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An ageing methodology, and growth parameters for silver warehou (*Seriolella punctata*) from off the southeast coast of the South Island, New Zealand

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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1. EXECUTIVE SUMMARY

A method is described to determine the age of silver warehou using the zones in sectioned otoliths. The technique was validated by examining the state of otolith margins from fish sampled regularly over 1 year, and by following the progression of length modes in length frequency distributions (for age classes 0+ to 3+). Von Bertalanffy growth parameters are estimated for silver warehou off the southeast coast of the South Island. The fish grow rapidly up to the time of first spawning, but growth slows markedly after sexual maturity (about 4–6 years). Growth is negligible after about 10 years. Female fish have a significantly faster rate of growth (and also appear to live longer) than males. An estimate of 0.25 for instantaneous natural mortality (*M*) is proposed. Instantaneous total mortality (*Z*) could not be estimated because population age structures could not be determined.

2. INTRODUCTION

Silver warehou (*Seriolella punctata*) are common around the South Island and on the Chatham Rise at depths of 200–600 m. Most of the commercial catch is taken from the Chatham Rise, Canterbury Bight, southeast of Stewart Island, and off the west coast of the South Island.

A major target trawl fishery in the mid 1970s was estimated to have taken about 13 000 t annually. Most landings in recent years were taken as a bycatch of the hoki, squid, barracouta, and jack mackerel fisheries, although some target fishing still occurs primarily on the western Chatham Rise and the Stewart-Snares shelf. Total annual landings have ranged from about 6000 to 9000 t in the last 10 years (Annala 1995).

The only ageing work on silver warehou from New Zealand is by Gavrilov (1974, 1979), the latter publication appearing to be a review of his earlier work. He reported only on scales, but did examine some otoliths. No details of ageing methods were given, although comments on the condition of the scale margin in various seasons implied that zone formation was an annual phenomenon. Gavrilov's 1974 paper gave a maximum age of 10 years, his 1979 review 10 years or more, and a study on population dynamics (Gavrilov 1975) 11 years.

An ageing study of *Seriolella punctata* from off the coast of southern Chile presented von Bertalanffy parameters, and showed no difference in growth between sexes (Aguayo & Chong 1991). Bands in whole otoliths were counted, with the maximum age being 8 years. An examination of otolith margins over time indicated that one hyaline and one opaque zone were laid down annually.

The present study aimed to develop a repeatable and validated methodology to age silver warehou using otoliths by interpreting early otolith growth and determining how many growth zones are laid down annually in the otoliths.

3. METHODS

Otoliths (sagittae) of silver warehou from around the South Island have been collected sporadically by scientific observers since 1992. Most sampled fish were taken as bycatch of the hoki, squid, and barracouta fisheries concentrated off the west coast of the South Island, the Stewart-Snares shelf, and the Chatham Rise. Otoliths were also available from silver warehou caught during trawl surveys of the Stewart-Snares shelf in February–March of 1993, 1994, and 1995. Fork length (FL, rounded to the nearest centimetre below actual length) and sex were recorded for all fish from which otoliths were taken. Otoliths were stored dry in paper envelopes.

Otoliths for the validation study were examined both whole and in cross-section. Whole otoliths were placed in water on a dark background, illuminated by reflected light at an incident angle of about 40°, and examined under a binocular microscope (X20). A pattern of white opaque and dark hyaline zones was apparent. Cross-sections were prepared by baking whole otoliths in an oven until amber coloured (275 °C for 4 min), embedding them in clear epoxy resin (Araldite K142), and cutting the otolith transversely through the nucleus with a revolving diamond edged saw. The cut surface of the resin block was coated in paraffin oil, illuminated by reflected light with an incident angle of about 30°, and examined under a binocular microscope (X40). A pattern of dark brown and light brown zones was apparent. The dark brown zones on the cross-section corresponded with the dark hyaline zones on the whole otolith. Counts of zones in the otolith section were generally made on the ventral side adjacent to the sulcus. On whole otoliths, zones were generally clearest on the ventral and anterior axes. Sometimes otolith clarity varied between the two sides of a single sectioned otolith, so if the zonation pattern appeared unclear on a section the other half of the same otolith was also examined. The number of complete dark zones (i.e., dark zones with lighter material outside them) were counted.

To convert zone counts to age estimates, it was necessary to validate the ageing methodology by determining when and how frequently the bands were laid down. Eleven otolith samples each comprising 18–47 otoliths (totalling 377 otoliths) collected over a period of about 13 months were selected to examine changes in otolith margin characteristics (Table 1). Most samples were collected between September 1993 and October 1994 from off the south and southeast coasts of the South Island. Exceptions were part of sample 3 which was collected in December 1992, and parts of samples 4, 8, 9, and 10 which were collected from the west coast of the South Island in January and July to September 1994. It was assumed that any regular banding pattern in the otoliths forms in a consistent manner between years and areas. Otoliths were examined both whole and in section, the margin was classified as either dark or light, and an age was estimated. For about half of the otoliths older than about 8 years, the marginal state was too indistinct to classify confidently, although an age could still be allocated.

