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P. L. Horn
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P. L. Horn[1]
N. W. Bagley[2]
C. P. Sutton[2]

[1]NIWA
PO Box 893
Nelson

[2]NIWA
PO Box 14 901
Wellington

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EXECUTIVE SUMMARY

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Von Bertalanffy parameters for silver warehou (*Seriolella punctata*), by sex and area, were calculated using the 4-parameter von Bertalanffy growth model. The 4-parameter model described the growth of this species better than the generally used 3-parameter model. Series of proportion-at-age indices from the commercial fishery in fishing years 1992–93 to 1995–96 are presented.

Mean lengths at age and series of year class strengths from three areas in the New Zealand EEZ were compared. There were no apparent differences between the samples from the Southern Plateau, west coast South Island, or Chatham Rise. However, the lack of any differences does not indicate that silver warehou from these three areas are a single stock.

Silver warehou spawn in four relatively distinct areas (off west coast South Island, southern South Island, eastern North Island, and on the Chatham Rise), so the existence of four stocks is postulated. However, these stock boundaries are tentative and the likelihood of mixing between them is high. Spawning occurs from July to September in all areas except the Chatham Rise, where the season appears to be from September to November.

1. INTRODUCTION

This report is in fulfilment of Objective 2 of Project SWA1999/01, Stock assessment of silver warehou.

Silver warehou (*Seriolella punctata*) are caught in coastal waters around mainland New Zealand and on the Chatham Rise, mainly in depths down to about 500 m (Anderson et al. 1998). The fishery peaked at an estimated 13 000 t in 1976 and 1977, and a total TAC of 18 000 t was set in 1979–80 based on estimated total warehou landings. In 1986, a TAC of 8010 t (divided between three administrative stocks) was set under the newly introduced QMS (Annala et al. 2000). The three stocks comprised the following areas: SWA 1 (off North Island and west coast South Island, QMAs 1, 2, 7, and 8), SWA 3 (off east coast South Island, QMA 3), SWA 4 (eastern Chatham Rise, Sub-Antarctic, and off Southland, QMAs 4, 5, and 6). As a result of quota appeals, the TAC is now 9512 t. Total landings have fluctuated between about 6000 and 13 000 t since 1986, which probably reflects changes in fishing effort and/or abundance.

The stock structure of silver warehou is unknown. Comparisons of growth rates and population age structures have been used to infer stock boundaries for several New Zealand fish species (e.g., for ling (Horn 1993) and hake (Horn 1997)). Also, descriptions of known spawning areas and distributions of juvenile fish have also been used to help determine stock boundaries (e.g., for gemfish (Horn & Hurst 1999)). No comprehensive analyses of these types of data have been completed for silver warehou, although large quantities of data collected by scientific observers and on research surveys are available. This report describes a "desk top" exercise to determine what information on stock differentiation can be derived from existing data.

A validated method to age silver warehou has been developed (Horn & Sutton 1995, 1996). However, this study provided no information on any likely stock boundaries based on differences in growth rates or population age structures, as virtually all the fish aged were from a single area. About 1070 silver warehou were aged; 960 from the area on or adjacent to the Stewart-Snares shelf, and 110 from off the west coast of the South Island. Silver warehou from the four Southland trawl surveys (1993–96) were aged, but the surveys appeared to poorly sample fish older than about 4 years, and inconsistently sample the juvenile year classes, so no progressions of strong or weak year classes were apparent in the series (Horn & Sutton 1996).

It was considered likely that the commercial fishery would sample mature silver warehou much more comprehensively than a trawl survey, because of the areal coverage and duration of commercial activities, and because this species is actively targeted at times. Substantial samples of length-frequency data and otoliths collected by scientific observers were available in most years from 1992 to 1998, from the Chatham Rise, west coast South Island, and Southern Plateau (including the Stewart-Snares shelf) regions. The work reported here describes the calculation of mean length at age, by sex, from each area, and the construction of commercial catch-at-age distributions from each area for the fishing years 1992–93 to 1995–96. Catch-at-age distributions and mean lengths at age are compared between areas.

Spawning by silver warehou is known to occur on the western Chatham Rise (Mernoo Bank), east coast North Island, and west coast South Island in late winter, and at the Chatham Islands in late spring and early summer (Livingston 1988). There is some evidence for another spawning ground on the Stewart-Snares shelf, also in late winter (Livingston 1988). Similar patterns of spawning were also found by Knuckey et al. (unpub. results) from more recent research and commercial catch sampling. The distribution of 0+ juveniles suggests spawning occurs in most areas around the mainland, at Mernoo Bank, and at the Chatham Islands (Hurst et al. 2000). The current administrative Fishstock boundaries bear little relation to the described spawning areas and juvenile distributions. However, it is not clear how the authors cited above treated the differences in gonad staging methods used by scientific observers and on different research surveys. We therefore present a review of the relevant literature, and an analysis that re-extracts, updates, and summarises gonad stage data from commercial and research databases.

2. METHODS

2.1 Growth data and population age structures

Scientific Observers (from the Ministry of Fisheries Observer Programme) have collected comprehensive samples of length-frequency data and otoliths from the main silver warehou fisheries in most years since 1992–93. Catch-at-age distributions were determined as follows for commercial catches, in each of fishing years 1992–93 to 1995–96, for three separate areas: west coast South Island (WCSI), Southern Plateau, and Chatham Rise.

From each year, in each area, 350 otoliths were selected (when possible) from the seasonal sample so that the length and sex distribution of the aged fish was proportional to the scaled length frequency of the whole catch. Some individual samples comprised less than 350 otoliths (most notably on the Chatham Rise where sample size ranged from 120 to 180 otoliths). In these situations, all available otoliths were selected. Otoliths were prepared and read using the method of Horn & Sutton (1996), and age-length keys were determined separately for each sex.

Some fish had already been aged from 1993 to 1996 on the Southern Plateau, and from 1994 off WCSI (Horn & Sutton 1996), and from 1991 to 1995 off WCSI (NZFIB unpublished data). These data were incorporated into the analysis.

Each fish was allocated two ages: a true age, and a year class age. True age took into account time of sampling. A 'birthday' of 1 September was assumed for silver warehou from all areas, and this is also about the time when the translucent zone in the otolith appears complete (Horn & Sutton 1996). So a fish sampled in July, with five complete otolith zones had a true age of 5.8 years. Year class age adjusted the true age of all fish to the integer age they would have been at the end of the fishing year in which they were caught, i.e., the 5.8 year old fish would have a year class age of 6 years.

Observers collected length and sex data from silver warehou caught in the three areas defined above, with data on the weight of silver warehou subsampled and the total weight of silver warehou caught in each sampled tow. These data were used to obtain a scaled length frequency for the various fisheries in each year. The scaled length frequency was applied to the age-length key to produce proportion-at-age distributions for the commercial catch from each area, in each fishing year.

All available age data were grouped by area, and by sex, and mean length at age was calculated for each year class age. Mean lengths at age for individual age classes were compared between areas, using pair-wise *t*-tests with significance levels modified with a Bonferroni correction for multiple tests (Zar 1996). A significant difference was classified as one where $P < 0.05$. Comparisons were made only when there were at least five data points per sample. Von Bertalanffy growth parameters were calculated, separately by sex, and using the true age data, for each area using a non-linear least-squares regression procedure (SAS Institute 1988). Initially, the data were fitted to the 3-parameter von Bertalanffy model:

$$l = L_\infty(1 - e^{-k(t-t_0)})$$

However, when this growth model appeared to provide a poor fit as evidenced by unbalanced residuals, other growth models were tried (Schnute 1981). The 4-parameter von Bertalanffy model was found to provide the best fits to the data, i.e.:

$$l = L_\infty(1 - e^{-k(t-t_0)})^P$$

2.2 Gonad stage data and juvenile distributions

The Ministry of Fisheries trawl survey and scientific observer databases contain information on fish length and gonad stages which can be used to plot the distribution of spawning and juvenile fish by area and season.

Juvenile distributions have already been summarised as part of a FRST project on fish communities (Hurst et al. 2000), but data from fish in their first year of life (i.e., 0+ fish) are presented here on a finer scale to better determine potential spawning areas and times. The distributions of 0+ fish (i.e., fish less than 29 cm FL, from Horn & Sutton 1996) were plotted by month.

The locations of mature female silver warehou classified as ripe (i.e., hyaline eggs present), running ripe, or spent were plotted to define spawning areas. Mature fish were defined as those with a fork length of at least 47 cm (from Hurst et al. 2000). Gonad stage data from each of the indicated spawning areas were then examined by month to define spawning times in each area.

