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Age and growth of Patagonian toothfish (*Dissostichus eleginoides*) and Antarctic toothfish (*D. mawsoni*) in waters from the New Zealand subantarctic to the Ross Sea, Antarctica

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Abstract

The margins of otoliths of Patagonian toothfish (*Dissostichus eleginoides*) from several samples collected throughout the year were classified as either opaque or translucent. The margins were generally opaque in summer and translucent in winter. Thus, this species appears to deposit one translucent zone in its otoliths each year, and counts of these zones are probably a valid method to determine fish age. Comparisons of readings of *D. eleginoides* otoliths by workers from various institutions indicated a reasonable between-reader consistency, but still suggested that the otoliths were difficult to read. Von Bertalanffy growth parameters were calculated from the author's readings only, separately by sex, for *D. eleginoides* caught from waters south of New Zealand to the Ross Sea, Antarctica, by longline and trawl fisheries. *D. eleginoides* appear to be moderately fast growing, at least to about age 10, and reasonably long-lived, reaching at least 50 years. Females grow at a faster rate and reach a larger size than males, but both sexes exhibit comparable maximum ages.

Von Bertalanffy growth parameters were also calculated, separately by sex, for Antarctic toothfish (*Dissostichus mawsoni*) caught by the longline fishery in the northern Ross Sea. Otoliths of this species were interpreted similarly to those of *D. eleginoides*, but this method of ageing *D. mawsoni* is invalidated. *D. mawsoni* appears to be moderately fast growing, at least to about age 10, and can live for at least 35 years. This species probably grows at a slightly faster rate, and reaches a larger size than *D. eleginoides*.

Keywords: Age determination; Otoliths; Otolith reading; *Dissostichus eleginoides*; *Dissostichus mawsoni*

1. Introduction

There are two species of toothfish: Patagonian toothfish, *Dissostichus eleginoides*, and Antarctic toothfish, *Dissostichus mawsoni*. They are similar in appearance, have been caught at depths between 70 and 2000 m, and both are predators of fish and squid (Fischer and Hureau, 1985). *D. eleginoides* occurs around some subantarctic islands and seamounts between about 50 and 60°S, including the southern New Zealand Exclusive Economic Zone (EEZ), where it is rare. It is also found on the continental shelf off the coasts of Chile and Argentina south of about 40°S. *D. mawsoni* occurs around mainland Antarctica, generally south of 60°S (DeWitt et al., 1990). The distribution of the two species overlaps north of the Ross Sea in CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) Sub-area

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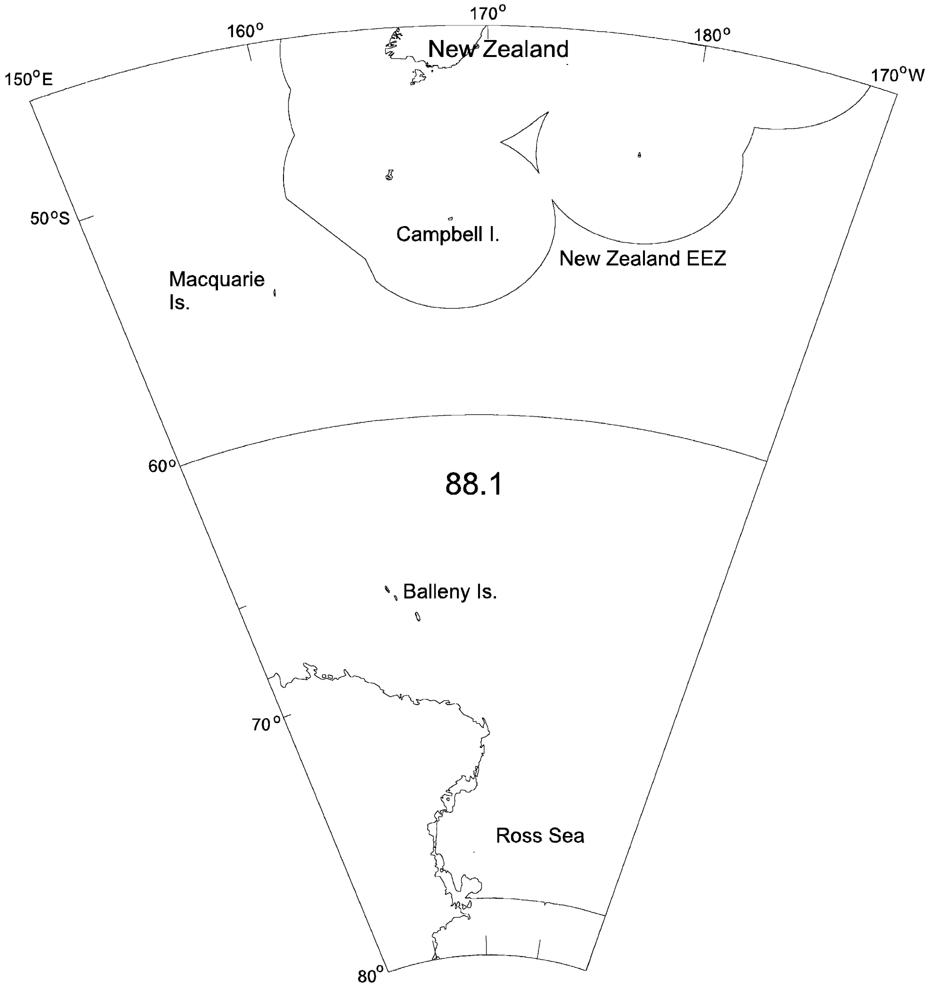

Fig. 1. Area from which fish were sampled, showing CCAMLR Sub-area 88.1, the New Zealand Exclusive Economic Zone (EEZ), and Macquarie Island.

