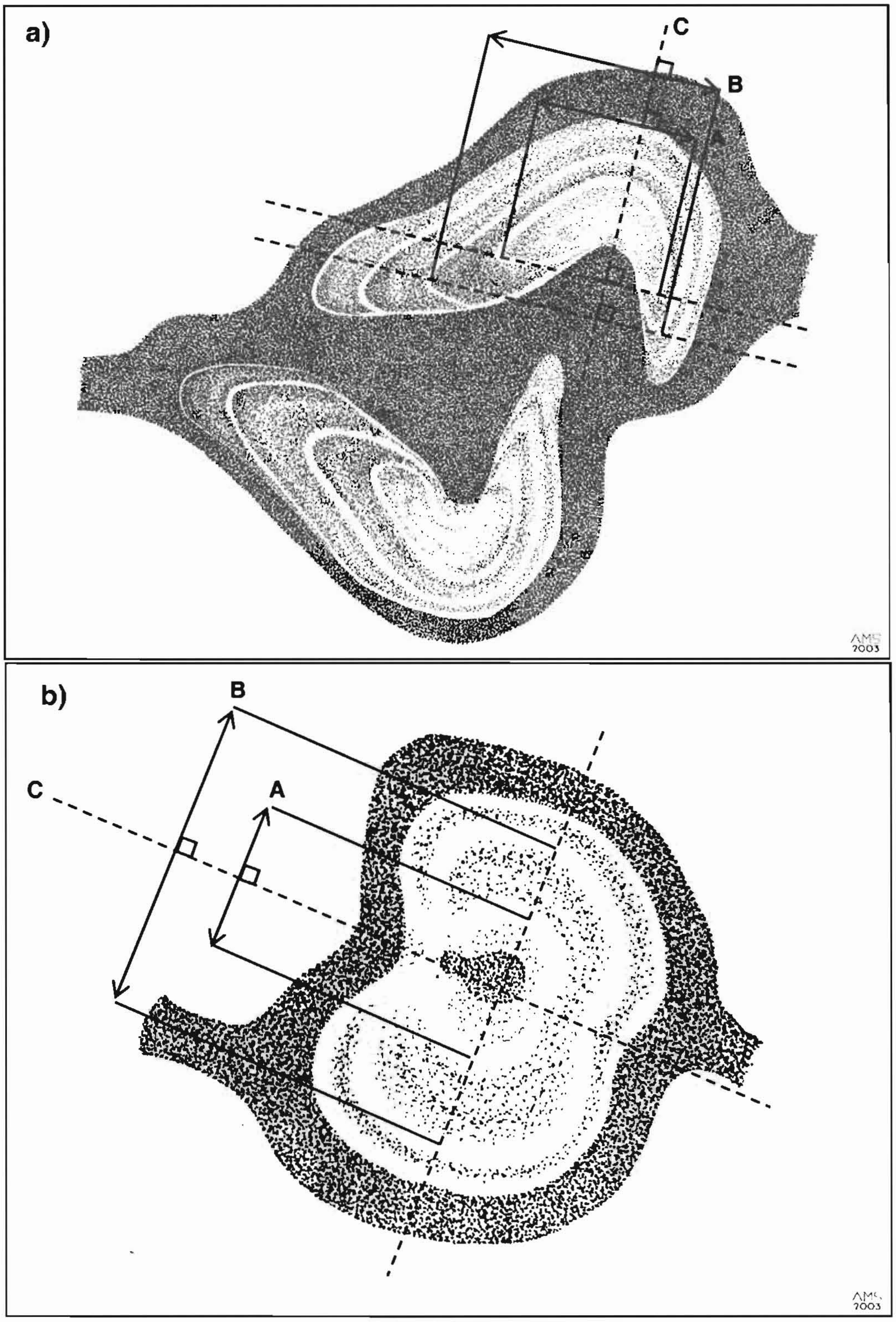


Figure 3. a) Second dorsal fin ray section showing the two fin ray elements and measurements of first (A) and second (B) annular diameters along axes perpendicular to the axis of the inner groove of the fin ray (C); b) first dorsal fin ray section showing measurements of first (A) and second (B) annular diameters along an axis perpendicular to the axis of the inner groove of the fin ray (C).