3. RESULTS

3.1 Length and age data

The collection of length-frequency data and otoliths from commercial landings of silver warehou was not structured. It relied on observers allocating some time to this work in between sampling other major target species. Consequently, the sampling intensity on silver warehou varied between years and areas.

Off WCSI, over 99% of data were derived from July to September, when warehou were being taken as a bycatch of the hoki target fishery (Figure 1). On the Southern Plateau, about 85% of data were collected during February to April, primarily from the eastern edge of the Stewart-Snares shelf during the target trawl fishery for squid. Trawl surveys of the Stewart-Snares shelf were also conducted in February–March 1993–96 (Hurst & Bagley 1997), and these provided additional length-at-age data used in this analysis.

Sampling on the Chatham Rise occurred in all months and exhibited no consistency between years (Figure 1). The numbers of fish sampled each year were lower than in the two other areas.

3.2 Comparison of catch-at-age distributions

Proportion-at-age distributions of the sampled silver warehou commercial catch are presented for WCSI from 1991–92 to 1995–96 (Figure 2), and from 1992–93 to 1995–96 on the Southern Plateau (Figure 3) and Chatham Rise (Figure 4). These figures plot the relative strengths of year class ages, so fish with a year class age of 8 represent those with a true age at time of death ranging from 7.1 to 8.0 years.

Raw data are listed in Appendix A. These data would be useful in any future stock modelling of this species.

For the WCSI distributions, there are no clear trends of strong or weak year classes running through the entire series (Figure 2). However, a strong year class 4 in 1993–94 (spawned in 1990) maintains its dominance in the two following years. There is also a reasonable likelihood that the 1988 year class (year class age 4 in 1991–92) is relatively weak, based on the first four years of data.

On the Southern Plateau, the 1990 year class is dominant in the distributions from 1993–94 to 1995–96 (Figure 3), as it is for WCSI. Also, the 1988 year class (year class age 5 in 1992–93) is particularly weak in the first and last distributions. There are indications that the 1985 and 1980 year classes (year class ages 8 and 13 in 1992–93) may be stronger than average.

The distributions calculated for the Chatham Rise are relatively imprecise, being based on small samples of length and otolith data (see Appendix A). However, as in the other two areas, the 1990 year class shows some dominance in 1993–94 and 1995–96 (Figure 4). No other clear trends are apparent.

3.3 Comparison of mean length at age

Mean lengths at age, by sex, are plotted for silver warehou from the three areas in Figure 5. Note that although the means were calculated for year class ages (i.e., integer ages), differences between areas in the mean date of sampling (see Figure 1) result in the true age means differing between samples. (All data are listed in Appendix B.) In general, Southern Plateau samples were taken about 0.4 year earlier than WCSI samples, with Chatham samples being intermediate.

The differences in time of year sampling cause some difficulties when comparing mean lengths, particularly at younger ages where growth over 0.4 year could be considerable. However, as fish approach their asymptotic length, differences in time of sample would have little effect. Consequently, comparisons of mean length at age were made only when true age was greater than 5 years. (This corresponded approximately to mean lengths greater than 90% of calculated von Bertalanffy asymptotic length; see Section 3.4.)

For females, none of the pair-wise comparisons was significantly different. For males, three pairings were significantly different (Table 1). Year class 8 fish from Chatham Rise were significantly smaller than similar aged fish from both other areas, and year class 9 Chatham Rise fish were smaller than those from the Southern Plateau.

3.4 Growth parameters

Calculated 3-parameter von Bertalanffy curves, by area and sex, are listed in Table 2. However, Horn & Sutton (1996) noted that this growth model was not ideal for silver warehou because most data points for fish older than about 13 years tended to be above the curves. A similar problem was also apparent from a growth study of white warehou, *Seriolella caerulea* (Horn 2001). Subsequently, for both species, the 4-parameter von Bertalanffy model was found to produce a good fit to the data, with lower residual mean squares than the 3-parameter fit and balanced residuals throughout the data range. The 4-parameter curves are listed in Table 2 and plotted in Figure 6. Female silver warehou grow significantly larger than males. Growth curves (by sex) are virtually identical from the three areas.

3.5 Distribution of spawning areas

The distributions of ripe and running ripe, and spent, female silver warehou are shown in Figure 7. Several separate spawning areas are apparent: northwest South Island, western Chatham Rise, eastern Chatham Rise, south and east Stewart-Snares shelf, and Puysegur Bank. There are also indications that spawning occurs on the Auckland Islands shelf, off the east coast of the North Island between Hawke Bay and Palliser Bay, and off Northland. The distribution of spawning and spent females is certainly narrower than the overall distribution of silver warehou (see Anderson et al. 1998), indicating distinct spawning areas within the range of the species.

Summaries of maturity stages, by month, from several areas are shown for scientific observer data (Figure 8) and research trawl data (Figure 9). Observer data indicate that spawning occurs on the

Chatham Rise (eastern and western areas combined) from September to November, and on grounds off southern South Island from June to September. Off west coast South Island, spawning fish were recorded from July to September, but months immediately following these were inadequately sampled. No running ripe females were recorded by observers from grounds around the North Island, but it appears most likely that peak spawning occurs about August–September, based on the presence of ripe fish in July–September and spent fish in October.

Research trawl data do not comprehensively sample any area through the whole year (Figure 9). However, they do support some conclusions drawn from the observer data, i.e., a small sample of mature fish around the North Island in August, and spawning off west coast South Island in July and August.

3.6 Distribution of 0+ fish

The distribution of 0+ fish, by month, as indicated from research trawl tows where silver warehou were measured (Figure 10) shows juveniles occurring in a high proportion of tows inside the 200 m depth contour, all around the New Zealand coast. Exceptions to this are the waters off Southland in November and around the Chatham Islands in December. However, these months immediately follow the likely spawning seasons in these areas, so the 0+ silver warehou would be very small, and unlikely to be retained in the trawl codend. Also, the species may have a pelagic post-larval phase, and so be unavailable to the bottom trawl. Silver warehou less than 11 cm FL were captured in a fine mesh midwater trawl on the south Chatham Rise in February 1992, at depths at depths between the surface and 330 m (A. Hart, NIWA, pers. comm.). Fish in their first year of life do occur in some areas where spawning or spent fish have not been recorded, i.e., Tasman Bay, north and south Taranaki Bights, and northeast North Island.

It must be noted that the distribution of measured silver warehou reflects the distribution of trawl survey effort, so Figure 10 probably does not truely represent the complete distribution of 0+ fish.

4. DISCUSSION

4.1 Stock structure overview

Gavrilov (1979) initially proposed that a single stock of silver warehou occurred in New Zealand waters. Three administrative Fishstocks were established on the introduction of the QMS in 1986. Livingston (1988) concluded that there were at least four stocks, based on the existence of distinct spawning areas (i.e., west coast South Island, Mernoo Bank, Chatham Islands, Stewart-Snares shelf). She also noted the inappropriateness of combining the eastern Chatham Rise with the Sub-Antarctic/Southland area in the administrative stocks.

Other species of *Seriolella* in New Zealand waters are also believed to comprise multiple stocks. The white warehou (*S. caerulea*) spawns around the Mernoo Bank, off west coast South Island, and off Southland, so three stocks centered around these areas are postulated (Bagley & Hurst 1997). The blue warehou (*S. brama*) occurs shallower than the other two species and is known to complete seasonal migrations. From seasonal trends in landings and known spawning locations, Bagley et al. (1998) tentatively suggested the existence of four stocks.

4.2 Growth and age structures

There are no differences in growth rates of silver warehou from the Southern Plateau, Chatham Rise, and WCSI. It is recommended that in any future stock modelling of this species the 4-parameter von Bertalanffy model be used to describe growth as it fits the data better than the 3-parameter model.

Patterns in year class strengths are comparable between Southern Plateau and WCSI fish. Both populations exhibit a relatively strong 1990 year class and a relatively weak 1988 year class. The 1990 year class also appears to be relatively strong on the Chatham Rise, but estimates of year class strength are imprecise for this area.

In conclusion, data on growth and year class strengths of silver warehou provide no indication of separate biological stocks in the three areas examined. However, a lack of any differences in these parameters cannot be taken as evidence that there is a single stock of silver warehou in New Zealand waters.

4.3 Spawning biology and juvenile distribution

Grimes & Robertson (1981) described the egg and larval development of silver warehou up to 4 days after hatching. However, no substantive information is available to indicate the likely length of the larval phase, or the position in the water column of recently hatched larvae. Hence, the likely direction and extent of dispersion of juveniles from the spawning grounds are uncertain.