88.1 (see Fig. 1). Both species are fished in this area, and *D. eleginoides* has also been targeted by New Zealand-based vessels in international waters north of Sub-area 88.1, and in the southern portion of the New Zealand EEZ. The commercial fishery for these species has been developing in this area since the mid-1990s with reported landings in 2000 of about 750 t (primarily *D. mawsoni*).

Growth parameters, estimates of age at maturity and recruitment, and population age structures are essential inputs in fisheries yield models. Growth parameters for *D. eleginoides* have been calculated from four studies which sampled fish adjacent to southern South America (summary in Cassia, 1998), one from the Kerguelen–Heard Ridge in the southern Indian Ocean (Hureau and Ozouf-Costaz, 1980), and one from the Macquarie Ridge southeast of Australia (Kalish and Timmiss, 1998). These investigations estimated ages from counts of zones in otoliths or scales, but only Kalish and Timmiss (1998) attempted to validate the methodology by showing that the zones were formed annually. They measured levels of radiocarbon ^{14}C in 37 otolith cores formed during the first year of life, taken from throughout the distribution range of *D. eleginoides*. From ages estimated from zone counts in otolith sections, they demonstrated a trend of increasing radiocarbon starting around 1960, consistent with the hypothesised effect of atmospheric testing of atomic weapons (Kalish, 1993). Thus, they concluded that estimation of the age of *D. eleginoides* based on counts of zones in otoliths is probably accurate. The use of scales to determine ages for the *Dissostichus* species probably leads to an underestimation of true age (Ashford et al., 2000).

No estimates of growth are available for *D. eleginoides* in the New Zealand EEZ or in CCAMLR Subarea 88.1. This work aimed to develop a reliable and validated ageing methodology for this species using an otolith marginal increment analysis, and to calculate growth parameters for toothfish from the southern New Zealand EEZ to the Ross Sea. It also aimed to check the consistency of otolith interpretation between institutions that have recently produced growth parameters for *D. eleginoides*.

The only growth data available for *D. mawsoni* are from the otoliths of 46 fish caught in McMurdo Sound (Burchett et al., 1984) and 20 fish caught in the northern Ross Sea (Horn, 1998). Neither of these studies used a validated methodology. DeVries and Eastman (1998) also reported growth increments from 13 tagged recaptured *D. mawsoni* from McMurdo Sound. The current work aimed to develop growth parameters for this species also.

2. Methods

2.1. *D. eleginoides*

2.1.1. *Age determination and indirect validation*

Otolith samples from *D. eleginoides* were available from the New Zealand EEZ, the Macquarie Ridge in the Australian EEZ, CCAMLR Sub-area 88.1, and international waters north of Sub-area 88.1 (Fig. 1). The collections had been made in various months from 1995 to 1999. Otoliths were selected to enable an age validation study involving an examination of the state of the otolith margin throughout the year. Suitable monthly samples were available from October, and December to June, with an additional small sample from August (Table 1). In combining samples from several years and areas to create data for a single ''synthetic'' year, it was assumed that inter-annual variability in otolith growth patterns was negligible.

Otoliths from the southern Macquarie Ridge collected in December, January, and February 1996 had been prepared in Australia using the method described by Kalish and Timmiss (1998), i.e., transverse sections about 0.5 mm thick were cut from untreated otoliths, mounted on glass slides and polished. All other otoliths examined in this work were baked whole in an oven at 275 °C for about 12 min, until amber coloured.

Table 1
Details of samples of *D. eleginoides* otoliths examined by month, year, and area

Month	Year	Area	Margin[a]	Aged[b]
January	1996	South Macquarie Ridge	23	23
	1997	South Macquarie Ridge	23	24
February	1996	South Macquarie Ridge	6	6
	1998	Ross Sea	16	17
March	1998	Ross Sea	27	32
	1996	North Macquarie Ridge	38	295
April	1996	North Macquarie Ridge	84	131
May	1997	Ross Sea	17	17
	1997	International waters (north of 88.1)	28	30
	1997	Southern Campbell Plateau	28	88
June	1997	Southern Campbell Plateau	10	13
	1995	Southern Campbell Plateau	11	0[c]
August	1995	Southern Campbell Plateau	3	3
October	1998	South Macquarie Ridge	44	44
December	1996	South Macquarie Ridge	46	47

[a] Number of confidently classified otolith margins.
[b] Number of successfully aged fish.
[c] No length data were associated with these otoliths.

They were then embedded in epoxy resin and sectioned transversely through the nucleus. The sectioned surfaces (and the mounted sections) were examined using reflected light under a binocular microscope at ×40, the number of complete translucent (dark) zones was counted, and the margin just ventral to the sulcus was classified as either translucent or opaque. Zone counts were generally made on the ventral part of the section, either on the proximal surface adjacent to the sulcus or along the dorso-ventral axis (Fig. 2). Sometimes the count was started near the sulcus, but finished in some other area of the proximal surface; counts in the two areas were linked by tracing a clear zone across the section. The margins were generally too narrow, or the borders between the opaque and translucent zones too indistinct to allow measurement of the width of the last incomplete zone.