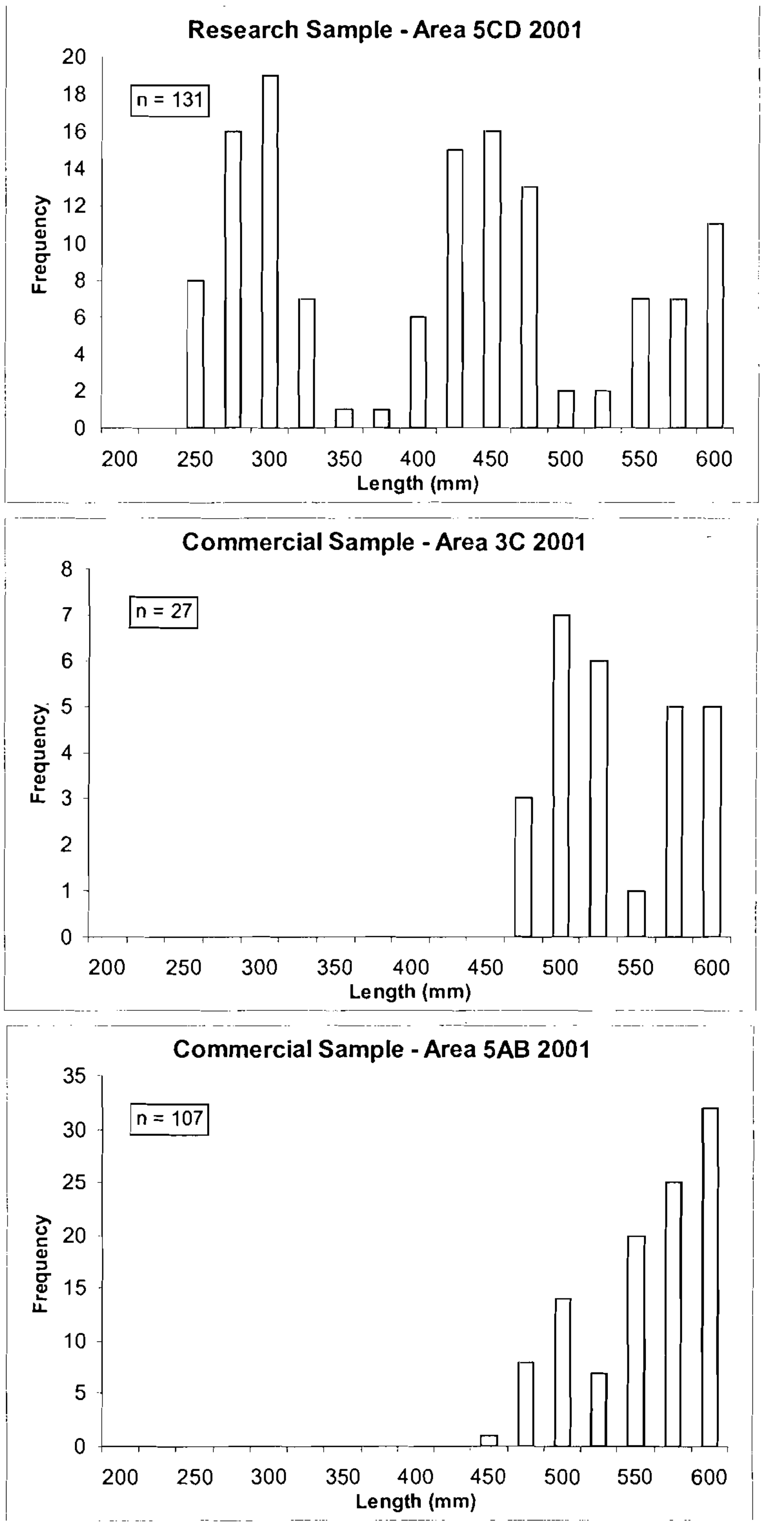


Figure 4. Length frequency of juvenile lingcod collected from a research survey in Hecate Strait (Area 5CD) in May-June, 2001, and from the commercial fishery off the west coast of Vancouver Island (Area 3C) and in Queen Charlotte Sound (Area 5AB) in August and September 2001.