Spawning by silver warehou has previously been reported near the Mernoo Bank from September to November (Gavrilov 1976). From unpublished research voyage reports, Livingston (1988) inferred that spawning also occurred off the west coast of the South Island in winter, at the Mernoo Bank in winter-spring, around the Chatham Islands in spring-summer, and possibly on the Stewart-Snares shelf in early spring.

Based on the current work, there appear to be four relatively distinct areas of silver warehou spawning (off west coast South Island, southern South Island, eastern North Island, and on the Chatham Rise), and it is postulated that these represent four stocks. However, sub-areas of spawning within these areas could also be discerned (e.g., the eastern and western sections of the Chatham Rise). Differences in timing of spawning are apparent between some areas. Peak spawning on the Chatham Rise is about 2 months later than the peaks off the southern and western South Island.

0+ silver warehou occur in shallow waters adjacent to the main spawning areas, and also in areas some distance from them. Juvenile fish in Tasman Bay and the south Taranaki Bight had likely been spawned off west coast South Island, then carried northwest by the prevailing currents. They could easily be carried through Cook Strait and incorporated in the populations either off east coast North Island or on the Chatham Rise. Also, the adult fish are known to school pelagically, so the relatively deep waters between the proposed stock areas may not prove as effective a barrier against stock mixing as they might to other species more dedicated to a demersal habitat. Thus, although four stocks are postulated, it is very likely that a degree of stock mixing occurs.

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Table 1: Students-*t* values for pairwise comparisons (by sex, and between areas) of mean length at age. Significance levels (following application of the Bonferroni correction for multiple tests) are indicated by * where $P < 0.05$ and ** where $P < 0.01$. SP, Southern Plateau; CR, Chatham Rise; WC, west coast South Island. –, insufficient data for comparison.

Age	Male			Female		
	SPvCR	SPvWC	WCvCR	SPvCR	SPvWC	WCvCR
6	2.029	0.595	2.652	0.701	1.913	0.163
7	2.206	0.368	2.489	2.521	1.579	1.699
8	**4.220	0.825	*3.962	1.697	0.840	2.369
9	*3.374	2.419	1.891	0.558	0.838	0.110
10	1.876	1.456	0.931	1.598	0.400	1.534
11	1.874	0.152	2.118	1.836	1.928	0.556
12	0.459	0.836	0.110	0.018	0.762	0.443
13	0.832	0.056	0.891	0.799	0.283	1.028
14	0.059	0.014	0.060	1.099	0.847	2.006
15	0.634	0.725	0.294	1.836	2.950	0.200
16	–	0.645	–	0.249	0.000	0.261
17	0.958	0.798	1.323	–	1.184	–

Table 2: Fits to the 3-parameter and 4-parameter von Bertalaffy growth models, by sex (with 95% confidence intervals), for silver warehou caught in three areas within the New Zealand EEZ. *n*, sample size.

	n	L_∞		*k*		t_0		*P*	
Southern Plateau									
Male	658	52.2	(51.8–52.6)	0.363	(0.344–0.382)	–0.94	(–1.06 to –0.82)	–	
Female	759	55.0	(54.6–55.4)	0.304	(0.290–0.318)	–1.20	(–1.33 to –1.07)	–	
Male	658	53.0	(52.4–53.6)	0.275	(0.237–0.314)	–0.06	(–0.29 to 0.16)	0.508	(0.407–0.610)
Female	759	56.1	(55.4–56.8)	0.217	(0.189–0.245)	–0.01	(–0.21 to 0.18)	0.462	(0.390–0.533)
Chatham									
Male	331	52.2	(51.4–53.0)	0.283	(0.251–0.314)	–1.77	(–2.13 to –1.40)	–	
Female	325	54.6	(53.7–55.5)	0.278	(0.241–0.315)	–1.66	(–2.10 to –1.25)	–	
Male	331	53.7	(52.1–55.3)	0.178	(0.119–0.237)	0.02	(–0.39 to 0.43)	0.359	(0.246–0.473)
Female	325	58.4	(56.9–59.9)	0.115	(0.101–0.129)	0.33	(0.02 to 0.64)	0.271	(0.244–0.299)
West Coast South Island									
Male	973	52.5	(52.2–52.8)	0.308	(0.291–0.326)	–1.46	(–1.70 to –1.23)	–	
Female	1222	55.3	(55.0–55.6)	0.257	(0.243–0.271)	–2.00	(–2.26 to –1.73)	–	
Male	973	53.8	(53.1–54.4)	0.195	(0.166–0.225)	0.30	(0.16 to 0.43)	0.338	(0.290–0.387)
Female	1222	56.8	(56.1–57.6)	0.157	(0.132–0.182)	0.28	(0.14 to 0.43)	0.318	(0.276–0.361)

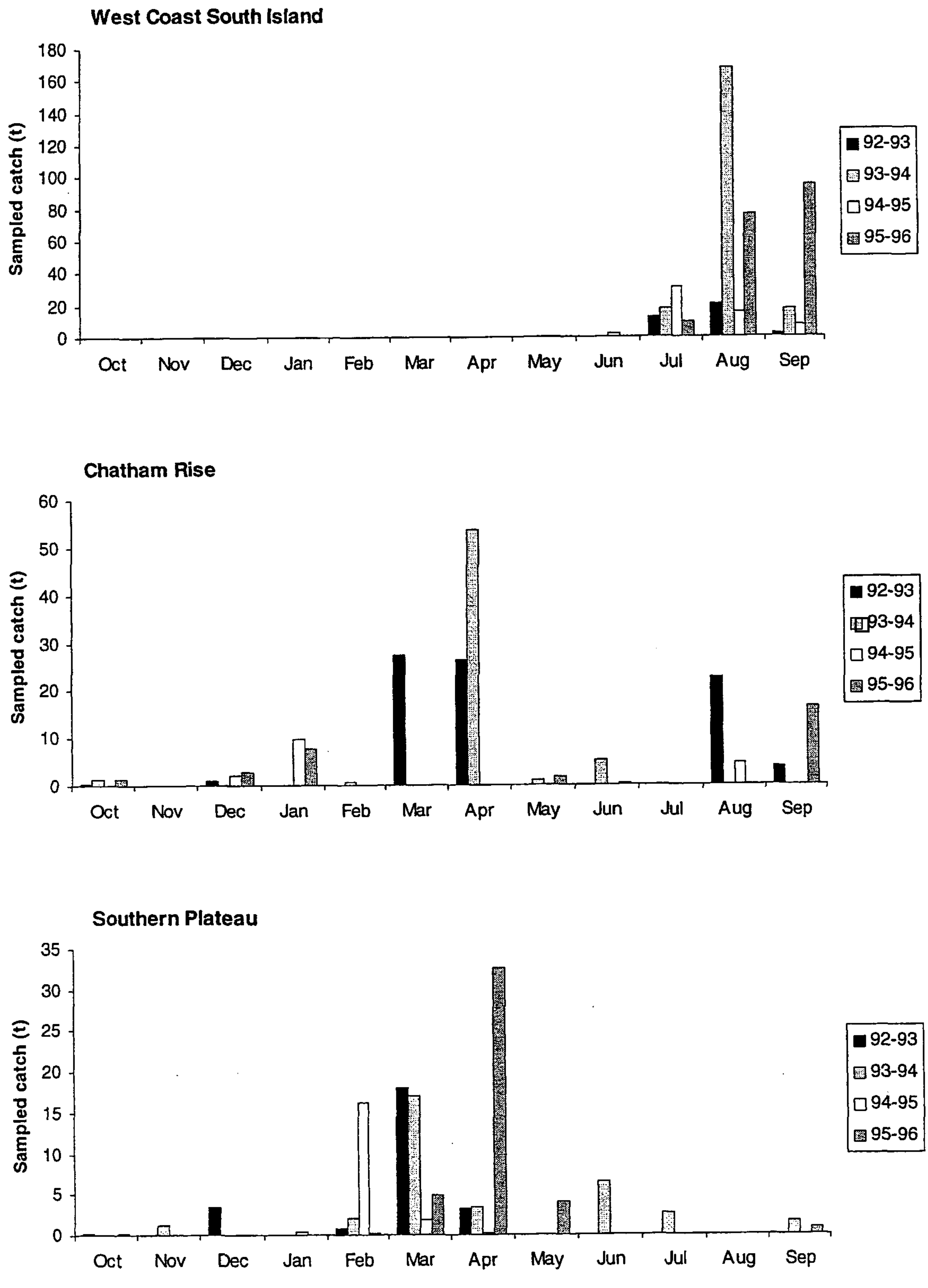


Figure 1: Timing and quantity of landings sampled by scientific observers in three areas of the New Zealand EEZ, in fishing years 1992–93 to 1995–96.

