Age and growth of greenback flounder (*Rhombosolea tapirina*) from southern New Zealand

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EXECUTIVE SUMMARY

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Two hundred and seventy-five greenback flounder were sampled from southern New Zealand waters. Biological data, including fish length, weight, sex, and gonad maturity were collected from all specimens.

Regression equations for defining length-weight relationships were calculated and presented for male and female fish separately and for both sexes combined.

Counts of growth zones in unprepared whole otoliths and prepared thin-sectioned otoliths were used to determine ages, von Bertalanffy growth parameters, and natural mortality. Growth is rapid throughout the lifespan of greenback flounder. Females reached a slightly greater maximum length than males, but the difference was not significant at the 95% level of confidence. Differences in growth rate were also not significant at this level. Over 90% of sampled fish were 2 or 3 years of age, with maximum ages of 5 and 10 years being obtained for male and female fish respectively.

Ageing error was considered to be minimal, as both within-reader and between-reader ageing variability showed no significant systematic difference or bias.

Natural mortality was 0.85 for males and 0.42 for females. It is suggested that 0.85 is the most appropriate estimate at this stage as only 1% of all fish exceeded 5 years.

Greenback flounder growth parameters and identification difficulties are discussed, and it is concluded that the species should continue to be managed as a single (FLA) complex under the Quota Management System (QMS).

1. INTRODUCTION

This document reports the results of Ministry of Fisheries Project FLA2006-01. The project objective was to determine the age and growth of greenback flounder (*Rhombosolea tapirina*).

Greenback flounder (Figure 1) occur in southern Australian waters and off southeast New Zealand to depths of about 100 m (Paul 2000). The fishery is mainly confined to the inshore domestic trawl fleet, which targets mixed finfish species.

Greenback flounder are managed as a single stock complex (FLA) under the Quota Management System (QMS) (Ministry of Fisheries 2008). The complex comprises seven other flatfish species including yellowbelly flounder (*Rhombosolea leporina*), sand flounder (*R. plebeia*), black flounder (*R. retiaria*), lemon sole (*Pelotretis flavilatus*), New Zealand sole (*Peltorhamphus novaezeelandiae*), brill (*Colistium guntheri*), and turbot (*C. nudipinnis*). This "single stock" management approach means that many fishers and processors use the generic flatfish code (FLA) to report estimated catches of all flatfish species (Ministry of Fisheries 2008). This makes it difficult to accurately quantify the amount of greenback flounder caught in New Zealand waters. However, total landings are likely to be relatively small given the limited distribution of this species.

Little previous work has been undertaken on greenback flounder. There are limited published data describing feeding, maturation and osmo-regulation (Purser 1998). Reproduction has been investigated by Barnett (1999) and physiology by Poortenaar (2000).

Similarly, flatfish age and growth studies are very limited. Historically, most ageing in New Zealand has focused on yellowbelly flounder and sand flounder, which are both fast growing, short lived (3–4 years) species (Colman 1974, Kirk 1988, Stevens & Sutton 2006). Research on lemon sole (Gowing et al. unpublished results) and New Zealand sole (James 1969, Stevens et al. 2004) has shown these two species also to be relatively short lived, reaching maximum ages of 5 years and 7 years, respectively.

These findings support the widely held view that New Zealand flatfish species are productive and subject to substantial fluctuations in recruitment. Consequently, flatfish TACCs have purposely been set at high levels to provide fishers with the flexibility to take advantage of the inherent variability associated with annual abundance (Ministry of Fisheries 2008).

However, Stevens et al. (2005) examined age and growth in brill and turbot and indicated that they reach a maximum age of 21 years and 16 years, respectively. They suggested that at least these two species may be more effectively managed outside of the FLA stock complex.

The purpose of this study was to investigate the age and growth of greenback flounder in New Zealand waters for the first time. We compare the findings with previously studied flatfish species. We provide discussion on whether there is an argument for managing greenback flounder and other flatfish as discrete species.