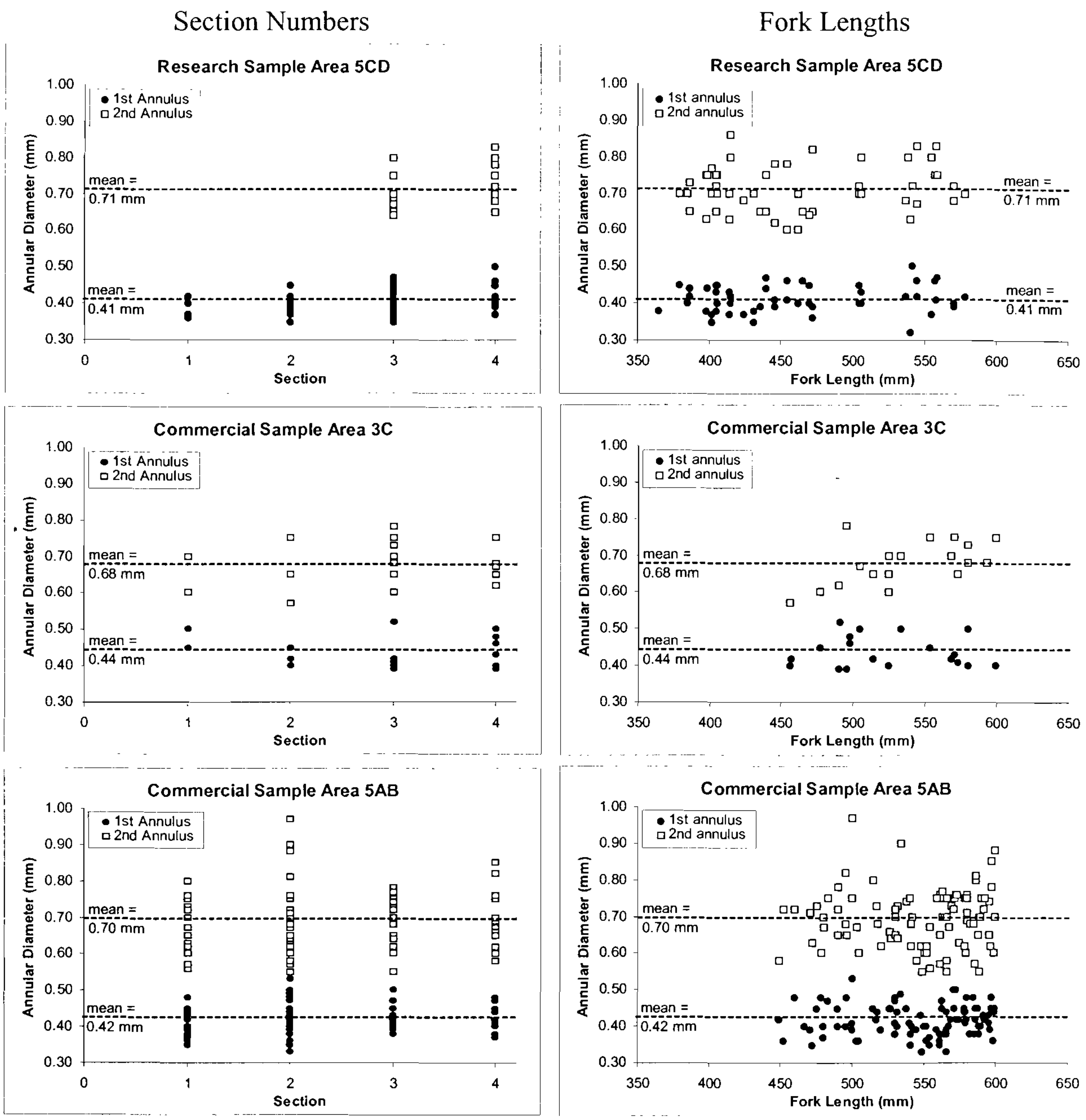


Figure 5. Mean annular diameters (mm) from second dorsal fin ray sections and corresponding section numbers and fork lengths (mm) for juvenile lingcod collected from a research survey in Hecate Strait (Area 5CD) in May-June, 2001, and from the commercial fishery off the west coast of Vancouver Island (Area 3C) and in Queen Charlotte Sound (Area 5AB) in August and September 2001.