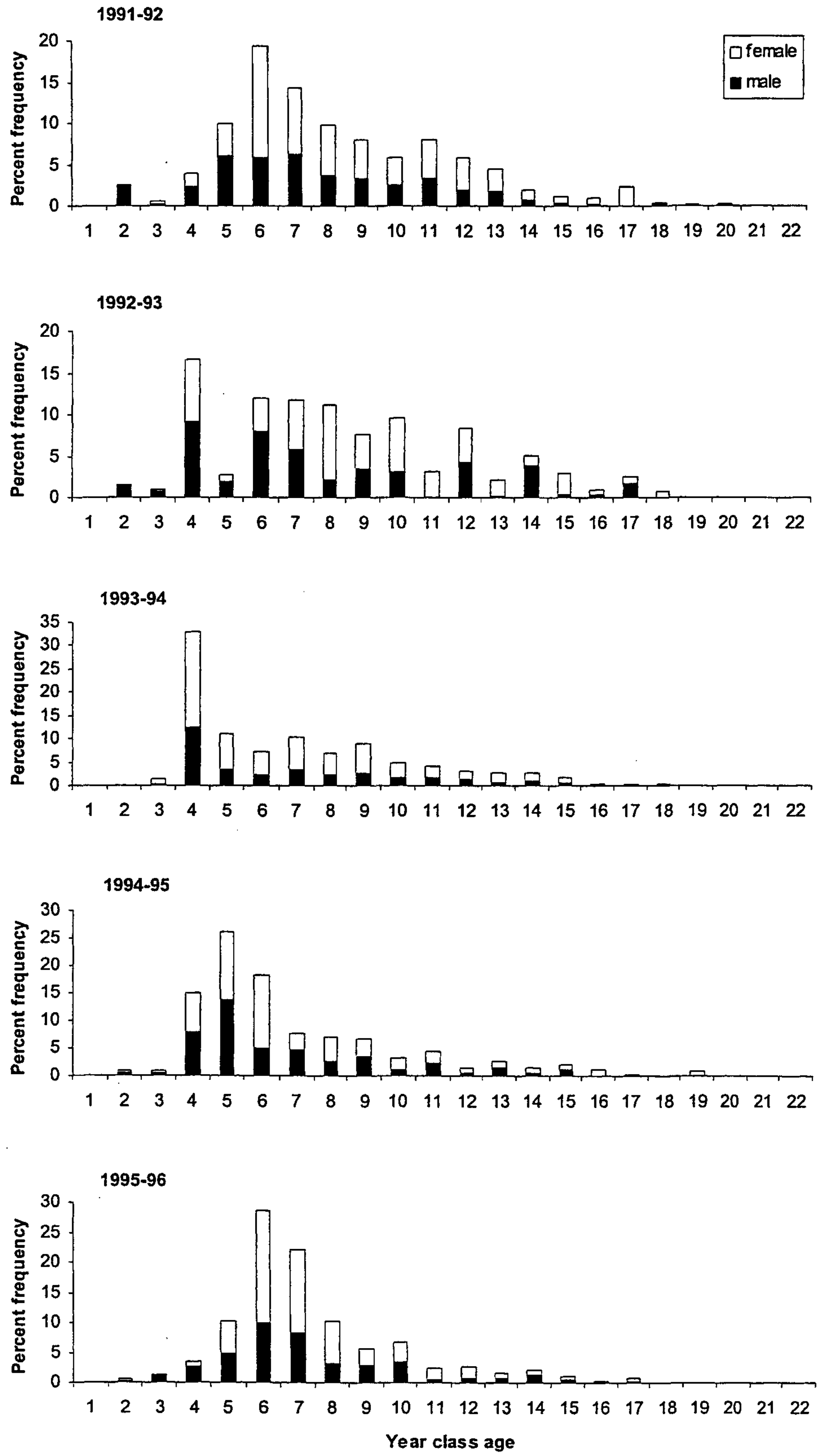


Figure 2: Calculated proportion-at-age distributions for commercial landings of silver warehou from WCSI in fishing years 1991–92 to 1995–96.

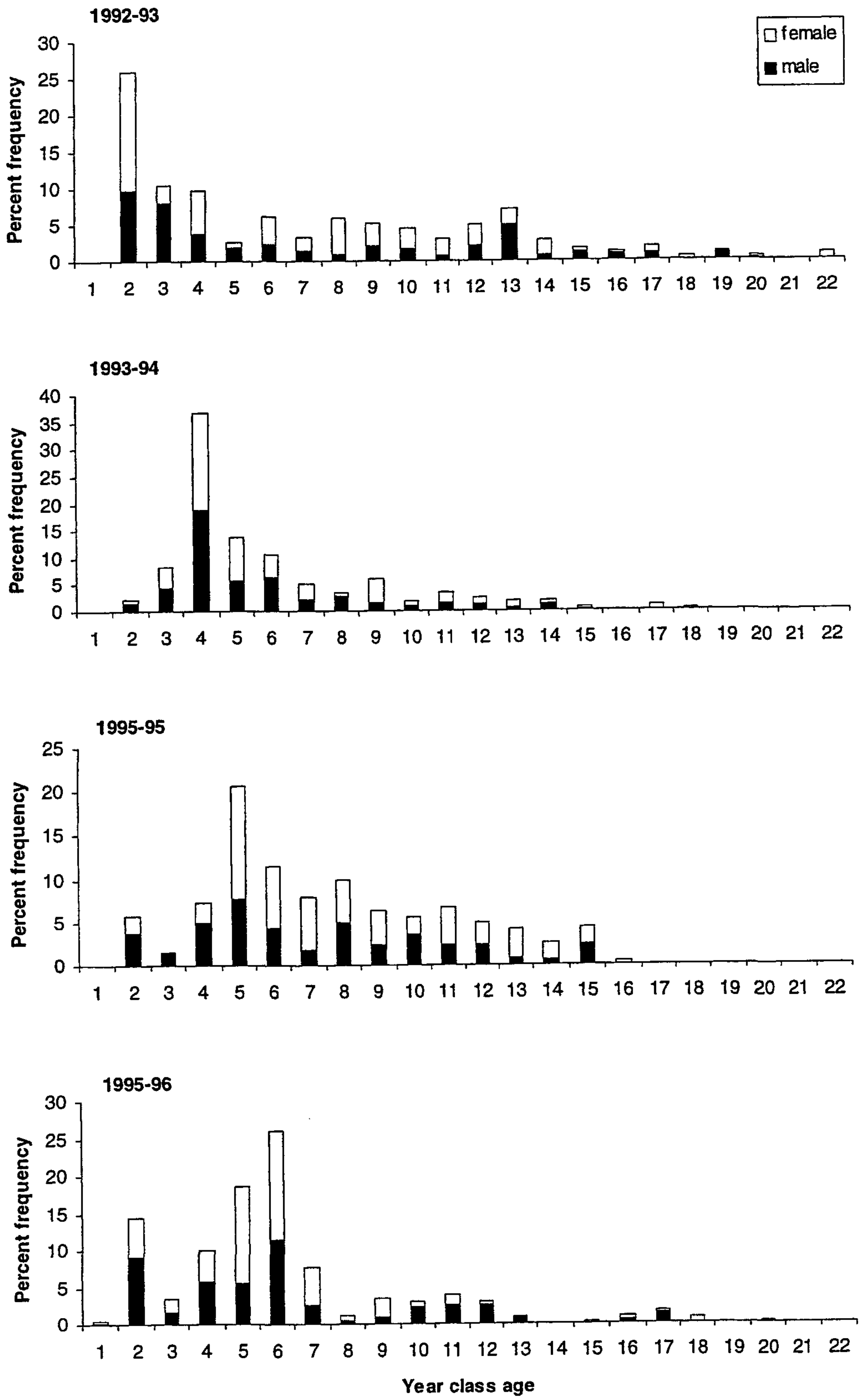


Figure 3: Calculated proportion-at-age distributions for commercial landings of silver warehou from the Southern Plateau in fishing years 1992–93 to 1995–96.