After validation of the methodology, additional samples collected during trawl surveys of the Stewart-Snares shelf in February–March 1993, 1994, and 1995 were aged by examining whole otoliths of fish less than 40 cm FL, and sectioned otoliths of fish greater than or equal to 40 cm FL.

Counting bands in otoliths is subjective; two readings of a single otolith can produce different results. To assess within-reader variability, 100 otoliths representing a range of sizes and both sexes were read twice by one author. First and second readings were made at least 3 weeks apart. Between-reader variability was assessed by having both authors read a sample of 357 otoliths.

Von Bertalanffy growth curves were fitted to the age-length data using a non-linear least-squares regression procedure (Ralston & Jennrich 1978). Separate equations were derived for each sex.

Length frequency histograms from research trawl surveys often exhibit up to three modes in the 10–40 cm length range, suggesting distinct juvenile year classes. Plotting the histograms chronologically and examining the progression of modes over time provides an independent check on the growth curve calculated for young fish from counts of bands in otoliths. Ten histograms were constructed from data collected on 16 trawl surveys (Table 2) conducted in various areas south and east of the South Island between September 1978 and May 1981. It is not known whether silver warehou in these areas make up a single stock.

Length frequency histograms from a series of trawl surveys of the Stewart-Snares shelf and Puysegur Bank conducted in February–March of 1993, 1994, and 1995 (Table 2) are also presented. They enable the comparison of positions of modal peaks between years, and provide further information on the rate of juvenile growth.

4. RESULTS

4.1 Otolith interpretation

Determining the age of young fish using whole otoliths was generally easy because of the relative clarity of the first three to four zones. Split zones were sometimes apparent, but they were usually easily identified because of the regularly decreasing distances between true zones with increasing age. It was also possible to correctly age fish older than 4 years from whole otoliths, but as fish got older there was an increasing risk of under-ageing fish using this method. Determining the age of silver warehou over 40 cm FL using the otolith cross-section method reduced the chance of ageing error. A few otoliths exhibited a clear double banding pattern (commonly adjacent to the sulcus) in older zones, but again the true interpretation was clear because of the regular overall banding pattern.

4.2 Marginal state

It was generally possible to determine whether an otolith margin was dark or light, though some interpretations for older fish were complicated because of the narrowness of the band. Percentages of otoliths with dark margins, for each sample separated into two groups of age classes (0+ - 4+, > 4+), are shown in Figure 1. It is apparent that dark material is initially laid down about April and that most fish are again laying down light material by October. (Because the marginal state of otoliths from some older fish could not be determined confidently, the sample sizes in Figure 1 are less than those given in Table 1.)

These data support the hypothesis that one dark and one light zone are laid down annually in the otoliths of silver warehou.

4.4 Growth parameters

The spawning season for silver warehou on the western Chatham Rise, west coast of the South Island, and the Stewart-Snares shelf is generally from late winter to early spring, and there is evidence of spawning at the Chatham Islands in late spring and early summer (Livingston 1988). The fish examined in this study were not from the Chatham Islands, so a "birthday" of 1 September was chosen. As the dark zone in the otoliths appears to be complete by late winter (August–September), fish are about 1 year old on completion of the first dark zone.

Errors would result if no account was taken of the variable timing of zone completion. Consequently, margins of otoliths collected during August to December were subjectively graded as either wide or narrow, although this was difficult at times because of the narrow zones on otoliths of older fish. Since the new light zone appears to start forming about 1 September, fish caught before September and showing n complete zones and a narrow margin were assigned to the same age class as fish with $n-1$ zones and a wide margin. Conversely, fish caught after 1 September and showing n zones and a wide margin were assigned to the same age class as those with $n+1$ zones and a narrow margin.

Male silver warehou had a maximum age of 19 years, but less than 5% of fish were older than 14 and only 1% were older than 17 years. Females were aged to a maximum of 23 years with 5% of fish older than 15 and 1% older than 19 years.

Data from all otoliths listed in Table 1 (except those collected from the west coast) were used to calculate von Bertalanffy growth curve parameters (with asymptotic 95% confidence intervals for the estimates) for fish from off the south and southeast coasts of the South Island (Table 3). Time of sampling, and hence part-year growth, is incorporated in this analysis (e.g., a fish with two complete zones sampled in early February would be allocated an age of 2.40 years). Mean lengths at age for fish sampled in February and March are presented in Table 4. The calculated curves and raw data as read by one author (PLH) are plotted in Figures 2 and 3. Female silver warehou grow significantly faster and reach a larger size than males, although length at age is virtually identical for the two sexes up to age 5.