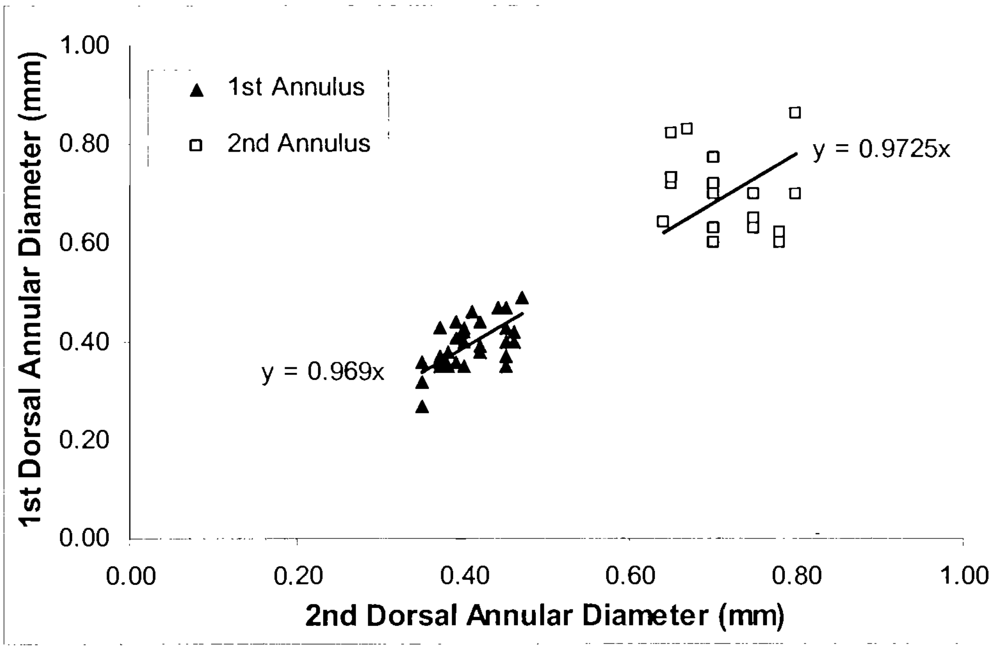


Figure 6. Comparison of annular diameters from the first and second dorsal fin ray sections for lingcod collected from Hecate Strait (Area 5CD) during the 2001 Hecate Strait research survey, May 28 – June 12, 2001, aboard the *CCGS W.E. RICKER*. The regression line for each annulus ($p<0.05$) with corresponding regression equation is indicated.

Appendix Table 1. Specifications for jeweller's saw blades used to section lingcod fin rays.

Blade Type	Thickness (mm)	Width (mm)	Teeth per cm
8/0	0.152	0.330	33
6/0	0.178	0.356	30
5/0	0.203	0.406	26

Appendix Table 2. Length frequency of juvenile lingcod collected from a research survey in Hecate Strait (Area 5CD) in May-June, 2001, and from the commercial fishery off the west coast of Vancouver Island (Area 3C) and in Queen Charlotte Sound (Area 5AB) in August and September 2001. (M=Male, F=Female, U=Unknown sex)

Length (mm)	Research - 5CD			Commercial - 3C				Commercial - 5AB			
	M	F	Total	M	F	U	Total	M	F	U	Total
231 - 240	1	2	3	0	0	0	0	0	0	0	0
241 - 250	3	2	5	0	0	0	0	0	0	0	0
251 - 260	2	3	5	0	0	0	0	0	0	0	0
261 - 270	2	3	5	0	0	0	0	0	0	0	0
271 - 280	4	8	12	0	0	0	0	0	0	0	0
281 - 290	2	5	7	0	0	0	0	0	0	0	0
291 - 300	1	5	6	0	0	0	0	0	0	0	0
301 - 310	1	2	3	0	0	0	0	0	0	0	0
311 - 320	3	1	4	0	0	0	0	0	0	0	0
321 - 330	0	0	0	0	0	0	0	0	0	0	0
331 - 340	0	1	1	0	0	0	0	0	0	0	0
341 - 350	0	0	0	0	0	0	0	0	0	0	0
351 - 360	0	0	0	0	0	0	0	0	0	0	0
361 - 370	1	0	1	0	0	0	0	0	0	0	0
371 - 380	1	0	1	0	0	0	0	0	0	0	0
381 - 390	2	0	2	0	0	0	0	0	0	0	0
391 - 400	2	1	3	0	0	0	0	0	0	0	0
401 - 410	6	0	6	0	0	0	0	0	0	0	0
411 - 420	3	2	5	0	0	0	0	0	0	0	0
421 - 430	3	2	5	0	0	0	0	0	0	0	0
431 - 440	2	8	10	0	0	0	0	0	0	0	0
441 - 450	2	3	5	0	0	0	0	0	1	0	1
451 - 460	3	2	5	1	0	1	2	0	3	1	4
461 - 470	3	2	5	0	0	1	1	1	0	0	1
471 - 480	0	4	4	0	1	0	1	3	2	2	7
481 - 490	0	1	1	0	1	1	2	2	0	2	4
491 - 500	0	0	0	1	2	1	4	2	1	3	6
501 - 510	1	1	2	1	0	0	1	0	2	0	2
511 - 520	0	0	0	1	1	0	2	2	3	0	5
521 - 530	0	0	0	0	0	3	3	4	1	2	7
531 - 540	2	3	5	0	1	0	1	2	2	1	5
541 - 550	1	1	2	0	0	0	0	3	5	0	8
551 - 560	0	4	4	0	0	1	1	4	2	0	6
561 - 570	1	2	3	0	1	2	3	5	9	1	15
571 - 580	1	1	2	1	0	2	3	3	9	2	14
581 - 590	2	3	5	0	0	0	0	7	5	0	12
591 - 600	1	3	4	2	1	0	3	5	5	0	10
Total	56	75	131	7	8	12	27	43	50	14	107