2. METHODS

2.1 Data collection

Two hundred and seventy-five greenback flounder were sampled from southern New Zealand waters; 257 of these fish were captured during two trips undertaken by a single commercial vessel operating in Foveaux Strait during October 2008. The rest were collected during two trawl surveys conducted by R.V. *Kaharoa* off the southeast coast of South Island during 1997 and 2007. The sampling locations were all in close proximity, so it was deemed unnecessary to consider each sample separately. The *Kaharoa* samples data were included in the analysis as they comprised both small and large fish.

Biological data (including total length, weight, sex, and gonad maturity) were recorded. Sagittal otoliths were extracted from each specimen, cleaned, and stored dry in paper envelopes for later analysis.

2.2 Length-at-weight

All 257 commercially caught fish were gutted at sea. Gonads were not removed during this process enabling all specimens to be sexed. Data from these fish were then used to estimate the length-gutted weight relationships for male and female fish separately, and for both sexes combined. *Kaharoa*-sampled fish were not included in the analysis as only green fish weights were available for these data.

The length-gutted weight relationships were calculated using the equation

$$W = \alpha L^{\beta} \tag{1}$$

where W = gutted weight (g) and L = total length (cm).

2.3 Age and growth

2.3.1 Otolith preparation

Otoliths were collected from 173 male, 99 female, and 3 unsexed greenback flounder.

It was deemed appropriate to read unprepared, whole otoliths immersed in water when two or fewer growth zones were evident. All other otoliths were thin-sectioned following a modified methodology of Stevens & Kalish (1998). They were transversely aligned in rows of four before being embedded in clear epoxy resin (Araldite K142) and left to cure at 50 °C for 24 hours. Once cured, the blocks were transversely cut along the nuclear plane using a diamond-edged saw. One half of the sectioned block was mounted (otolith section down) onto a microscope slide using clear epoxy resin. Preparations were left to cure at 50 °C for 24 hours. A 1200μm diamond-coated disc was used to grind the upper surface of each mounted, sectioned block to a thickness of about 300μm.

Whole otoliths were examined under a stereo microscope (x32) illuminated by reflected light. A pattern of translucent (dark) and opaque (light) zones was evident with the number of complete opaque zones interpreted as annuli. Thin-sectioned otoliths were also examined using a stereo-microscope, but these preparations were illuminated with transmitted light. They showed a pattern of translucent (light) and opaque (dark) zones with the number of complete opaque zones interpreted as annuli. A three-point "margin-state" score and a five-point "readability" score were recorded for each otolith reading (Tables 1a, 1b, 2, and 3).

Margin-state involved categorising each otolith margin (i.e., the material outside the outermost complete opaque zone) as narrow, medium, or wide. Otoliths with a narrow margin were assigned an age equal to the zone count, whereas otoliths with a wide margin were assigned an age equal to the zone count +1 year. An additional year was added to this latter group as the margin effectively represented one full year of growth. The methodology for converting zone counts to age estimates is provided in Section 2.3.2. No medium margin-states were observed.
Measurements of margin width were not made as the diffuse nature of the zones meant it was impractical to identify a single consistent border separating the opaque and translucent zones.

A five-point "readability" score was used to provide an indication of the relative ageing certainty held by each reader.

2.3.2 Age interpretation

To convert otolith zone counts to age estimates it is necessary to know when sampling was conducted, when spawning occurred, and when formation of the opaque zone in the otolith was completed.

Colman (1974) concluded that most sand flounder and yellowbelly flounder sampled from the Hauraki Gulf had completed formation of one complete opaque zone by October. Similarly, Stevens et al. (2004) assigned a hypothetical "birthday" of 1 October for New Zealand sole, based on earlier work by James (1969). This study made no adjustments between zone counts and age estimates as the capture data were also obtained in October. The present study followed the approach of Stevens et al. (2004) as most otoliths showed an opaque margin and sampling occurred predominantly in October. A few otoliths showed a "completed" translucent zone and were therefore assigned an age equal to the zone count +1 year.

2.3.3 Mean length-at-age

Von Bertalanffy growth curves were fitted to the age-length data from male and female fish. Three unsexed fish were not included in the analysis. Separate equations (with 95% confidence intervals) were calculated for each sex using a likelihood ratio procedure (Kimura 1980).