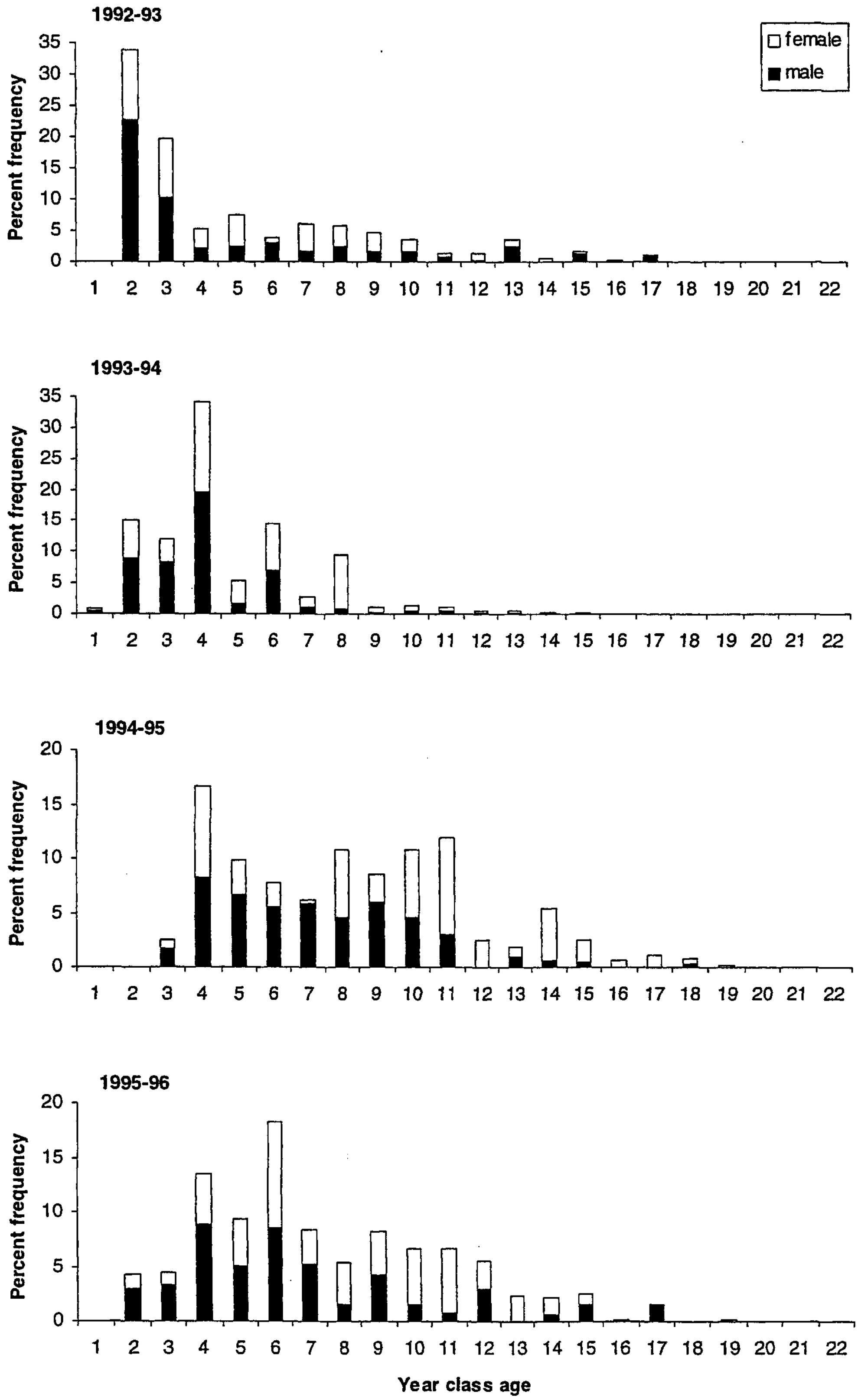
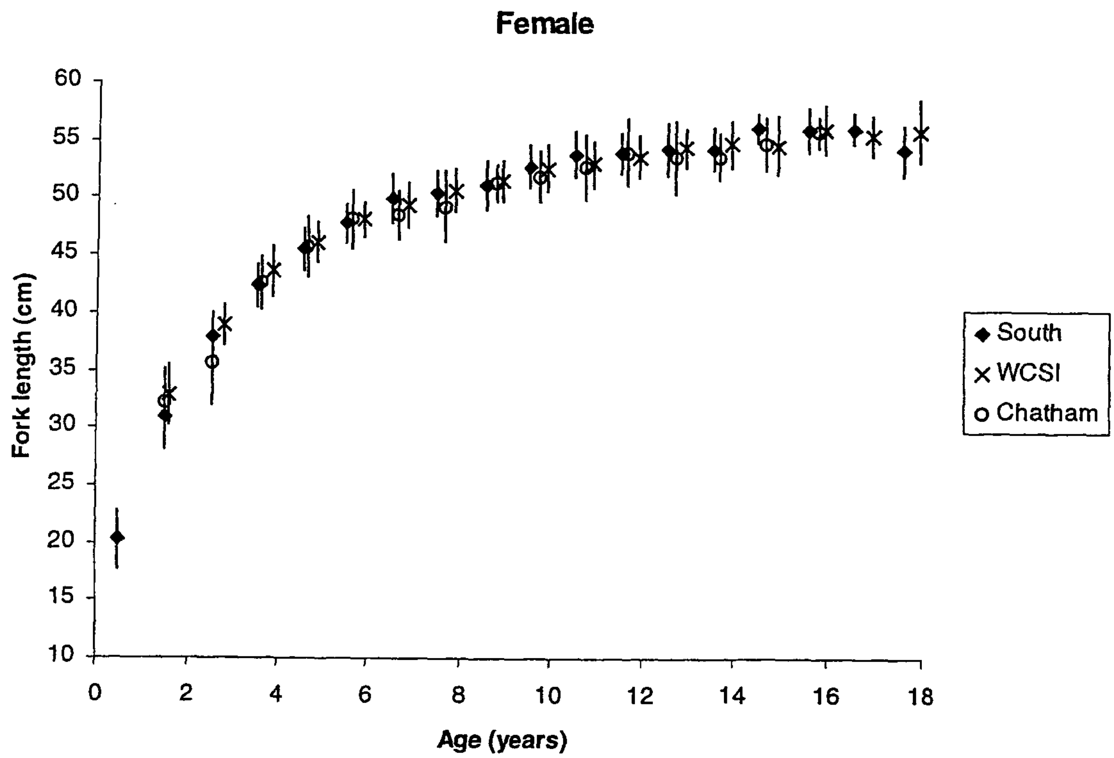


Figure 4: Calculated proportion-at-age distributions for commercial landings of silver warehou from the Chatham Rise in fishing years 1992–93 to 1995–96.