Appendix Table 3. Fork lengths and annular measurements from the first and second dorsal fins for juvenile lingcod collected from Hecate Strait (Area 5CD) during the 2001 Hecate Strait research survey, May 28 – June 12, 2001, aboard the *CCGS W.E. RICKER*.

Record ID	Length (mm)	2nd Dorsal Annular Diameters (mm)		1st Dorsal Annular Diameters (mm)	
		1st annulus	2nd annulus	1st annulus	2nd annulus
150	236	0.37	--	0.37	--
206	239	0.36	--	--	--
151	245	0.35	--	0.27	--
205	245	0.40	--	--	--
152	247	0.37	--	0.36	--
149	250	0.35	--	0.32	--
204	252	0.39	--	--	--
170	255	0.39	--	0.44	--
203	256	0.43	--	--	--
169	258	0.40	--	0.35	--
167	274	0.39	--	0.41	--
172	279	0.41	--	--	--
182	279	0.40	--	--	--
202	280	0.40	--	--	--
158	284	0.45	--	--	--
155	285	0.42	--	0.38	--
160	285	0.45	--	0.37	--
168	285	0.42	--	0.39	--
156	286	0.35	--	0.36	--
177	290	0.45	--	--	--
157	291	0.45	--	0.35	--
148	292	0.40	--		--
171	293	0.40	--	0.43	--
181	293	0.36	--	--	--
208	294	0.42	--	--	--
159	300	0.46	--	0.40	--
201	301	0.46	--	--	--
179	310	0.45	--	--	--
200	310	0.40	--	--	--
154	313	0.47	--	0.49	--
183	316	0.38	--	--	--
199	318	0.42	--	--	--
198	320	0.40	--	--	--
153	335	0.45	--	0.47	--
185	365	0.38	--	--	--
196	379	0.45	0.70	--	--
195	385	0.40	0.70	--	--
178	386	0.42	0.65	0.44	0.73
176	398	0.38	0.75	0.38	0.63
197	399	0.44	0.75	--	--
187	402	0.37	0.70	0.35	0.77
184	405	0.45	0.65	0.43	0.72
191	405	--	--	0.38	0.75
189	406	0.45	0.75	0.40	0.70
188	414	0.37	0.70	0.43	0.63
175	415	0.40	0.80	0.42	0.86
220	424	0.37	0.68	--	--
186	431	0.38	0.70	0.35	0.70
209	436	0.39	0.65	--	--
194	440	0.44	0.75	0.47	0.65

Appendix Table 3 (Cont.)