2.3.4 Ageing error

Otolith zone counts were assessed for ageing bias and precision. To assess the within-reader variability of the results, all otoliths were read twice by the primary author (CPS). First and second readings were made 3 weeks apart. To assess the level of between-reader variation, 98 otoliths (representing a range of lengths and both sexes) were also read by a second experienced otolith reader (DWS). Any readings that differed between readers were re-examined and a final agreed age was determined.

Ageing bias was determined from reader bias plots with error bars denoting 95% confidence intervals.

2.3.5 Estimating natural mortality

An estimate of the natural mortality coefficient, M, was obtained using Hoenig's (1983) regression equation describing the relationship between mortality rate and life span:

$$\log_e M = 1.46 - 1.01[\log_e(t_{max})] \quad (2)$$

where t_{max} = the maximum age reached by 1% of an unexploited population (Sparre et al. 1989).

3. RESULTS

3.1 Length-at-gutted weight

The raw data and calculated length-gutted weight equations are shown in Figure 2. The relationship between length and gutted weight produced similar α estimates of 0.039 for males and 0.036 for females, respectively. β estimates were also similar between sexes, with 2.64 for males and 2.70 for females, respectively. The relationship between length and gutted weight was positively correlated with little deviation around the mean.

3.2 Age and growth

3.2.1 Otolith intrepretation

Whole and transversely thin-sectioned greenback flounder sagittal otoliths from 1+ and 6+ fish, respectively are shown in Figures 3 and 4.

Whole otoliths (of fish older than 2+ years) are very thick, which greatly reduces light penetration and makes “annuli” interpretation difficult. In contrast, thin-sectioned preparations provide a much clearer pattern of dark (opaque) and light (translucent) zones, which assist interpretation.

3.2.2 Mean length-at-age

Data from all examined otoliths of sexed fish ($n = 272$) were used to calculate von Bertalanffy growth curve parameters (with asymptotic 95% confidence intervals for the estimates) for both males and females (Table 4). The 95% confidence intervals are very wide, particularly for the L_∞ values. This is because only a few age-classes are well represented and, therefore the model calculates a high level of uncertainty around the upper age limit.

The raw age-length data and calculated von Bertalanffy growth curves for greenback flounder are plotted in Figure 5.

The graphs show that both male and female fish grew rapidly throughout their life and that growth rates are consistent between the sexes. Females were slightly larger than males at corresponding ages and reached a greater maximum length, but the difference in L_∞ and k was not significant at the 95% level of confidence (Table 4). Maximum ages of 5 and 10 were attained for male and female fish, respectively. However, only about 0.5% of males and 6% of females reached an age greater than 4 years. Over 90% of sampled fish were 2 or 3 years of age.

There was considerable overlap in the length-at-age data for both sexes. This was particularly evident for 2 and 3 year old fish; Table 5 shows mean lengths-at-age (with standard deviation and sample size) for all fish aged. The calculated von Bertalanffy curves in Figure 5 fit these data reasonably well.

3.2.3 Ageing error

Both readers found greenback flounder otoliths relatively easy to interpret. This is supported by the high proportion of otoliths that were assigned a readability score of 2 or less (Table 3), along with the high level of consistency shown by the age bias plots for both the within-reader and between-reader comparison tests (Figures 6 and 7). These plots showed that no systematic bias was detected in the results, and ageing error appeared to be negligible over the aggregated age range. In general, the error bars are absent or small, indicating close agreement between all readings. The exception is the large error bars evident in Figure 7, which are a consequence of the small sample size ($n = 2$).

3.2.4 Estimating natural mortality

The samples aged suggest a t_{max} of about 5 years for male, and 10 years for female greenback flounder, giving estimates for M of 0.85 and 0.42, respectively. However, only 1% of all fish exceeded 5 years of age, so 0.85 is probably the most logical estimate at this stage.

4. DISCUSSION

This is the first study of greenback flounder age and growth in New Zealand waters.

It developed a consistent and reproducible method to age the species by counting zones in whole and sectioned otoliths. Whole otoliths could be used only when two or fewer growth zones were evident, as resolution decreased with increasing otolith thickness.

Von Bertalanffy growth parameters indicated that growth is rapid and consistent (between sexes) throughout the lifespan of this species. This is expected given that most fish (over 90%) were 2 or 3 years of age. Variable growth rates between sexes typically occur with increasing age.