4.5 Age replication

The results of the within-reader comparison for one author are shown in Table 5. Of the 100 otoliths examined twice, 77 were aged identically and all but two differed by 1 year or less. There was no apparent bias in the ageing error over the entire age range. Ageing error increases with increasing age.

Of the 357 between-reader comparisons available, 66% were aged identically and 93% differed by 1 year or less (Table 6). There was evidence of some bias between readers. One reader appeared to age fish slightly older over the 1–10 year age range, and slightly younger over the 11+ age range, than the other. However, the von Bertalanffy parameters calculated separately for each reader's data set were not significantly different.

4.6 Length frequency modal progression

Length frequency histograms of silver warehou caught during research trawl surveys off the south and east coasts of the South Island from September 1978 to May 1981 are presented in Figure 4. Raw data are presented; they have not been scaled by size of catch or area trawled. Not all year classes are represented in all samples, but it is possible to follow the progression of the 1976, 1977, and 1978 year classes through much of the time series, and also to identify the 1979 and 1980 year classes in some samples. These histograms indicate that silver warehou grow to about 20–25 cm in their first year, 30–35 cm in their second, and 38–43 cm by the end of the third year.

Length frequency histograms of silver warehou sampled in consecutive years from the Puysegur Bank and Stewart-Snares shelf area exhibit modes with similar positions throughout the time series (Figure 5), i.e., at 17–23 cm, 25–35 cm, 35–42 cm, and 43–47 cm. These length frequencies have been scaled by size of catch and area trawled to represent the total population of silver warehou in the survey area. As these samples were taken about 6 months after the spawning season, then it could be assumed that these modes represent fish aged about 0.5, 1.5, 2.5, and 3.5 years, respectively. Counts of otolith rings generally confirmed this for the first three modes. However, the 37–43 cm mode in the 1993 sample comprised both 2+ and 3+ fish, with both these year classes appearing quite weak. The same year classes were also combined in a single weak mode in 1994, and were completely overlapped in 1995 by the 1991 year class. The 1991 year class is strong in all samples, and exhibits a broad distribution (24–36 cm) with bimodality in the 1993 sample. The 2+ mode (1990 year class) is very poorly represented in the 1995 sample, despite it being relatively strong in the two previous samples. The 1993 year class was virtually uncaught as 0+ fish in the 1994 survey, but was a major component of the 1995 catch. Adult fish were very abundant in 1993, but were poorly represented in the 1995 and, particularly, 1994 surveys.

5. DISCUSSION

The age and growth of centrolophid fishes has been superficially studied in New Zealand and overseas. Studies of New Zealand silver warehou by Gavrilov (1974) indicated that the species was relatively fast growing and short lived. Similar growth characteristics were estimated for the centrolophid bluenose, *Hyperoglyphe antarctica*, sampled off the east coast of New Zealand (Horn 1988). Silver warehou off Chile demonstrated rapid initial growth and a maximum age of 8 years (Aguayo & Chong 1991), findings consistent with those of Gavrilov.

The data presented here also show silver warehou to have rapid initial growth with calculated length at age in the first 5 years being similar to estimates made by Aguayo & Chong (1991) and Gavrilov (1974). However, the current work does not support the hypothesis of a relatively short lifespan; many fish were aged greater than 10 years, up to a maximum of 23 years. Differences in the ageing methods between studies are the most likely cause of the different estimates of maximum age. Aguayo & Chong (1991) examined only whole otoliths. Gavrilov's (1974) work was based on scales, although some otoliths were examined. Gavrilov (1974) noted that both scales and otoliths displayed annual zones that were fairly easy to interpret in fish younger than about 9 years; in fish older than this, age determination was difficult because of the presence of additional zones.

In the current study, otoliths were initially examined both whole, and in transverse section after baking and embedding in resin. It was quickly apparent that whole otoliths could be relatively reliably aged up to about 5–6 years (and sometimes even to 12 years). However, transverse sections of the same otoliths gave a clearer picture for fish older than 5 years and generally showed a greater number of rings in otoliths of older fish than had been apparent in whole otoliths. Hence, the chosen methodology in this study was to examine whole otoliths from silver warehou up to 40 cm FL, and transverse sections of otoliths from all larger fish. The studies of Aguayo & Chong (1991) and Gavrilov (1974) are probably flawed because they examined whole otoliths or scales, and so failed to identify the older fish in their samples.