A sample of 360 *D. eleginoides* otoliths, additional to those used in the examination of marginal state, was prepared and read to create sufficient age data (a total of about 760 readings) to allow the calculation of comprehensive von Bertalanffy parameters using a non-linear least-squares regression procedure (SAS Institute, 1988). The additional otoliths were derived from the Macquarie Ridge in 1996 and the Southern Campbell Plateau in 1995 (see Table 1). Separate equations were derived for each sex using only the results produced by a single reader (R1).

2.1.2. Age verification

Age data produced by four readers (R1, R2, R3, R4) all familiar with toothfish otoliths, and from different institutions, were compared. R1, R2, and R3 all examined a sample of 60 otoliths from the same fish, prepared in New Zealand as described above. R1 and R4 examined a set of 100 otoliths prepared in Australia as described above. Indices of average percentage error (IAPE) (Beamish and Fournier, 1981) were produced for comparisons between R1 and the other three readers. This index is independent of fish age, and is used to compare precision within or between readers. Greater precision is achieved as the IAPE is minimised.

2.2. D. mawsoni

A sample of about 1520 otoliths of *D. mawsoni* was selected from collections made in Sub-area 88.1 in 1998, 1999, and 2000. These otoliths were prepared and interpreted in the same manner as for *D. eleginoides* otoliths prepared in New Zealand. Von Bertalanffy parameters were calculated, separately by sex, using a non-linear least-squares regression procedure (SAS Institute, 1988). It was not possible to conduct an age validation study similar to that presented for *D. eleginoides* as otolith samples from *D. mawsoni* were available only from February and March.

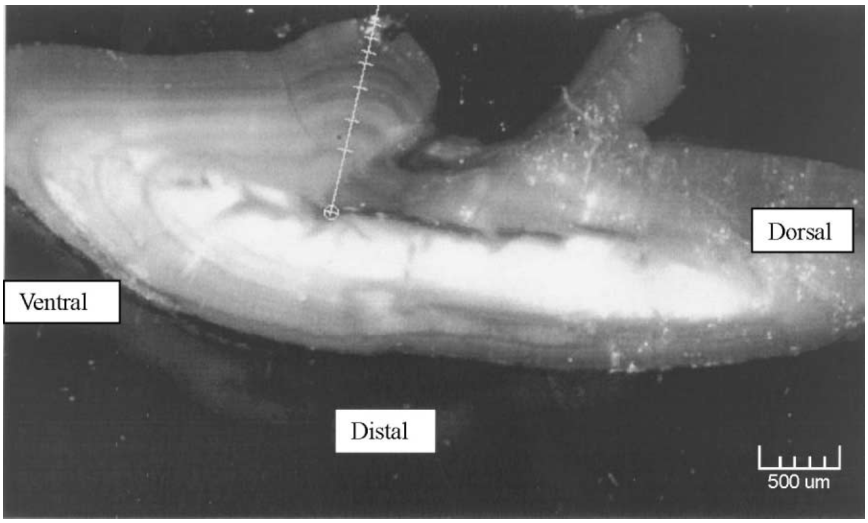

Fig. 2. Section through an otolith of *D. eleginoides* estimated to be age 7. Note the relatively dark (translucent) fourth zone, and the clarity of the three zones inside the dark zone.

3. Results

3.1. *D. eleginoides*

3.1.1. *Otolith interpretation*

The clarity of the zonation pattern in otoliths of *D. eleginoides* varied considerably, but zone counts were derived for over 95% of otoliths examined. Interpretation of the first three to five growth zones was often complicated because of an abundance of what were considered to be false rings (also noted by Cassia, 1998). The conclusion that they were false was based on the occurrence in many relatively clear otoliths of an exceptionally dark growth zone (usually the fourth zone, but sometimes third or fifth) This characteristic is shown in Fig. 2. The very dark zone was also generally apparent in otoliths with the confusing multiple banding structure, and it could be used as a boundary inside which the false rings could usually be subjectively, but logically, grouped into three (but sometimes two or four) multi-banded zones (Fig. 3). Zones outside the dark growth zone were generally narrow and regular in width, but sometimes a region of transition was apparent outside the darkest zone where consecutive annuli became increasingly narrow before becoming regular in width.

3.1.2. *Age validation*

Determining whether an otolith margin was translucent or opaque was difficult at times, particularly for older fish, which had very narrow otolith zones. Sometimes an age could be allocated to an otolith with reasonable confidence, though its marginal state was very unclear. In these situations, the data were used in the calculation of growth parameters, but not for classification of marginal state.

The proportions of otoliths with opaque margins in each monthly sample are presented in Fig. 4. Although only one small otolith sample was available for July–September, the data indicate that opaque material is laid down probably from about September until February. Translucent material begins to be laid down after February, and by June virtually all otoliths have a translucent margin. Thus, it appears very likely that one opaque and one translucent zone are laid down each year in otoliths of *D. eleginoides*.