These findings are consistent with those presented for lemon sole (Gowing et al. unpublished results), New Zealand sole (Stevens et al. 2004) and yellowbelly flounder (Stevens & Sutton 2006). However, in contrast to these studies, greenback flounder reached maximum ages of 5 years for males and 10 years for females. While only one female fish attained an age of 10, this is significantly older than has been recorded for other flatfish species, with the exception of turbot (16 years) and brill (21 years) (Stevens et al. 2005).

Stevens et al. (2005) suggested that turbot and brill could be more effectively managed outside the FLA stock complex. This view was based on the belief that these two species may be less productive than other short-lived flatfish species. Therefore, they may not be able to sustain TACCs that are purposely set high to provide fishers with the flexibility to take advantage of variable annual abundance (Ministry of Fisheries 2008).

This argument is unlikely to apply to greenback flounder for two reasons. First, the species is typical of most New Zealand flatfish in that most individuals are fast growing and short-lived. We found that 97% of all fish sampled did not exceed 5 years of age, with the remainder being two fish aged 6 and one aged 10. Given that the oldest fish was sampled during a research survey, it is possible that this age class is unlikely to occur in the commercial catch. Therefore, greenback flounder growth parameters are not atypical relative to most of New Zealand flatfish species. Second, owing to identification problems associated with this species it is not feasible to require fishers and processors to distinguish between greenback flounder and other flatfish species, in particular sand flounder and yellowbelly flounder. This view is supported by the finding that during this study 5 of the 257 fish identified by fish processors as greenback flounder were, in fact, sand flounder. This issue is unlikely to be a significant problem for turbot and brill as these species are more readily identified.

5. ACKNOWLEDGMENTS

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Table 1(a): Three-point otolith margin-state scores used in readings.

Margin-state

Margin	Description
Narrow	Last translucent zone considered to be fully formed; a thin layer of opaque material may be present outside the last translucent zone
Medium	Last translucent zone considered to be fully formed; a thicker layer of opaque material is present outside the last translucent zone
Wide	Last translucent zone considered to be fully formed; a thick layer of opaque material is deposited outside the last fully formed translucent zone

Table 1(b): Five-point otolith readability scores used in readings.

Readability

Readability	Description
1	Otolith very easy to read; excellent contrast between successive opaque and translucent zones
2	Otolith easy to read; good contrast between successive opaque and translucent zones, but not as marked as in 1; potential error ± 1 opaque zone
3	Otolith readable; less contrast between successive opaque and translucent zones than in 2, but alternating zones still apparent; potential error ± 2 opaque zones
4	Otolith readable with difficulty; poor contrast between successive opaque and translucent zones; potential error ± 3 opaque zones
5	Otolith unreadable

Table 2: Number of otoliths at each margin-state for primary and secondary readers.

Margin	Primary reader (CPS)	Secondary reader (DWS)
Narrow	194	93
Medium	–	–
Wide	81	5

Table 3: Number of otoliths at each readability score for primary and secondary readers.

Readability	Primary reader (CPS)	Secondary reader (DWS)
1	–	7
2	267	77
3	4	11
4	4	3
5	–	–

Table 4: Von Bertalanffy growth parameters (with 95% confidence intervals in parentheses) for greenback flounder sampled from southern New Zealand.

	Male	Female
L_∞	52.21	55.82
	(42.55–174.62)	(51.90–728.37)
k	0.24	0.26
	(0.04–0.45)	(0.01–0.33)
t_0	-1.32	-1.06
	(-2.75 to -0.45)	(-4.35 to -0.51)
Age range	1–5	2–10
n	173	99

Table 5: Mean lengths at age (cm, with standard deviation, S.D., and sample size, *n*) for fish sampled from southern New Zealand.

	Male			Female		
Age	Mean	S.D.	n	Mean	S.D.	n
1	23.2	1.6	5	-	-	-
2	28.7	2.1	137	30.2	2.0	60
3	34.3	1.7	28	35.9	2.2	28
4	36.0	3.0	2	38.2	3.0	5
5	40.0	-	1	46.3	4.7	3
6	-	-	-	49.0	0.0	2
10	-	-	-	50.0	-	1

Figure 1: Greenback flounder (*Rhombosolea tapirina*). (Source: Peter McMillan, NIWA.)