Validation of the ageing method used here was achieved in general. However, it was not possible to validate the method for every year class (in particular, fish aged from their mid-teens or older) due to relatively small samples of old fish and a reduction in clarity of the otolith margin with increasing age. The formation of one zone annually in otoliths of fish up to 5 years old was demonstrated by the otolith margin analysis, and otoliths of older fish exhibited a virtually identical pattern. The calculated growth rate of the first three year classes was also supported by the progression rate of length frequency peaks over a period of about 2.5 years. Silver warehou mature sexually at about 4–6 years (Gavrilov 1975) and are unlikely to experience any major lifestyle changes after this age that would change the otolith growth pattern. Hence, if silver warehou are laying down one otolith zone annually throughout their juvenile years and after sexual maturity into their early teens, it is logical to assume that this pattern will continue throughout life.

Female silver warehou are larger than males at corresponding ages after about 5 years, and they have a significantly larger L_∞ value. Aguayo & Chong (1991) also calculated a larger L_∞ value for females, but concluded that the difference was not statistically significant. Females appear to have a slightly greater life expectancy than males, a point also noted by Gavrilov (1974).

Silver warehou grow rapidly during the years before first spawning, but the growth rate slows markedly near sexual maturity (at about 4–6 years). Length frequency histograms from trawl surveys indicate that growth is fast during spring and summer, and slow during autumn and winter. The mean sizes of the first three year classes 6 months after their birthday and near the end of the fast growth period (from Figure 5) are only slightly less than their estimated sizes on their next birthday. The slow winter growth was particularly apparent in 1979 (*see* Figure 4). Growth is negligible after about 10 years.

Data collected by scientific observers (NIWA, unpublished data) indicates that over 80% (by number) of fish caught are longer than 42 cm, implying that most of the commercial catch is over 3 years old. No estimates of population age structure have been made for silver warehou from the Stewart-Snares shelf because the trawl survey of this area does not appear to sample the whole population. The 0+ year class in 1994 and the 2+ year class in 1995 were virtually absent from the catch even though data from other years indicated that they should have been more abundant. Estimates of the absolute numbers of adult fish in the survey area varied markedly between surveys. Such results demonstrate the problems of using a random trawl survey to sample a highly mobile, migratory species that is known to school by size. Without a population age structure it is not possible to estimate instantaneous total mortality (*Z*).

Estimates of instantaneous natural mortality (*M*) were derived from the equation

$$M = \log_e(100) / A_{max}$$

where A_{max} is the age reached by 1% of a virgin population (Sparre *et al.* 1989). The samples aged here suggest an A_{max} of about 19 years for female silver warehou and 17 years for males, giving estimates of *M* of 0.24 and 0.27 for females and males, respectively. However, these samples were not from virgin populations, so *M* may be slightly overestimated. Also, the sampling method did not comprehensively sample the whole population, which could bias *M* either up or down depending on the part of the population poorly represented. Given these qualifications, *M* is almost certainly in the range 0.2–0.3, and 0.25 is probably a satisfactory estimate at this stage.

6. ACKNOWLEDGMENTS

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7. REFERENCES

Aguayo, M. & Chong, J. 1991: Determinación de edad y estimación de crecimiento en cojinoba moteada (*Seriolella punctata* Bloch & Schneider, 1881) de la zona sur de Chile. *Revista de Biología Marina, Valparaíso 26*: 363–374.

Annala, J. H. (Comp.) 1995: Report from the Fishery Assessment Plenary, May 1995: stock assessments and yield estimates. 277 p. (Unpublished report held in NIWA library, Wellington.)

Gavrilov, G. M. 1974: The age and rate of growth in the silver warehou (*Seriolella maculata* Forster). *Issledovanya po Biologii Ryb i Promyslovoi Okeanografii* [Studies in Fish Biology and Fisheries Oceanography], *TINRO, No. 5*: 50–59. [In Russian; English translation (FRC Translation No. 29) held in NIWA library, Wellington.]

Gavrilov, G. M. 1975: Natural mortality rate and theoretical prerequisites for the optimum intensity of fishing, using as an example the unexploited population of *Seriolella maculata* Forster. *Izvestiya TINRO 96*: 187–195. [In Russian; English translation (FRC Translation No. 205) held in NIWA library, Wellington.]

Gavrilov, G. M. 1979: *Seriolella* of the New Zealand Plateau: fishery biology. TINRO, Vladivostok. 59 p. [In Russian; English translation (FRC Translation No. 204) held in NIWA library, Wellington.]

Horn, P. L. 1988: Age and growth of bluenose, *Hyperoglyphe antarctica* (Pisces: Stromateoidei) from the lower east coast, North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 22*: 369–378.

Livingston, M. E. 1988: Silver warehou. New Zealand Fisheries Assessment Research Document 88/36. 13 p.

Ralston, M. L. & Jennrich, R. I. 1978: DUD, a derivative-free algorithm for nonlinear least squares. *Technometrics 20*: 7–14.