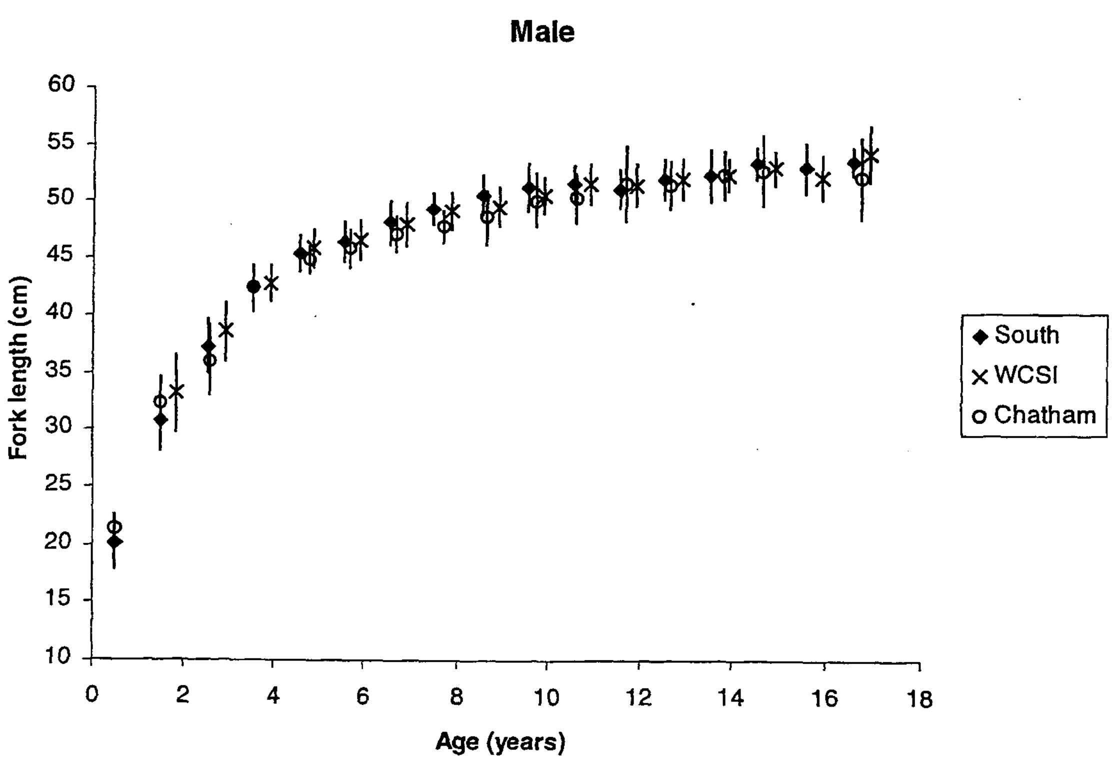
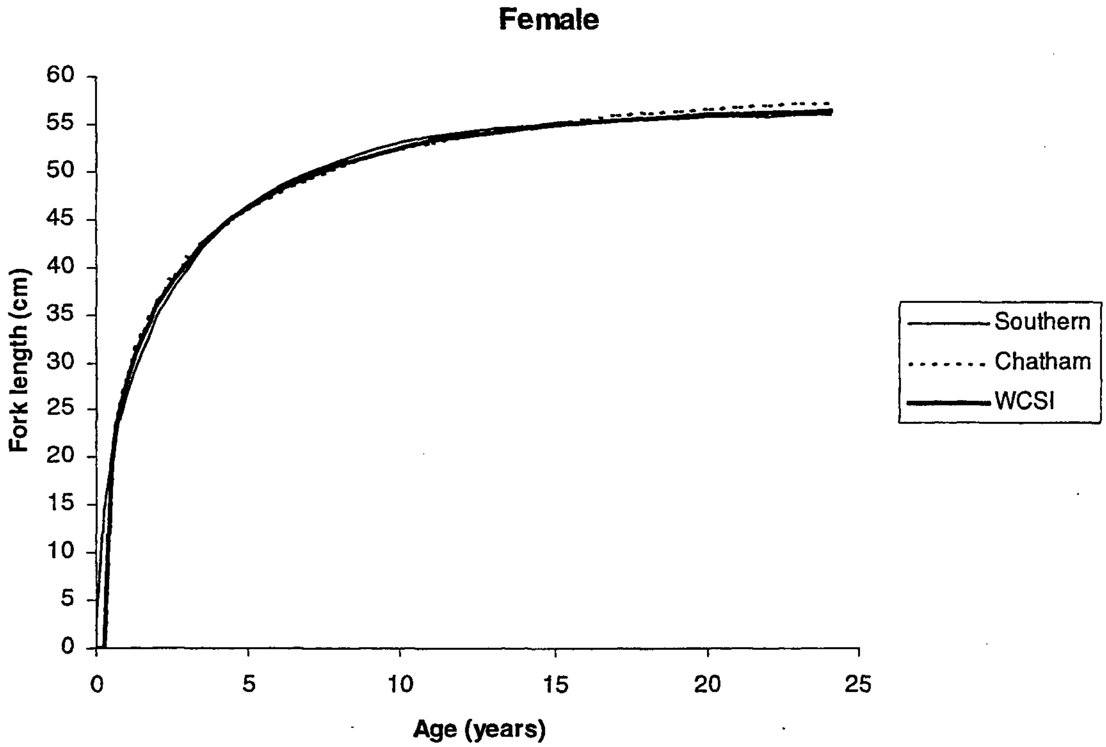


Figure 5: Mean lengths at age, by sex, for silver warehou from the Southern Plateau (South), west coast South Island (WCSI), and the Chatham Rise (Chatham). Error bars are ± 1 standard deviation.



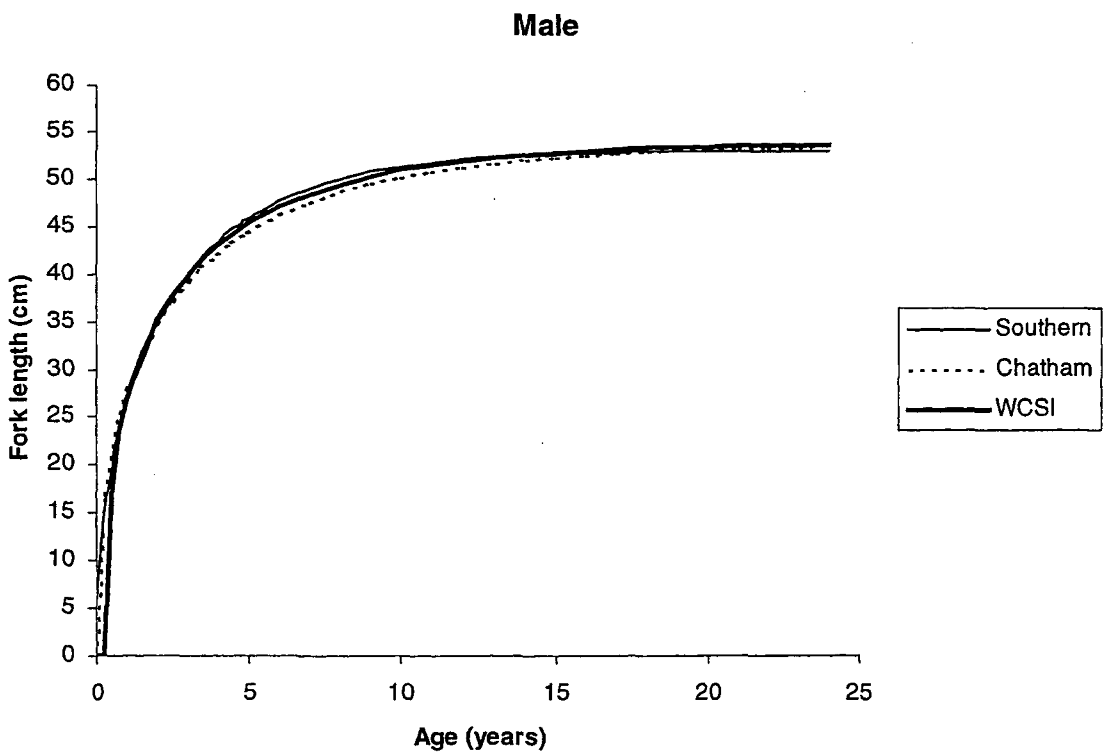


Figure 6: Plots of calculated 4-parameter von Bertalanffy growth curves, by sex, for silver warehou from the Southern Plateau (South), west coast South Island (WCSI), and the Chatham Rise (Chatham).

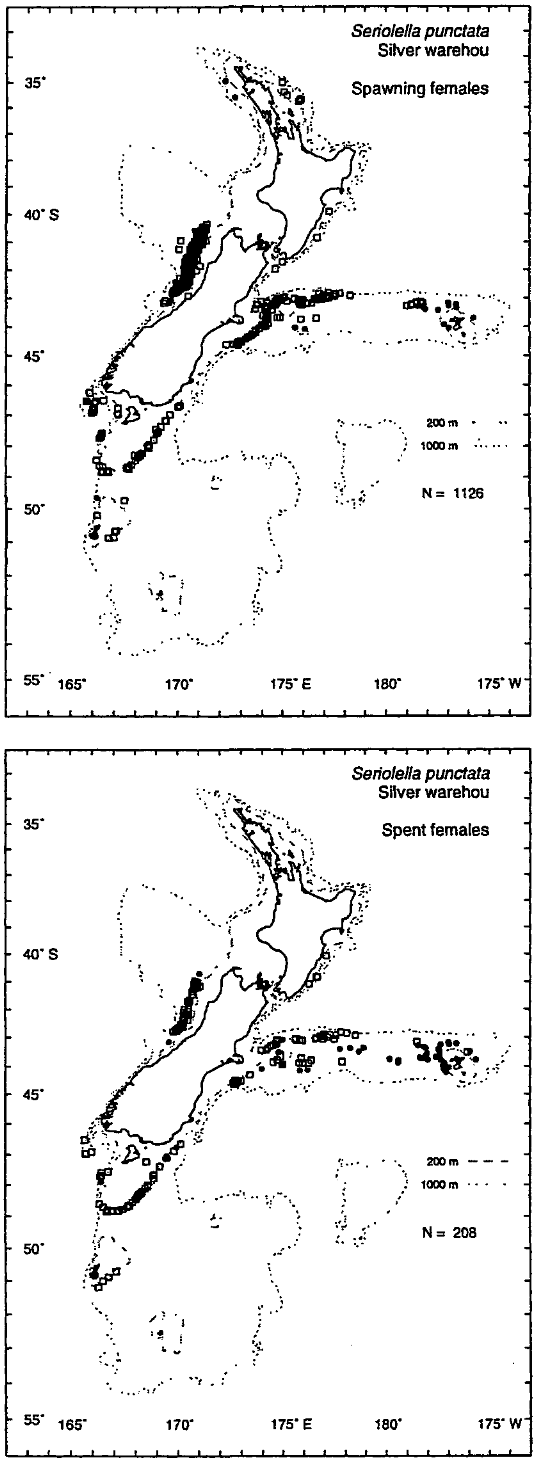


Figure 7: Location of ripe and running ripe, and spent, female silver warehou. Observed commercial tows are indicated by open squares and research tows by closed circles. N, total number of tows.