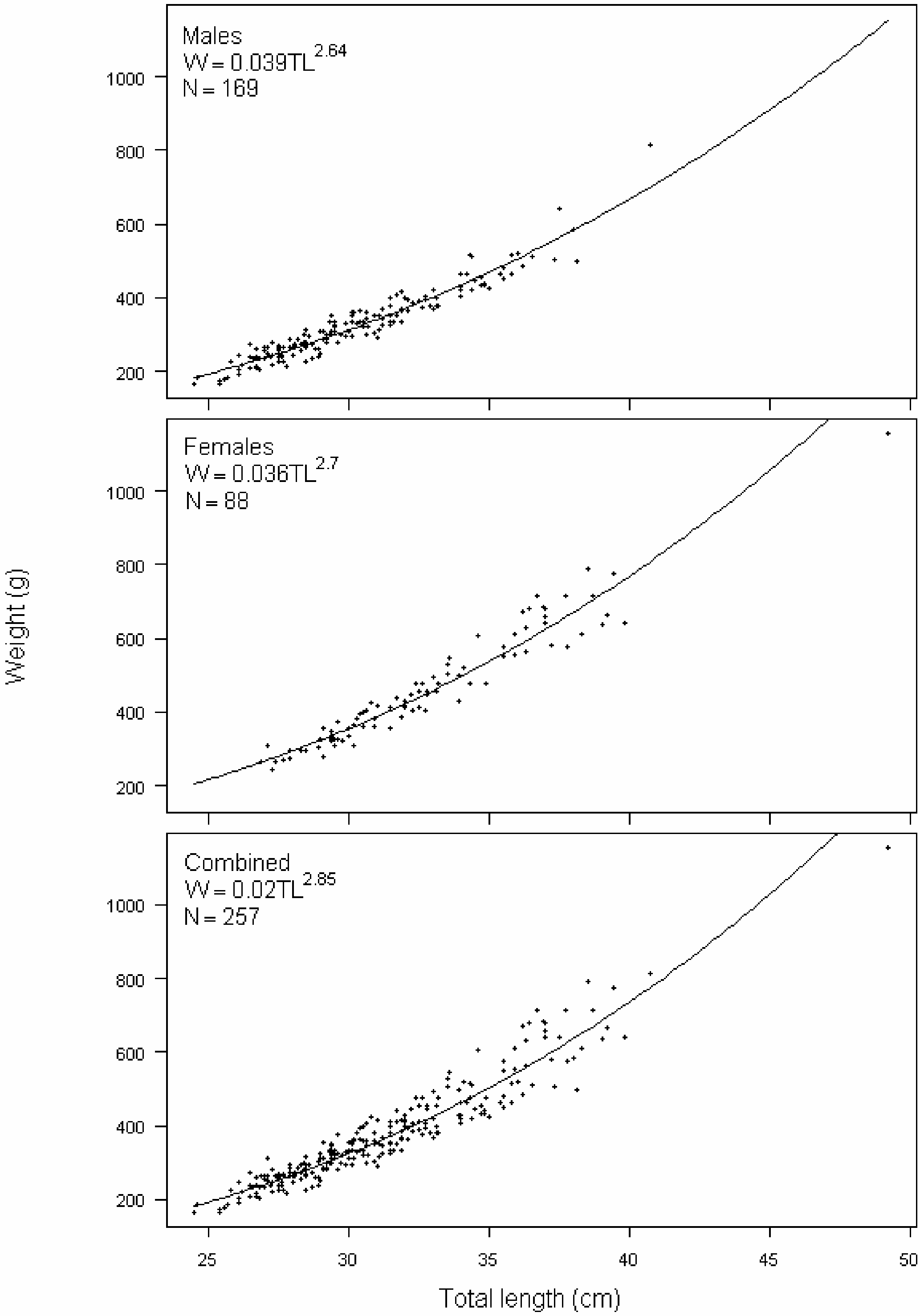

Figure 2: Length-gutted weight relationship for male, female, and combined sex greenback flounder from southern New Zealand.