However, this study has not demonstrated how old the fish is when the first zone is laid down. Spawning by *D. eleginoides* is believed to occur from about July to September (Kock and Kellermann, 1991). The translucent zone appears to be completed sometime after June but before October. Hence, it is suggested that *D. eleginoides* are just over 1-year-old at the time of completion of the first translucent zone, and that a

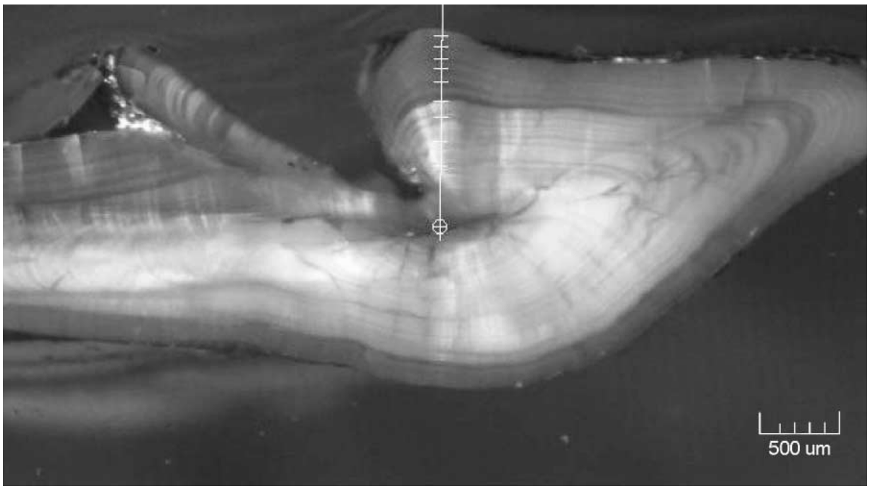

Fig. 3. Section through an otolith of *D. eleginoides* estimated to be age 9. Note the relatively dark (translucent) zone (denoted as the fourth zone), and the multiple banding structure inside that zone. The white ladder scale originating from the nucleus indicates how the multiple banding has been grouped into three distinct zones.

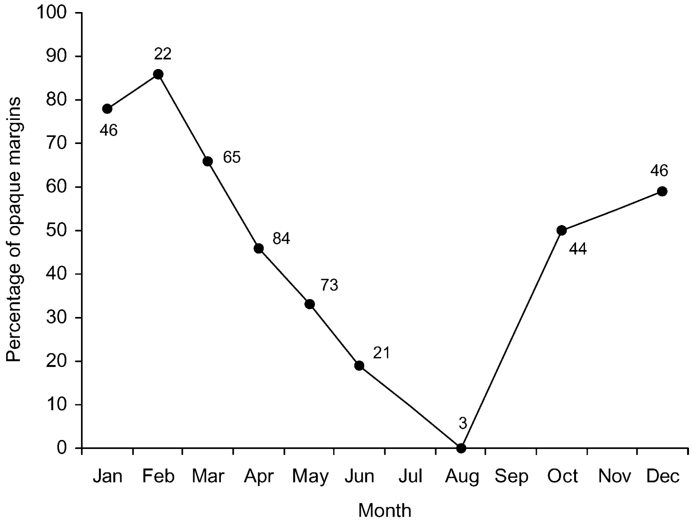

Fig. 4. Seasonal change in the percentage of *D. eleginoides* otoliths with an opaque margin. Numbers adjacent to symbols denote sample size. For details of area and year of sample collection, see Table 1.

count of the translucent zones will provide a reliable estimate of fish age. Thus, a count of four translucent zones and a translucent margin indicates a fish approaching its fifth birthday, while a count of five translucent zones and an opaque margin indicates a fish aged 5+ years. Part year growth was not incorporated in this study as most of the aged fish were from a relatively narrow sampling period (i.e., March–May).

3.1.3. Between-reader comparisons

Age readings by R1 are compared with those of the other three readers in Fig. 5. Details of the comparisons and IAPEs (Beamish and Fournier, 1981) are presented in Table 2. Readers R1, R2, and R4 appear to interpret otoliths similarly, although there may be a trend for R4 to read younger fish (i.e., less than 8 years) slightly older, and for R2 to read older fish (i.e., greater than 10 years) slightly younger, than R1. The

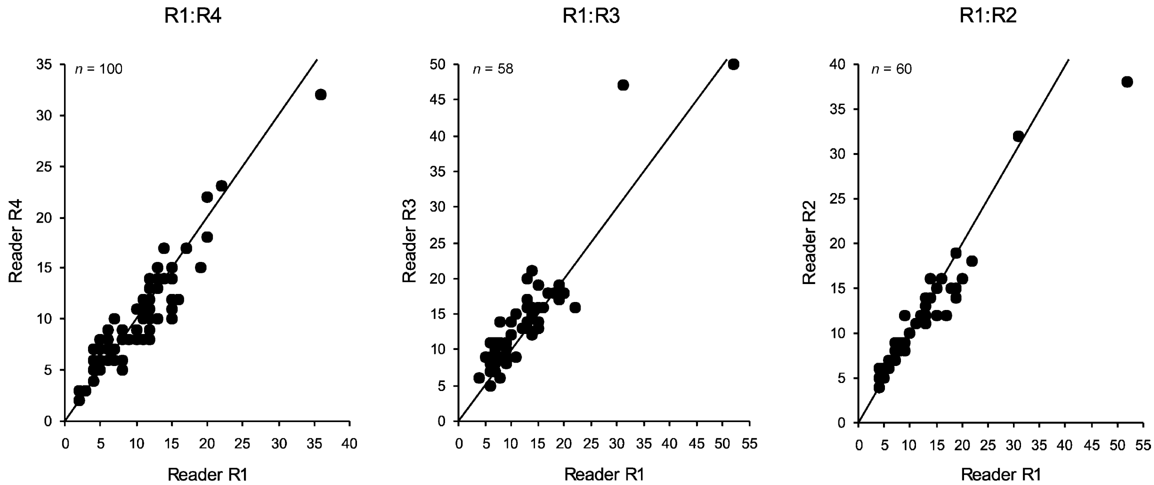

Fig. 5. Comparisons of ages allocated to sets of *D. eleginoides* otoliths by four readers (i.e., readings by R1, compared with those by R2, R3, and R4). Diagonal lines represent the relationship of perfect between-reader agreement. *n*, sample size.