Sparre, P., Ursin, E., & Venema, S. C. 1989: Introduction to tropical fish stock assessment. Part 1. Manual. *FAO Fisheries Technical Paper 306*. 337 p.

Table 1: Details of otolith samples examined to determine marginal state (samples 1–11), and to provide additional data to calculate growth parameters (samples 12–14). Area: SOU, south and southeast coast South Island; WCSI, west coast South Island.

Sample no.	Area	*n*	Sample period	Mean date	Total *n*
1	SOU	31	19–28 Sep 1993	24 September	31
2	SOU	45	2–29 Oct 1993	16 October	45
3	SOU	16	9–18 Dec 1992		
	SOU	14	5 Nov – 16 Dec 1993	30 November	30
4	WCSI	17	31 Jan 1994		
	SOU	10	4–6 Feb 1994	2 February	27
5	SOU	30	25–27 Feb 1994	26 February	30
6	SOU	39	23 Mar – 7 Apr 1994	29 March	39
7	SOU	38	16 Apr – 13 May 1994	7 May	38
8	SOU	18	27 Jun – 6 Jul 1994		
	WCSI	29	10–25 Jul 1994	10 July	47
9	WCSI	40	1–23 Aug 1994	11 August	40
10	WCSI	25	1–7 Sep 1994		
	SOU	7	15 Sep 1994	6 September	32
11	SOU	18	8–10 Oct 1994	9 October	18
12	SOU	249	9 Feb – 5 Mar 1993	23 February	249
13	SOU	129	13 Feb – 5 Mar 1994	23 February	129
14	SOU	153	14 Feb – 8 Mar 1995	23 February	153

Table 2: Details of trawl surveys providing the data for the 10 length frequency histograms in Figure 4 (data sets 1–10), and the 3 length frequency histograms in Figure 5 (data sets 11–13). Vessel names are indicated by the trip code: WJS, *W.J. Scott*; WES, *Wesermünde*; SHI, *Shinkai Maru*; JCO, *James Cook*; TAN, *Tangaroa*. *n*, number of fish measured in each sample.

Sample no.	Trip code	*n*	Date	Area
1	WJS7902		2–9 Sep 78	East coast South Island
	WJS7903	913	17–25 Sep 78	East coast South Island
2	WES7901	1538	23 Jan – 18 Mar 79	Southern Plateau & Chatham Rise
3	WES7902	428	25 Mar – 20 May 79	Southern Plateau & Chatham Rise
4	WES7903	766	22 May – 24 Jul 79	Southern Plateau & Chatham Rise
5	WES7904	493	17 Sep – 14 Oct 79	Southern Plateau & Chatham Rise
6	WJS7925		6–12 Mar 80	East coast South Island
	WJS7926		18–27 Mar 80	East coast South Island
	JCO8006	373	22–27 Mar 80	Canterbury Bight
7	WJS7927		4–17 Apr 80	East coast South Island
	WJS7928		23 Apr – 3 May 80	East coast South Island
	WJS7929	477	9–20 May 80	East coast South Island
8	WJS7932	66	27 Aug – 5 Sep 80	East coast South Island
9	JCO8103		7–11 Feb 81	Canterbury Bight & Pegasus Bay
	SHI8101	1178	26 Jan – 27 Feb 81	Stewart-Snares & Auckland Island shelves
10	JCO8108	41	16–23 May 81	Canterbury Bight & Pegasus Bay
11	TAN9301	6354	9 Feb – 11 Mar 93	Puysegur Bank & Stewart-Snares shelf
12	TAN9402	2152	13 Feb – 11 Mar 94	Puysegur Bank & Stewart-Snares shelf
13	TAN9502	1551	12 Feb – 13 Mar 95	Puysegur Bank & Stewart-Snares shelf

Table 3: Von Bertalanffy parameters from this study (with 95% confidence intervals) for silver warehou off the southeast coast of the South Island, and comparable parameters from Aguayo & Chong (1991) (A&C) and calculated from Gavrilov (1974) (Gav).

Parameter	Female		Male		A&C	Gav
L_∞	54.5	(54.0 – 55.0)	51.8	(51.3 – 52.3)	55.7	58.4
k	0.33	(0.31 – 0.35)	0.41	(0.38 – 0.43)	0.23	0.36
t_0	–1.04	(–1.19 to –0.89)	–0.71	(–0.83 to –0.60)	–0.49	–0.20
n		413		383	717	–

Table 4: Mean lengths at age (cm, with standard deviation and sample size) for fish sampled during February and March off the south and east coasts of the South Island. Fish at this time are about X + 0.5 years old, where X is the age class.