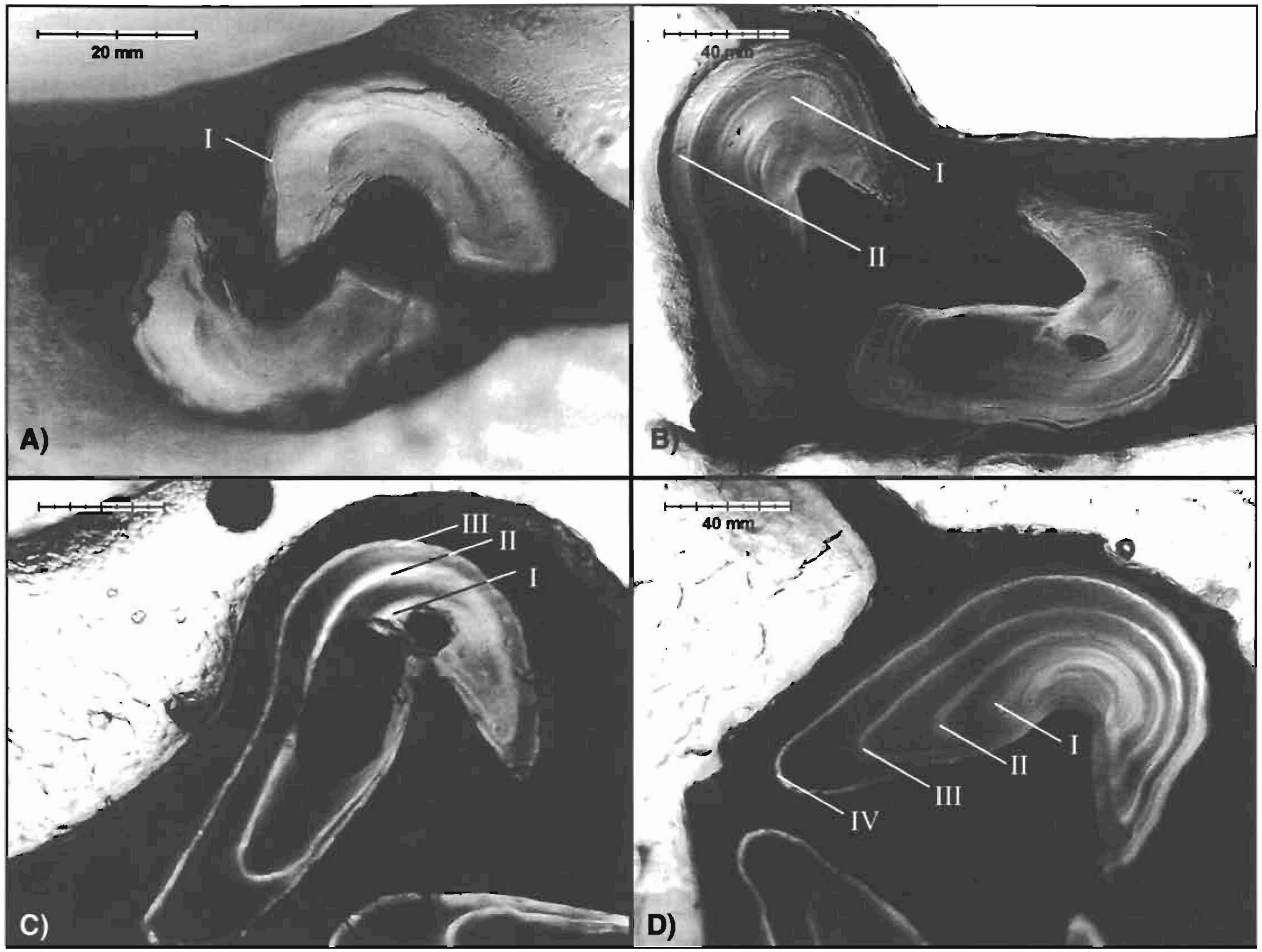
Record ID	Length (mm)	2nd Dorsal Annular Diameters (mm)		1st Dorsal Annular Diameters (mm)	
		1st annulus	2nd annulus	1st annulus	2nd annulus
190	446	0.39	0.78	0.41	0.62
193	454	0.41	0.78	0.46	0.60
192	462	0.40	0.70	0.40	0.60
163	465	0.46	0.65	--	--
174	470	0.45	0.64	0.40	0.64
173	472	0.39	0.65	0.36	0.82
164	505	0.45	0.70	0.40	0.72
180	506	0.40	0.80	0.43	0.70
215	537	0.42	0.68	--	--
166	540	--	--	0.32	0.63
162	542	0.50	0.72	--	--
165	545	0.46	0.67	0.42	0.83
161	555	--	--	0.37	0.80
212	557	0.46	0.75	--	--
216	558	0.41	0.83	--	--
218	559	0.47	0.75	--	--
211	570	0.39	0.68	--	--
213	570	0.40	0.72	--	--
210	578	0.42	0.70	--	--

Appendix Table 4. Fork lengths and annular measurements from the second dorsal fin for juvenile lingcod collected from the commercial fishery off the south west coast of Vancouver Island (Area 3C) in August and September 2001.