Table 2
IAPE from comparisons of age data for *D. eleginoides* derived by reader R1 with data derived by other three readers (R2, R3, R4)

Reader	n[a]	IAPE (%)
R2	60	4.3
R3	58	10.6
R4	100	6.8

[a] Sample size.

comparison between R1 and R3 indicates that R3 reads consistently older over the entire age range.

3.1.4. Growth parameters

All age–length data derived for *D. eleginoides* in this study are plotted, separately by sex, in Fig. 6. Ages ranged from 2 to 53 years, though fish older than 23 years were not common. Calculated von Bertalanffy growth parameters are presented in Table 3. As for many teleosts, female *D. eleginoides* appear to grow to a larger size, and have a faster growth rate, than males.

3.2. D. mawsoni

Sections through otoliths of *D. mawsoni* exhibited a structure very similar to that observed in *D. eleginoides* otoliths. A relatively dark (translucent) zone at about age 4 was often apparent, but it was generally less distinctive than the comparable zone in *D. eleginoides* otoliths. The fourth zone was usually the darkest, but this characteristic could occur from the

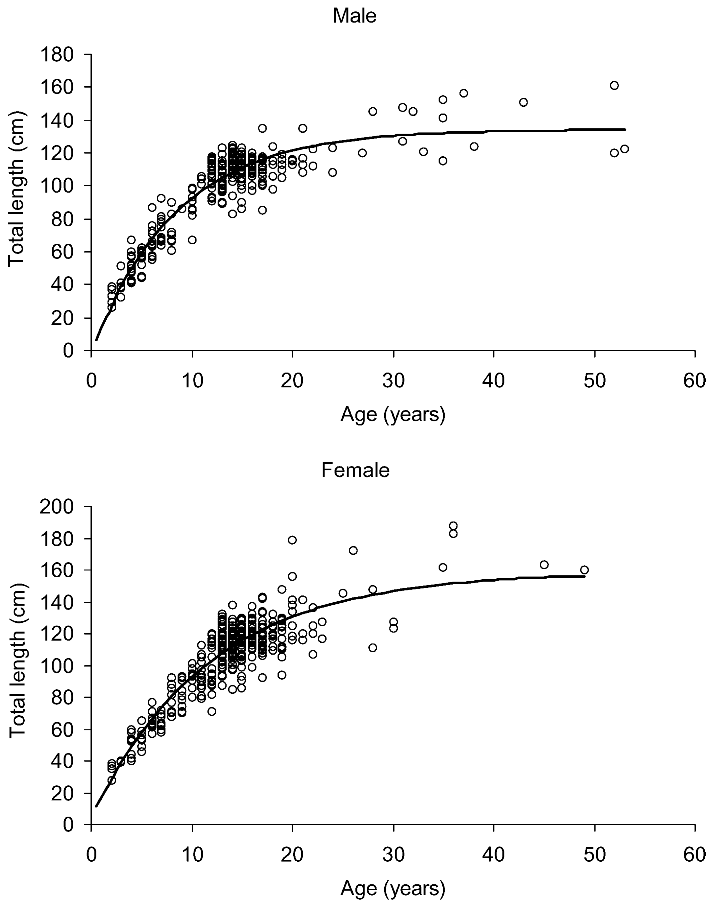

Fig. 6. Raw age–length data and the calculated von Bertalanffy growth curves for male and female *D. eleginoides* sampled from the southern New Zealand EEZ to the Ross Sea. For curve equations, see Table 3.