	Female			Male		
Age class	Mean	S.D.	n	Mean	S.D.	n
0+	20.3	2.4	14	20.2	2.1	18
1+	30.7	2.7	88	30.5	2.3	105
2+	38.1	1.7	35	38.8	1.7	39
3+	42.4	1.8	37	43.1	2.2	24
4+	44.3	2.4	10	45.1	2.1	10
5+	47.2	2.2	11	46.9	1.5	8
6+	50.0	1.8	10	48.8	1.9	11
7+	50.5	1.6	21	49.1	1.7	5
8+	51.6	1.4	15	50.7	1.5	11
9+	52.6	1.3	9	51.9	1.4	12
10+	54.3	1.5	12	52.0	1.1	8
11+	54.3	2.0	14	51.5	1.6	6
12+	54.1	2.3	16	52.0	1.4	13
13+	53.4	1.5	6	53.5	1.9	5
14+	56.5	1.5	6	53.1	1.3	9
15+	54.8	2.3	4	53.6	0.5	2
16+	55.4	4.0	7	53.9	1.9	2
17+	52.3	–	1	53.0	–	1
18+	56.4	2.0	2	56.7	0.4	2
19+	56.9	1.9	3	55.2	–	1
20+	56.0	–	1	–		0
21+	–		0	–		0
22+	57.0	–	1	–		0
23+	54.4	–	1	–		0

Table 5: Within-reader comparisons of 100 otoliths (by author PLH). Age, age at first reading; Diff, the extent by which the second reading differed from the first; Sim, the percentage of fish by age for which both readings were the same.

	Age											
Diff	0	1	2	3	4	5	6	7–9	10–12	13–16	17+	Total
+2									1			1
+1		1				1	1	2	3	1	1	11
0	5	25	18	4	3	3	2	4	5	7	2	77
−1			2		1		1	2	2	2		10
−2									1			1
Sim	100	96	90	100	75	75	50	50	42	70	67	77

Table 6: Between-reader comparisons of 357 otoliths. Age, age allocated by first reader (PLH); Diff, the extent by which the age allocated by the second reader (CPS) differed from that of the first reader; Sim, the percentage of fish by age for which both readings were the same.

	Age														
Diff	0	1	2	3	4	5	6	7	8	9–10	11–12	13–14	15–16	17+	Total
+2				1	1		1		2	2	1				8
+1		3	2	3		4	3	5	6	9	9	5	3		52
0	18	46	38	31	17	12	12	14	10	14	13	8	1	3	237
−1				1		1	2	4	5	5	12	4	7	2	43
−2										1	4	2	2	2	11
−3										1		1	1	1	4
−4												1	1		2
Sim	100	94	95	86	94	71	67	61	43	44	33	38	47	25	66

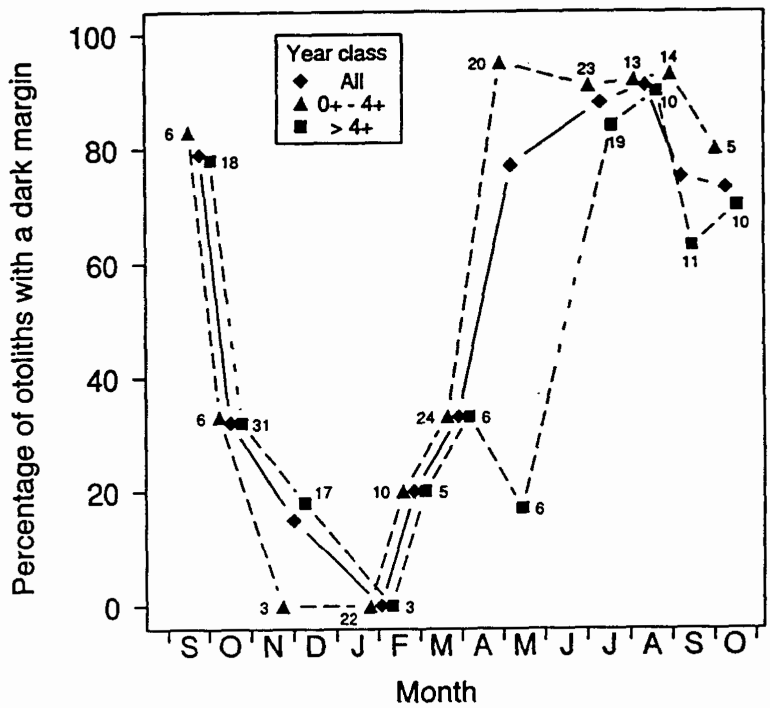

Figure 1: Seasonal change in the percentage of otoliths with a dark margin, over the period September 1993 to October 1994. Numbers adjacent to symbols denote sample size for the two year class groupings (i.e., 0+ - 4+, > 4+).