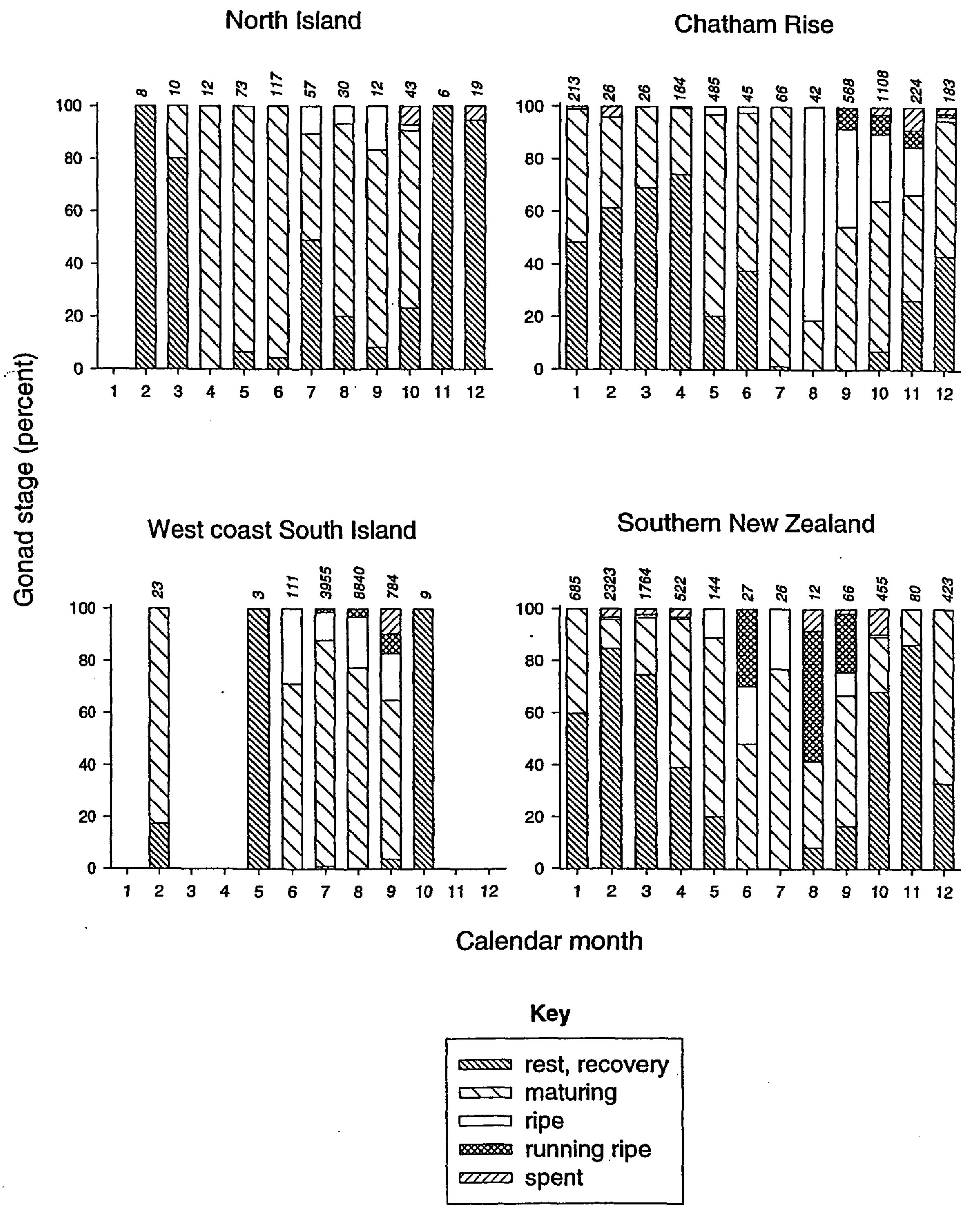


Figure 8: The percentage of female silver warehou gonad stages by area and month from scientific observer data. Numbers in italics are the numbers of mature females staged per month.

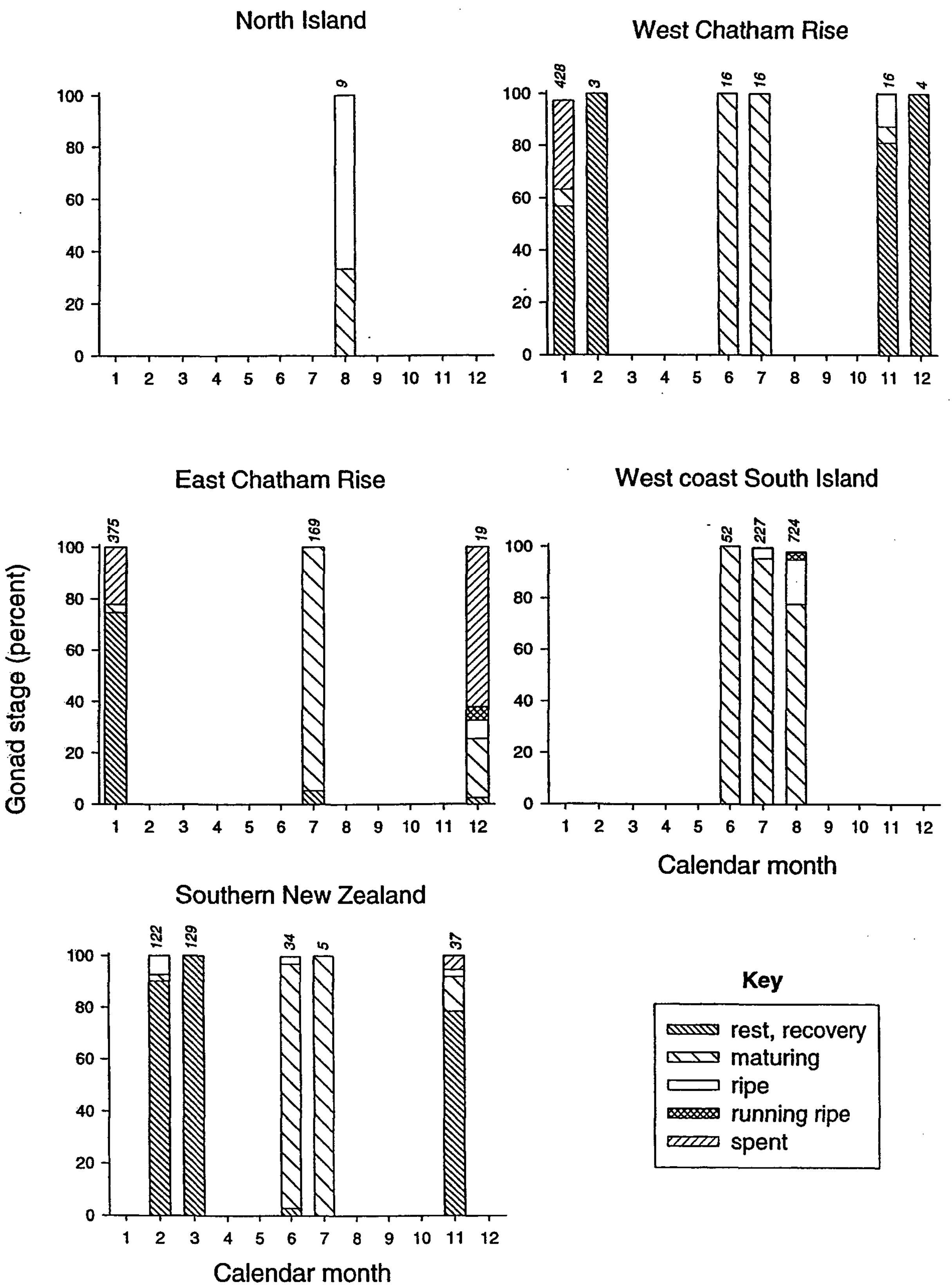


Figure 9: The percentage of female silver warehou gonad stages by area and month from research data. Numbers in italics are the numbers of mature females staged per month.