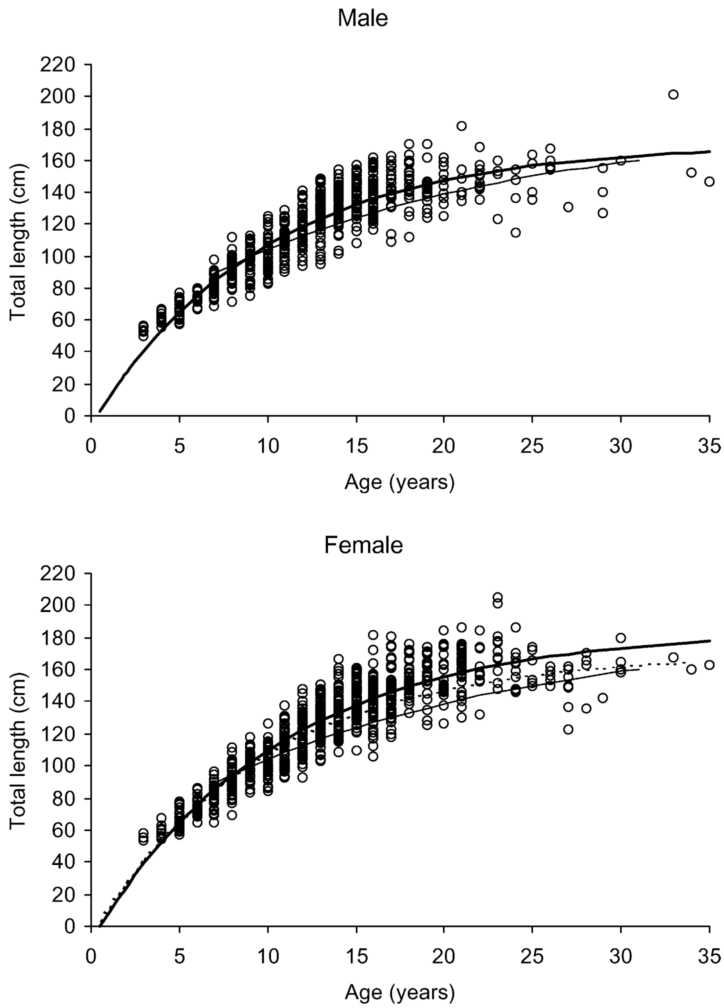

Fig. 7. Raw age–length data and the calculated von Bertalanffy growth curves (thick lines) for male and female *D. mawsoni* sampled from the Ross Sea. For curve equations, see Table 3. Thin line shows the equation calculated by Burchett et al. (1984) for both sexes combined. The curve calculated for males is also presented as a broken line on the plot of female data to enable a visual comparison of the sexual difference in growth.

third to the sixth zone, and sometimes two distinct zones of more or less equal darkness were present. Juvenile zones with multiple banding structure were also common in this species. Zones outside the dark growth zone were generally narrow and regular. However, as in otoliths of *D. eleginoides*, a region of transition was sometimes apparent outside the darkest zone where consecutive annuli became increasingly narrow before becoming regular in width.

All age–length data derived for *D. mawsoni* are plotted, separately by sex, in Fig. 7. Ages ranged from 3 to 35 years. Calculated von Bertalanffy growth parameters are presented in Table 3. All otoliths were sampled from longline catches. Because the longline fishery takes few small fish (i.e., smaller than 55 cm), those young fish that are caught are probably unrepresentative of the mean length of their age classes, so the resulting curve may poorly define juvenile growth. All the 3- and 4-year-old fish are above the fitted von Bertalanffy curve, but with the exception of data from these two age classes, the curves appear to fit the raw data reasonably well. To examine the effect on the

Table 3
Von Bertanlaffy parameters, by sex (with 95% confidence intervals) for *D. eleginoides* caught in waters from the southern New Zealand EEZ, south to CCAMLR Sub-area 88.1, and for *D. mawsoni* caught in CCAMLR Sub-area 88.1

Sex	n[a]	L_∞	k	t_0
D. eleginoides				
Male	328	134.3 (129.7–139.0)	0.118 (0.104–0.132)	0.08 (−0.39 to 0.54)
Female	435	158.7 (149.9–167.5)	0.085 (0.072–0.097)	−0.35 (−1.01 to 0.32)
D. mawsoni				
All data				
Male	661	170.3 (164.0–176.7)	0.102 (0.090–0.114)	0.31 (−0.21 to 0.82)
Female	864	184.5 (178.3–190.8)	0.095 (0.085–0.104)	0.50 (0.03 to 0.96)
Excluding 3 and 4 year data				
Male	643	165.0 (159.3–170.6)	0.119 (0.104–0.134)	1.19 (0.64 to 1.74)
Female	849	180.9 (175.0–186.7)	0.103 (0.092–0.114)	1.02 (0.52 to 1.51)

[a] Sample size.

growth parameters of the 3- and 4-year-old fish, the growth model was re-fitted to all data from fish 5 years and older (Table 3). The growth parameters changed, but resulting curves were found to be virtually identical, over the 5–28 year range, to those plotted in Fig. 7.

As in *D. eleginoides*, female *D. mawsoni* also appear to grow to a larger size, and have a faster growth rate than males.

4. Discussion

4.1. *D. eleginoides*

4.1.1. Otolith interpretation

The margins of *D. eleginoides* otoliths collected at several times throughout the year were found to be generally opaque in summer and translucent in winter. It was pleasing to note that although samples from several years and areas were combined, a clear cyclical pattern of margin condition was still apparent, indicating low levels of inter-annual or inter-areal variation. Thus, this species probably deposits one translucent zone each year, and counts of these zones are likely to be a valid method to determine fish age. No previous study has examined otolith marginal state of this species over time, though Young et al. (1992) did note that most margins were translucent in winter. The work presented here corroborates the conclusions of Kalish and Timmiss (1998), based on a trend (starting around 1960) of increasing radiocarbon in otolith aragonite deposited during the first year of a fish's life that counts of zones in otoliths is probably a valid method to age *D. eleginoides*.

However, the interpretation of zones in otoliths of *D. eleginoides* is problematic. Cassia (1998) noted the frequent occurrence of multiple banding structure in the juvenile section of the otoliths; similar characteristics were observed in the current work. Ashford and Wischiniowski (1998) proposed two otolith interpretation models, but did not attempt a validation of either. One model (C1) included all zones along a count path as long as they persisted clearly on both sides of the path. The second model (C2) counted zones only if they persisted on both the proximal and distal sides of the section. In general, counts using C1 were greater than those using C2 by about 4.