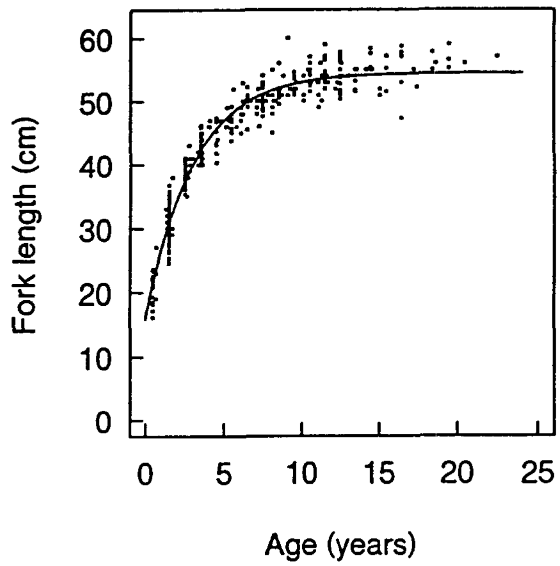

Figure 2: Raw age-length data and the calculated von Bertalanffy growth curve for female silver warehou from off the south and east coasts of the South Island.

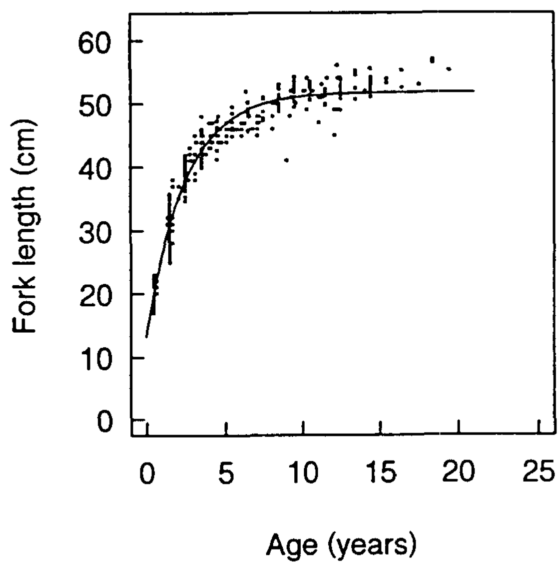

Figure 3: Raw age-length data and the calculated von Bertalanffy growth curve for male silver warehou from off the south and east coasts of the South Island.