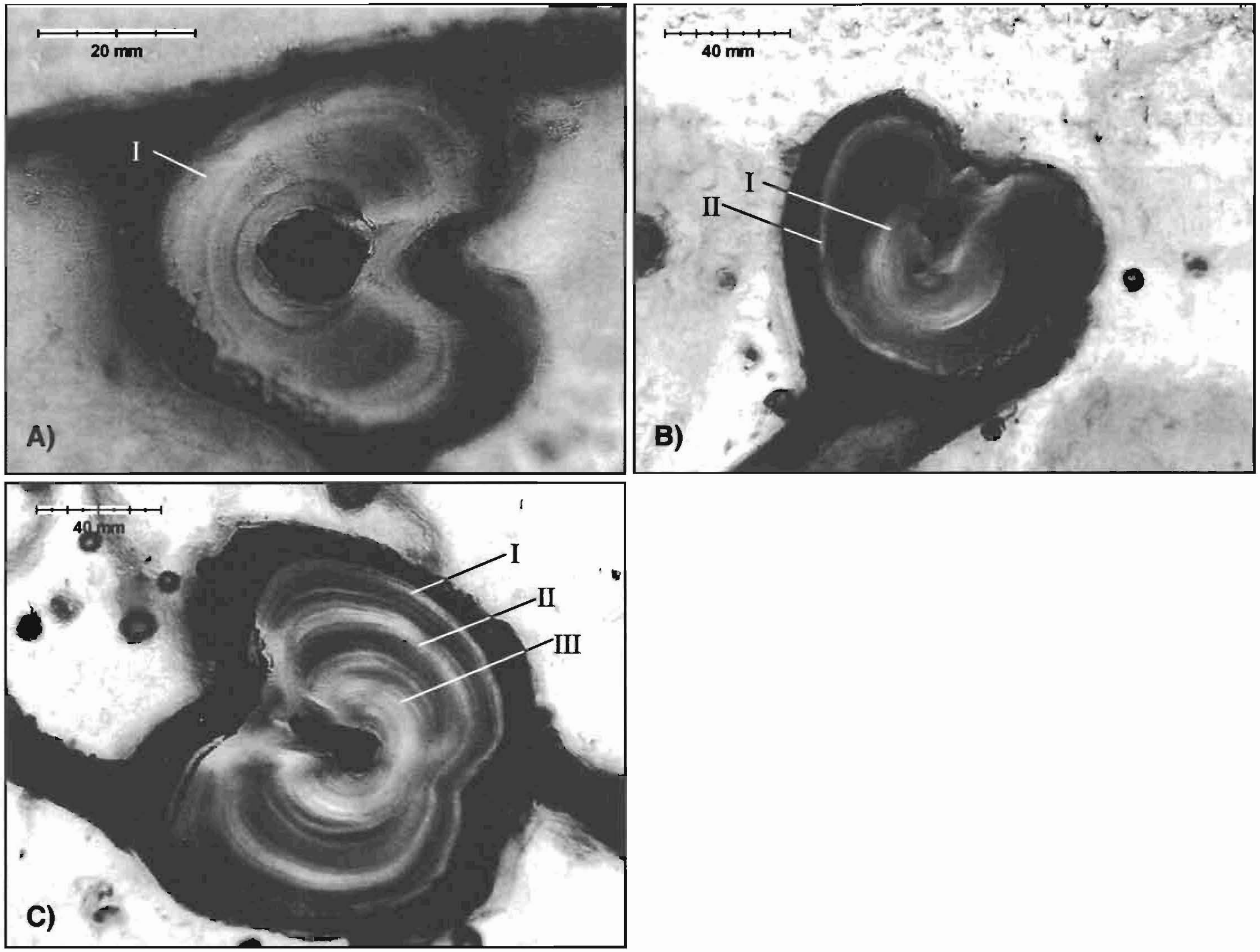
Record ID	Length (mm)	Annular Diameter (mm)	
		1st Annulus	2nd Annulus
65	456	0.40	0.57
85	457	0.42	--
88	477	0.45	0.60
125	490	0.39	0.62
89	491	0.52	--
128	495	0.39	0.78
86	498	0.46	--
93	498	0.48	--
90	505	0.50	0.67
92	514	0.42	0.65
121	525	0.40	0.65
127	525	0.40	0.70
130	525	0.40	0.60
91	533	0.50	0.70
124	553	0.45	0.75
69	568	0.42	0.70
123	570	0.43	0.75
66	573	0.41	0.65
126	580	0.50	0.68
129	580	0.40	0.73
70	593	--	0.68
67	599	0.40	0.75

Appendix Table 5. Fork lengths and annular measurements from the second dorsal fin for juvenile lingcod collected from the commercial fishery in Queen Charlotte Sound (Area 5AB) in August and September 2001.