The otolith interpretation model used in the current study was similar to C2 of Ashford and Wischiniowski (1998) except that zones were counted only on the ventral, rather than the dorsal, part of the section. It has been shown that this is probably a valid ageing method, although the validation was derived by combining marginal state data from all age classes combined, rather than validating individual year classes. Insufficient marginal state data from throughout the year are available for age classes 2–4 to indicate whether the interpretation of these zones was correct. However, the frequently observed occurrence of a distinctive fourth zone (although sometimes the third or fifth zones were the most distinctive) in most otoliths with clear juvenile zones does indicate that this characteristic could be similarly interpreted in otoliths with less clear juvenile zones.

4.1.2. Between-reader comparisons

The comparisons of age data produced by four readers indicated a reasonable consistency. Reader R3 generally produced older ages, but it was noted that he used model C1 of Ashford and Wischiniowski (1998). The bias between R1 and R3 did not appear to change with age, so it is likely that it was caused by the different interpretations of the first few increments (i.e., the difference between interpretation models C1 and C2). The indices of average percent error for comparisons between R1, R2 and R4 are satisfactory, but do suggest that otoliths of *D. eleginoides* are not particularly easy to read. Kalish and Timmiss (1998) compared readings from 34 otoliths (most older than 15 years) and showed that the difference between the two readers was generally 4 or less, but that this sometimes equated to a percentage error for individual fish of 33%. The IAPE for the data set presented by Kalish and Timmiss (1998) is 5.1%.

Kalish and Timmiss (1998) recorded a maximum age of 43 years, with fish over 38 years recorded from Macquarie Island, Prince Edward Island, and off southern South America. Aguayo (1992) aged females from South Georgia to 35 years, but males to only 20 years. Cassia (1998) reported a maximum age of 24 years also from South Georgia. The maximum age of 53 years estimated from the current work indicates that *D. eleginoides* are long-lived. Maximum ages for males and females were comparable, i.e., 53 for males and 49 for females. However, most fish caught by the commercial longline fishery in and adjacent to the New Zealand EEZ were aged from about 10 to 20 years. The commercial trawl fishery around Macquarie Island catches younger fish (owing to differences in gear selectivity between line and trawl, and differences in fish distribution by size), with most ranging in age from 3 to 16 years (Kalish and Timmiss, 1998).

4.1.3. Growth parameters

Von Bertalanffy growth parameters were calculated, separately by sex, using all the age data derived by reader R1. These equations are probably applicable to *D. eleginoides* in the general region from the Ross Sea to the New Zealand EEZ as they are based on the full size range of fish taken by commercial operations trawl and longline in this area. An analysis of mitochondrial DNA indicated that *D. eleginoides* from the Macquarie Ridge and Ross Sea areas probably comprise a single genetic stock (P. Smith and P. Gaffney, NIWA, pers. comm.). The species appears to be moderately fast growing, and quite long-lived. There are significant differences between sexes in size at age, with females growing faster and bigger than males. A similar conclusion was drawn by Kalish and Timmiss (1998) for *D. eleginoides* from the Macquarie Ridge. However, Aguayo (1992) and Young et al. (1992) found no sexual differences in growth for fish off southern South America. Cassia (1998) did not test for differences. Based on length–frequency distributions of *D. eleginoides* caught at various locations around the Antarctic (e.g., see Moreno, 1998; López Abellán and González Jiménez, 1999), the largest fish tend to be female, indicating that there are sexual differences in growth in those areas also.

A comparison of the various growth curves calculated for *D. eleginoides* shows wide variation, although most are consistent up to about age 15 (Fig. 8). There is a trend showing curves for fish off South America to have higher L_∞ values, and more rapid growth, than those from south of New Zealand. It is not known whether this is a true biological difference, or an artefact of sample characteristics or otolith interpretation differences. Analyses of mitochondrial DNA have indicated genetic differences between *D. eleginoides* from these two areas (P. Smith and P. Gaffney, NIWA, pers. comm.). Differences in curves from Cassia (1998), Kalish and Timmiss (1998), and the current study are unlikely to have been caused by different otolith interpretation as the readers who produced them have been shown above to read otoliths similarly. Differences in the length range of the aged samples can influence the calculated parameters; the shape of a fitted curve can be altered markedly by, for example, adding a few very large or old fish to a data set. The differences in the curves calculated by Kalish and Timmiss (1998) and in the current study for *D. eleginoides* from waters south of New Zealand are probably caused by the sampling method. Kalish and Timmiss had access only to trawl-caught fish, which are generally smaller than those caught by longline (author's unpublished data). They noted the poor fit of their data to the von