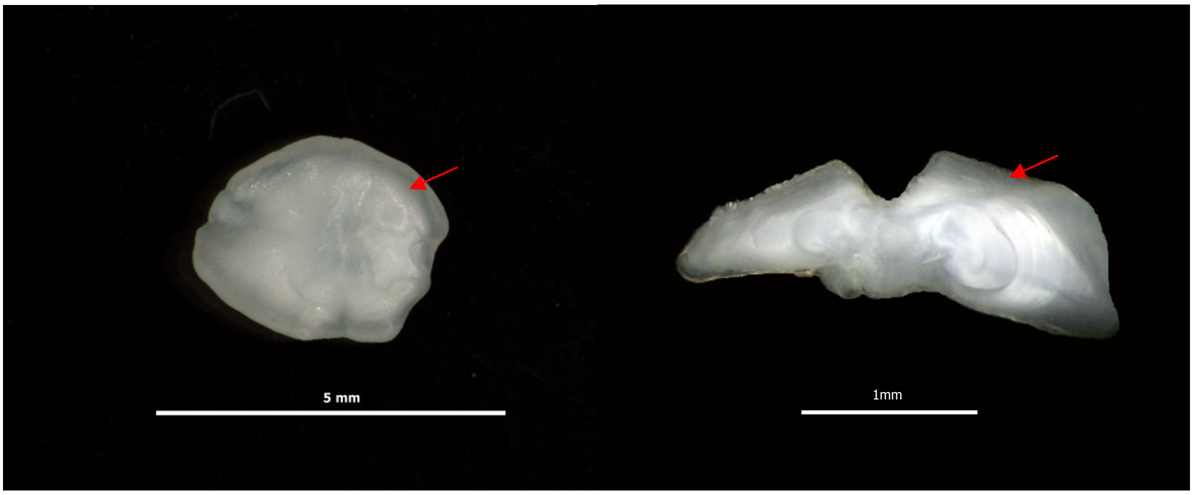

Figure 3: Whole (left) and transversely thin-sectioned (right) greenback flounder sagittal otolith from a 1+ fish. The red arrows indicate zones interpreted as annuli. Note: the whole otolith was examined under reflected light and the prepared section was examined under transmitted light.

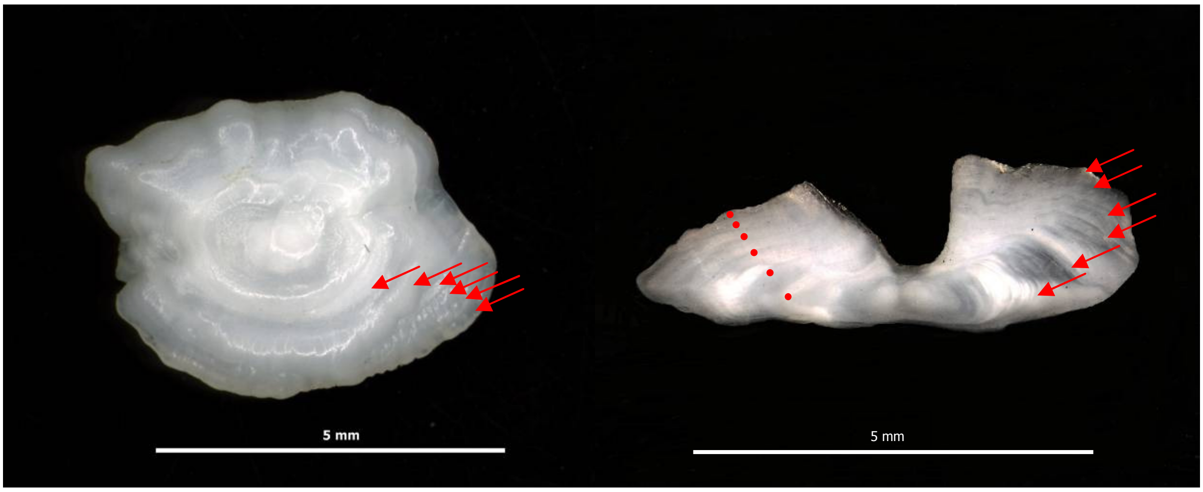

Figure 4: Whole (left) and transversely thin-sectioned (right) greenback flounder sagittal otolith from a 6+ fish. The red arrows and dots indicate zones interpreted as annuli. Note: the whole otolith was examined under reflected light and the prepared section was examined under transmitted light.