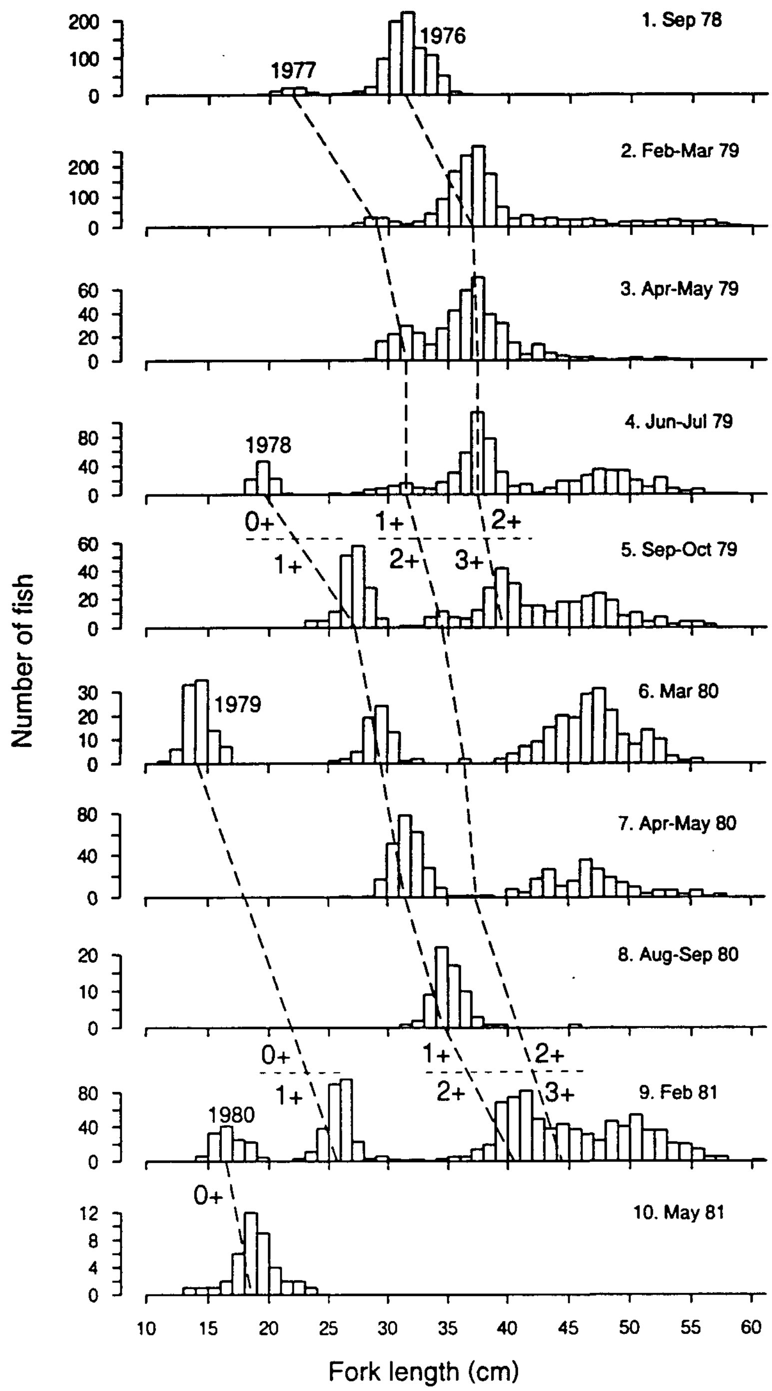

Figure 4: Length frequency histograms of silver warehou (both sexes combined) caught in research trawl surveys off the south and east coasts of the South Island between September 1978 and May 1981. Sample number (from Table 2) and survey date are shown on the histograms. Means (estimated by eye) of individual year classes are joined with broken lines. Year class ages (0+ to 3+) and year of spawning are indicated on the figure.

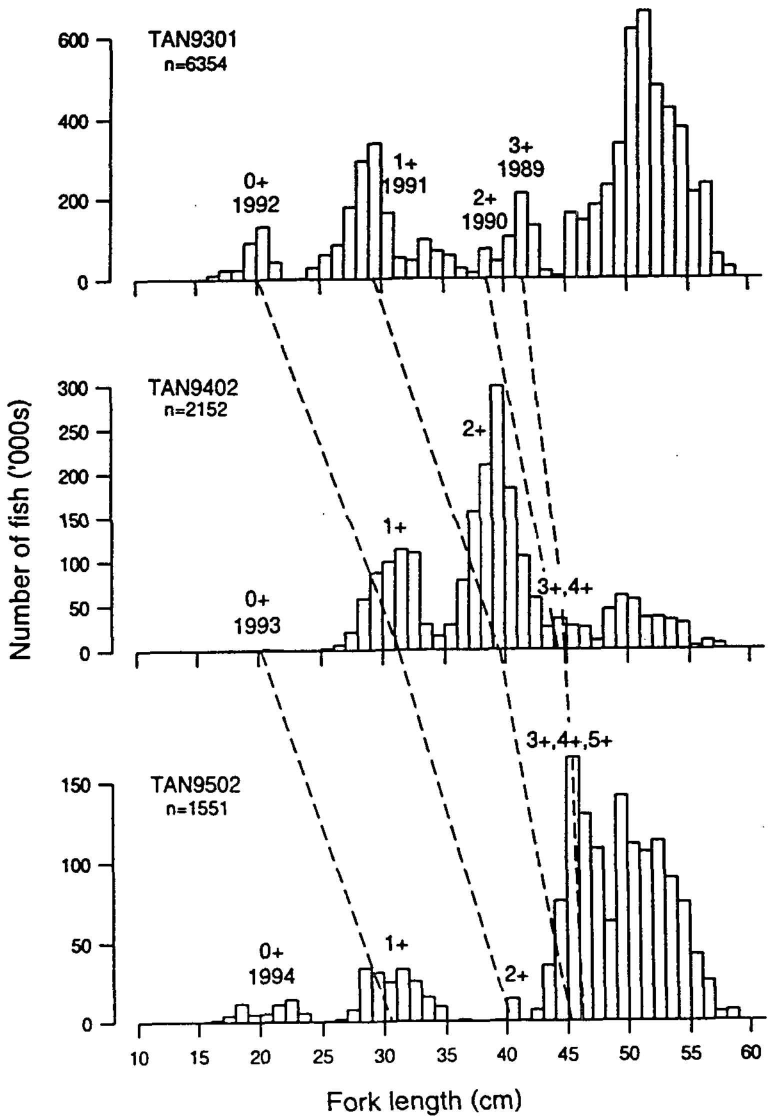

Figure 5: Length frequency histograms of silver warehou (both sexes combined) caught in research trawl surveys of the Puysegur Bank and Stewart-Snares shelf regions, in February-March 1993, 1994, and 1995, scaled to represent the total number of fish in the survey area. Trip number and sample size (n) are shown on the histograms. Means (estimated by eye) of individual year classes are joined with broken lines. Year class ages (0+ to 5+) and year of spawning are indicated on the figure.