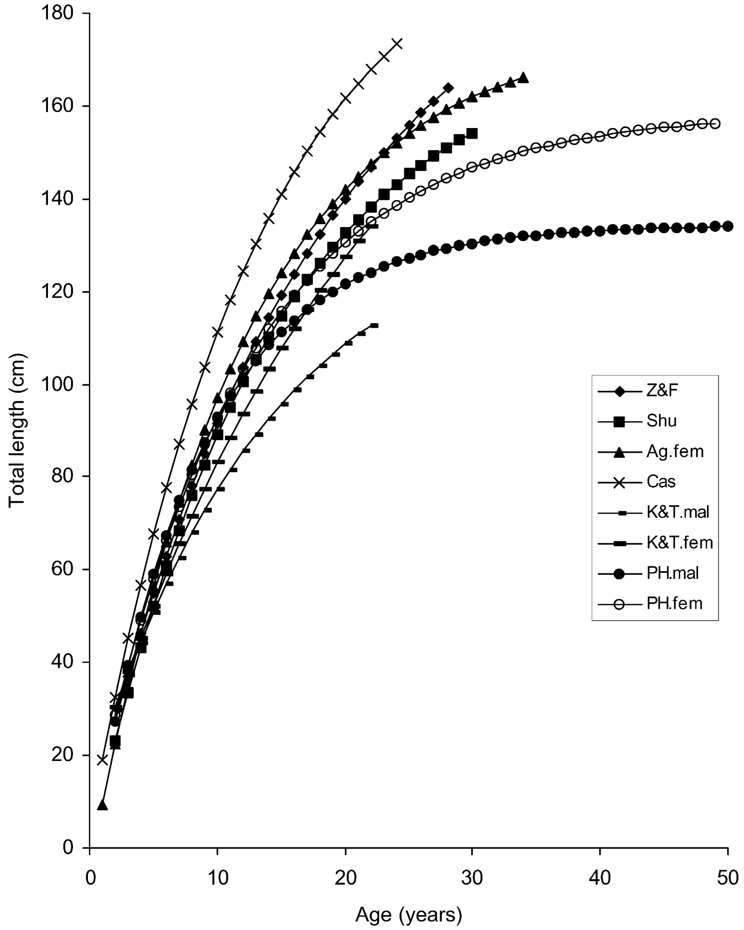

Fig. 8. Von Bertalanffy growth curves calculated for *D. eleginoides*. Z&F, Zakharov and Frolkina (1976); Shu, Shust et al. (1990); Ag.fem, Aguayo (1992) females; Cas, Cassia (1998); K&T, Kalish and Timmiss (1998) male and female; PH, current study male and female. Z&F, Shu, Ag, and Cas analysed samples from off southern South America; K&T and PH sampled south of New Zealand.

Bertalanffy model, and attributed this to the lack of very small and large fish. Fish aged in the current study were derived from both the longline and trawl fisheries, ranged from 28 to 190 cm, and so probably represent most of the size range of the population. The parameters derived here are believed to provide the best currently available description of growth of *D. eleginoides* in waters south of New Zealand to the Ross Sea.

The generally observed characteristic of a marked change in otolith structure after about the fourth year is probably indicative of some change in life history. For many fish species, the reduction in otolith zone width seems often to be associated with a slowing of somatic growth at the time of onset of first maturity (e.g., Horn and Sutton, 1996; Horn, 1997). This is logical given the necessary diversion of energy into reproductive products. However, a marked change in otolith structure has seldom been linked directly to onset of maturity, and there are examples where a marked structural change is not associated with maturity (e.g., deepwater oreo species, see Francis and Horn, 1997). For *D. eleginoides* from South Georgia, length at 50% maturity has been determined as 75–80 cm for males and 95–110 cm for females (Moreno, 1998; Everson and Murray, 1999). These lengths equate to ages of about 7 and 12 years for males and females, respectively, using the growth curves from the current study, or ages 6 and 9 years, respectively, using the growth equation from Cassia (1998). Hence, the change in structure in otoliths of *D. eleginoides* is probably not related to onset of sexual maturity. However, it could be related to a change in habitat or feeding. García de la Rosa et al. (1997) concluded that juvenile *D. eleginoides* are pelagic predators, and adults are benthic feeders capable of undertaking feeding migrations in pelagic waters.

4.2. *D. mawsoni*

The growth parameters presented for *D. mawsoni* are based on the most comprehensive data set yet produced. However, although the otoliths appear quite similar to those of the *D. eleginoides*, and they were interpreted similarly, the method used to age this species is invalidated.

It is possible that otolith interpretation in the present study was different from that of Burchett et al. (1984). They described the otoliths as having ''an easily recognisable nucleus with seven to eight large annuli, followed by narrower and more regular annuli'', and concluded that the reduction in zone width after about the seventh or eighth zone was indicative of onset of maturity. In the present study, three to six large annuli were generally identified, but Burchett et al. (1984) may have included zones in the section of transition as ''large'' annuli. However, even though the described patterns of otolith interpretation appear to differ between the two studies, the calculated growth curves are quite similar.

D. mawsoni appear to grow faster, and possibly reach a larger maximum size, than *D. eleginoides*. However, the maximum recorded age (35 years) is less than that for *D. eleginoides*. The growth curves calculated for male and female *D. mawsoni* are similar to that calculated by Burchett et al. (1984) from 46 fish of undetermined sex (see Fig. 7). Parameters presented here are based on a much larger data set, and comprehensively cover the size range of fish caught by the longline fishery. However, because this fishery catches few small fish (i.e., smaller than 55 cm), and those that are caught may be unrepresentative of the mean length of their age classes, the curve may poorly define juvenile growth. Growth data derived from 13 recaptured tagged *D. mawsoni* from McMurdo Sound indicated an annual growth rate of 2.3 cm yr^{-1} (DeVries and Eastman, 1998). This is generally less than the expected growth rate indicated by the calculated von Bertalanffy curves which suggest rates of about 2–5 cm yr^{-1} for fish aged from 8 to 25 years. However, the adverse effects of tagging on growth rates has been noted for other teleosts (e.g., Stevens and Kalish, 1998), and could be a factor in this comparison also. It is suggested that the parameters presented here for *D. mawsoni* are currently the best available to describe the growth of this species.

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