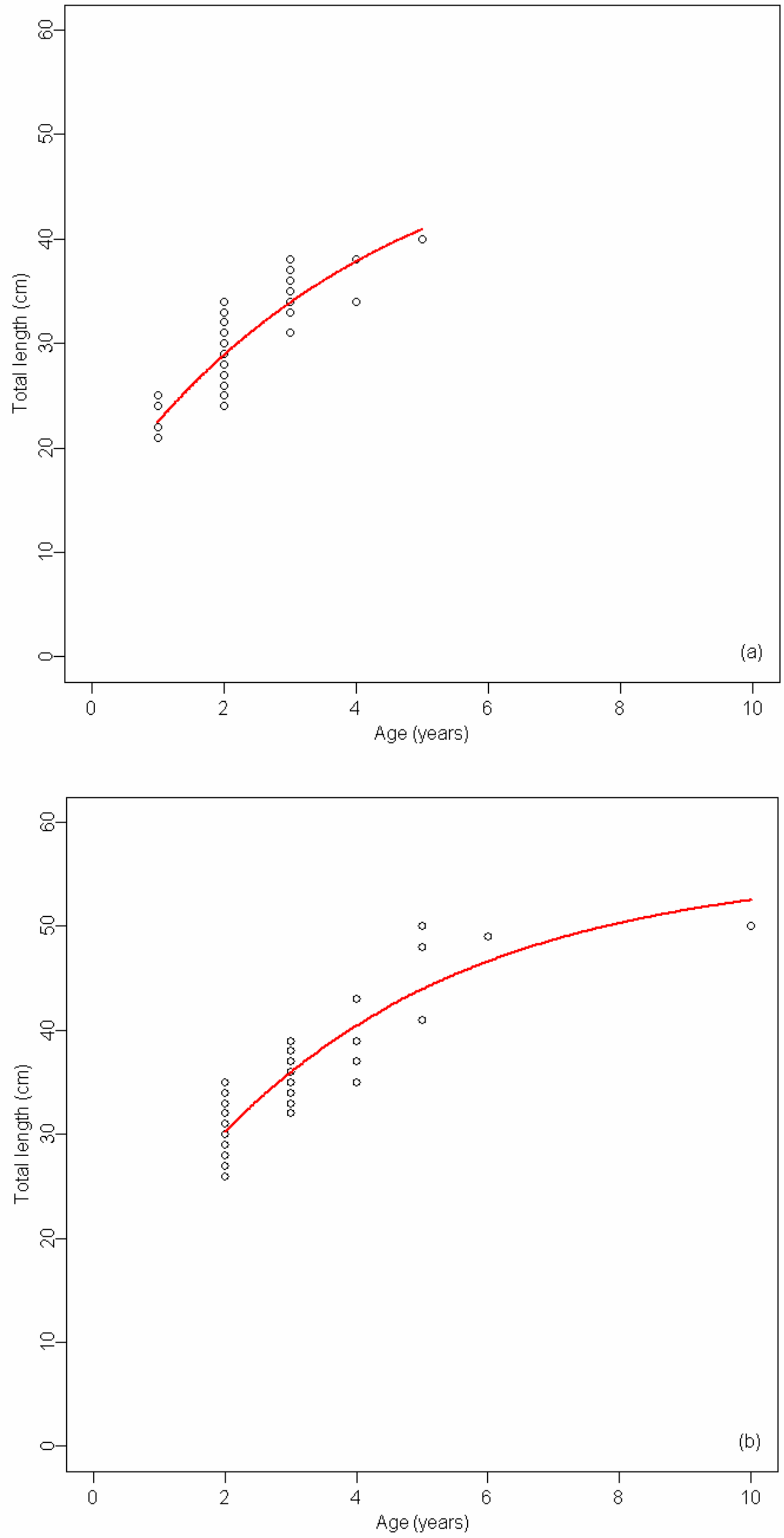

Figure 5: Raw length-at-age data and von Bertalanffy growth curves for (a) male and (b) female greenback flounder sampled from southern New Zealand.