Area	Record ID	Length (mm)	Annular Diameter (mm)		Area	Record ID	Length (mm)	Annular Diameter (mm)	
			1st Annulus	2nd Annulus				1st Annulus	2nd Annulus
5A	16	452	0.36	0.72	5B	10	532	0.40	0.64
5A	61	471	0.39	0.71	5B	59	534	0.49	0.90
5A	110	472	0.35	0.63	5B	97	540	0.41	0.75
5A	60	475	0.45	0.73	5B	6	541	0.38	0.62
5A	15	478	0.48	0.60	5B	27	541	0.35	0.68
5A	18	483	0.47	0.75	5B	35	542	0.40	0.70
5A	13	515	0.45	0.80	5B	46	545	0.39	0.58
5A	17	518	0.44	0.68	5B	101	548	0.43	0.62
5A	40	520	0.39	0.62	5B	48	549	0.33	0.55
5A	39	532	0.44	0.73	5B	99	550	0.40	0.60
5A	63	538	0.45	0.74	5B	23	552	0.40	0.62
5A	14	561	0.36	0.76	5B	49	552	0.36	0.60
5A	108	563	0.45	0.75	5B	22	554	0.35	0.67
5A	109	563	0.45	0.70	5B	53	554	0.37	0.56
5A	72	567	0.44	0.74	5B	31	559	0.39	0.75
5A	62	569	0.42	0.73	5B	24	561	0.35	0.65
5A	105	571	0.45	0.75	5B	54	561	0.38	0.57
5A	12	572	0.50	0.76	5B	58	563	0.47	0.77
5A	45	580	--	0.71	5B	30	564	0.38	0.70
5A	44	586	0.42	0.81	5B	3	566	0.33	0.70
5A	71	586	0.45	0.80	5B	29	566	0.44	0.75
5A	38	587	0.45	0.65	5B	47	566	0.38	0.58
5A	74	590	0.40	0.75	5B	52	566	0.39	0.55
5A	43	591	0.43	0.72	5B	7	567	0.40	0.67
5A	73	595	0.41	0.74	5B	116	570	0.50	0.72
5A	75	595	0.43	0.65	5B	132	573	0.42	0.76
5B	145	449	0.42	0.58	5B	26	574	0.42	0.63
5B	9	460	0.48	0.72	5B	20	578	0.44	0.62
5B	50	467	0.40	--	5B	136	578	0.45	0.75
5B	111	480	0.37	0.67	5B	5	579	--	0.60
5B	120	480	0.40	0.70	5B	134	579	0.41	0.75
5B	98	490	0.45	0.72	5B	137	579	0.44	0.75
5B	115	490	0.40	0.78	5B	28	580	0.48	0.76
5B	118	490	0.45	0.65	5B	114	580	0.42	0.69
5B	104	495	0.40	0.82	5B	147	580	0.42	0.75
5B	140	495	0.40	0.68	5B	55	582	0.38	0.68
5B	141	496	0.48	0.65	5B	36	584	0.48	0.68
5B	102	500	0.53	0.97	5B	32	585	0.38	0.57
5B	113	500	0.39	0.75	5B	2	588	0.40	0.70
5B	119	500	0.41	0.75	5B	57	588	0.38	0.55
5B	11	503	0.36	0.67	5B	131	589	0.40	0.70
5B	37	505	0.36	0.60	5B	135	592	0.42	0.75
5B	143	517	0.42	0.73	5B	1	596	0.39	0.62
5B	144	526	0.45	0.66	5B	133	597	0.45	0.78
5B	146	527	0.45	0.64	5B	142	597	0.48	0.85
5B	4	530	0.41	0.72	5B	21	598	0.36	0.60
5B	94	530	0.48	0.70	5B	25	599	0.45	0.70
5B	100	530	0.47	0.70	5B	34	599	0.44	0.88
5B	117	530	0.38	0.65	--	--	--	--	--



Appendix Figure 1. Photos of representative second dorsal fin ray sections from juvenile lingcod illuminated with transmitted light under a compound microscope at 4x magnification, unless otherwise indicated. Annuli are indicated by Roman numerals. A) age-1 at 10x magnification, showing a very wide translucent zone at the first annulus; B) age-2, showing a small amount of resorption in the centre of one element; C) age-3, with the first annulus almost completely obscured by resorption; D) age-4, showing very clear annuli with no resorption.



Appendix Figure 2. Photos of representative first dorsal fin ray sections from juvenile lingcod illuminated with transmitted light under a compound microscope at 4x magnification, unless otherwise indicated. All show a small amount of resorption at the centre. Annuli are indicated by Roman numerals. A) age-1 at 10x magnification; B) age-2; C) age-3.