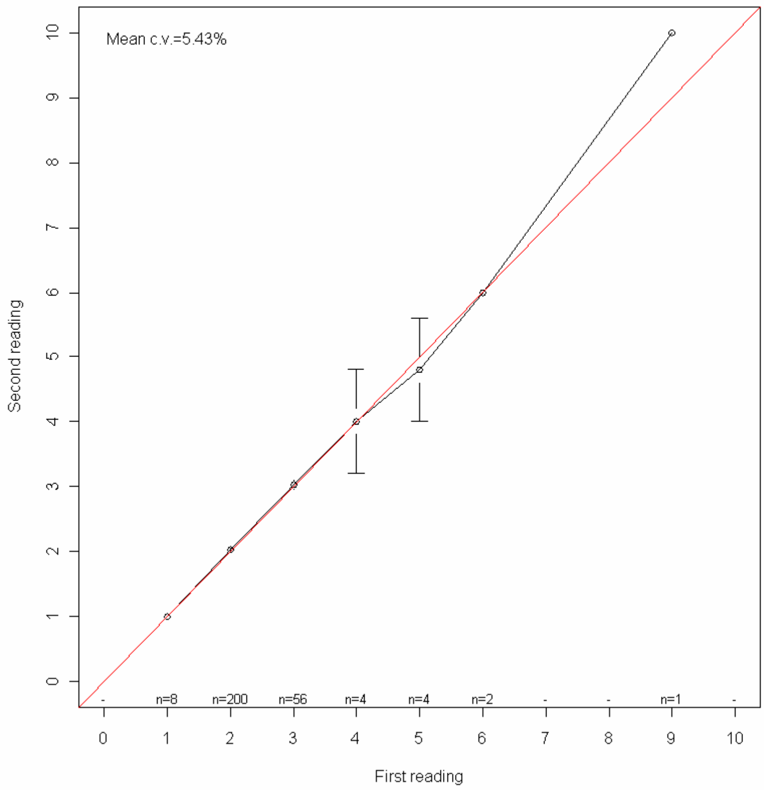

Figure 6: Within-reader comparison (with sample size for each age, *n*) of 275 greenback flounder otoliths.

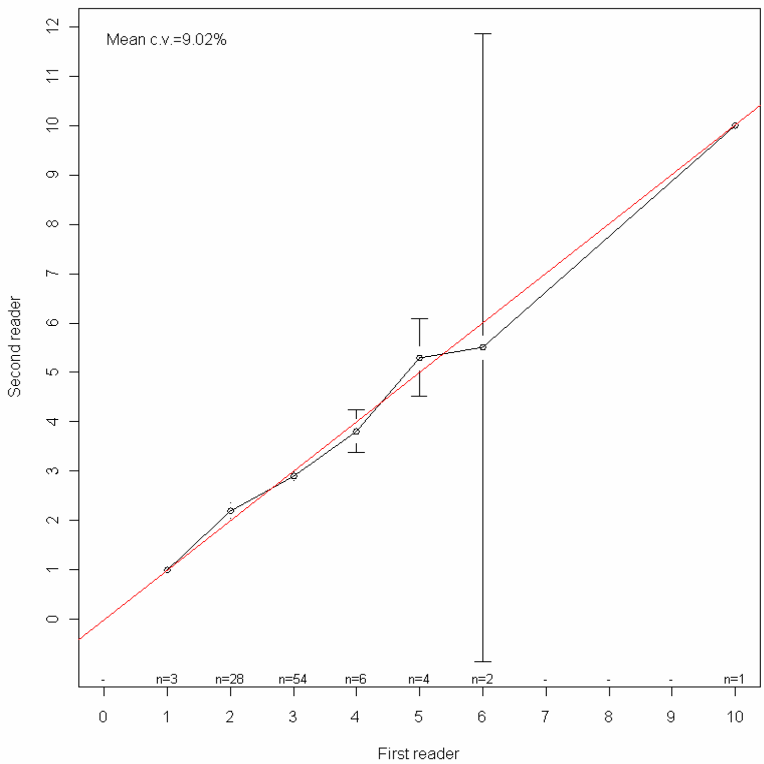

Figure 7: Between-reader comparison (with sample size for each age, *n*) of 98 greenback flounder otoliths.