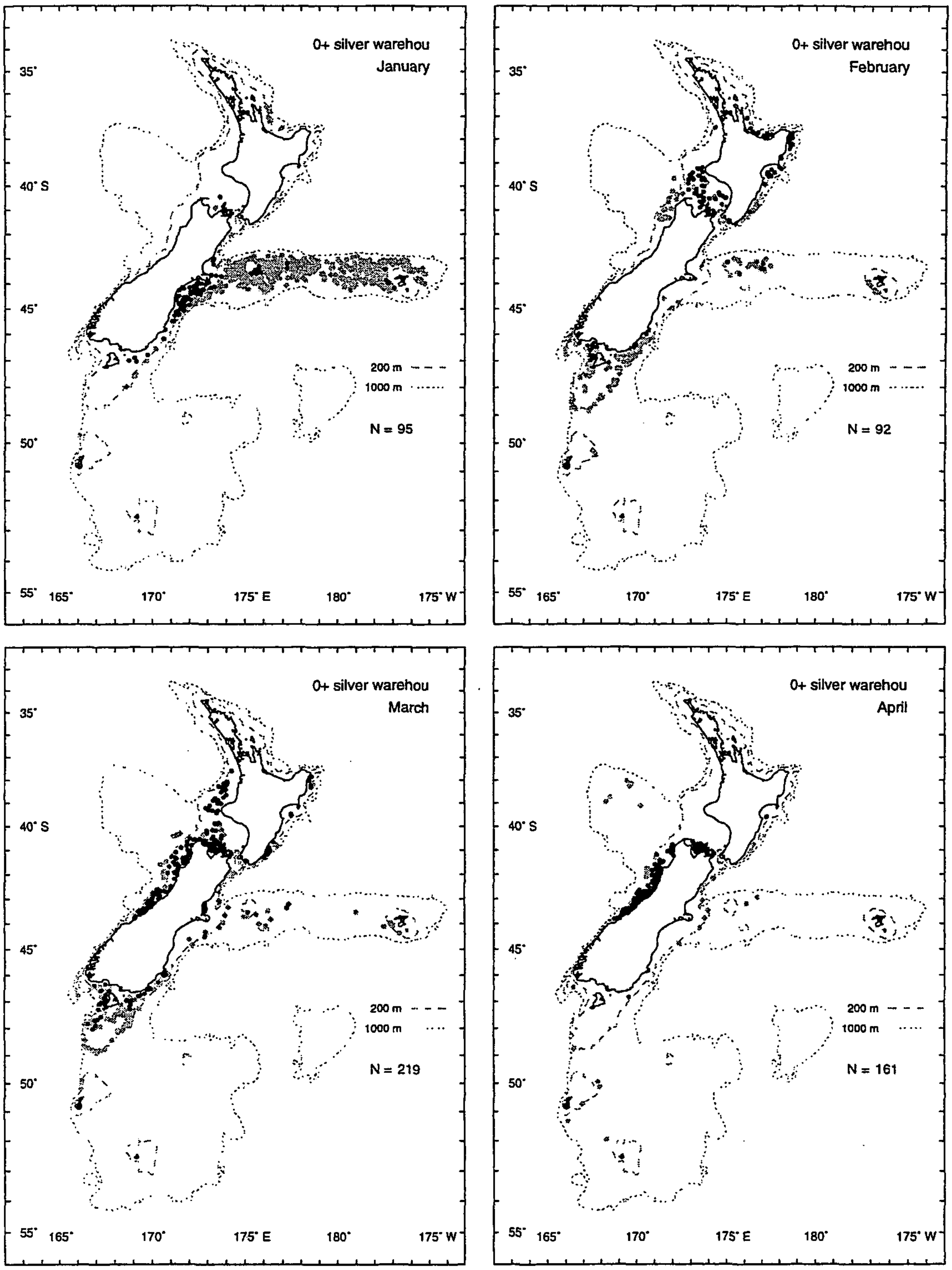


Figure 10: The distribution of 0+ silver warehou by month from the research trawl database. The grey background points represent trawl stations where silver warehou were measured, but where 0+ fish did not occur. N, number of 0+ fish measured. [Note: Figure 10 continues on the following two pages.]

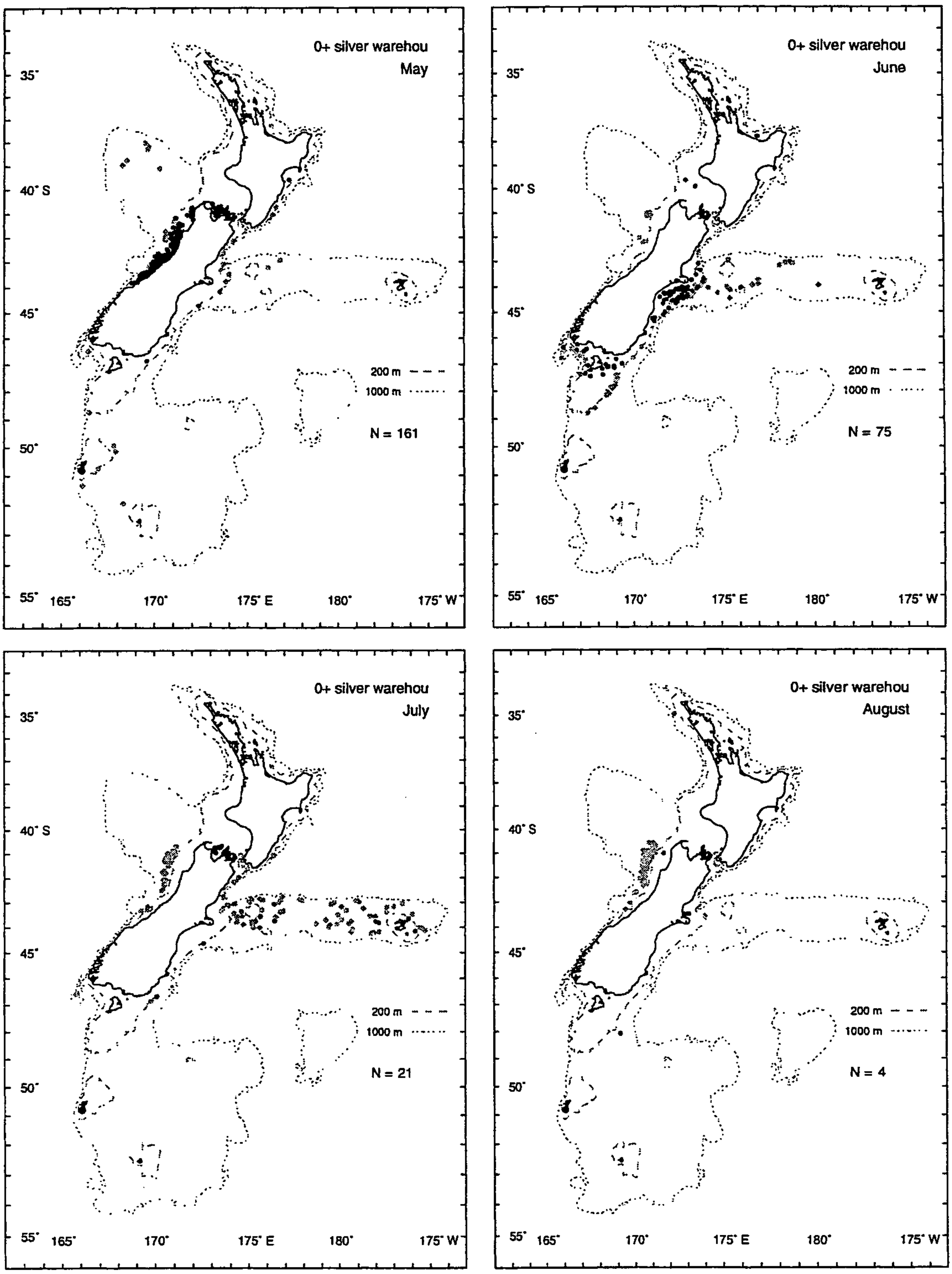


Figure 10 ctd.

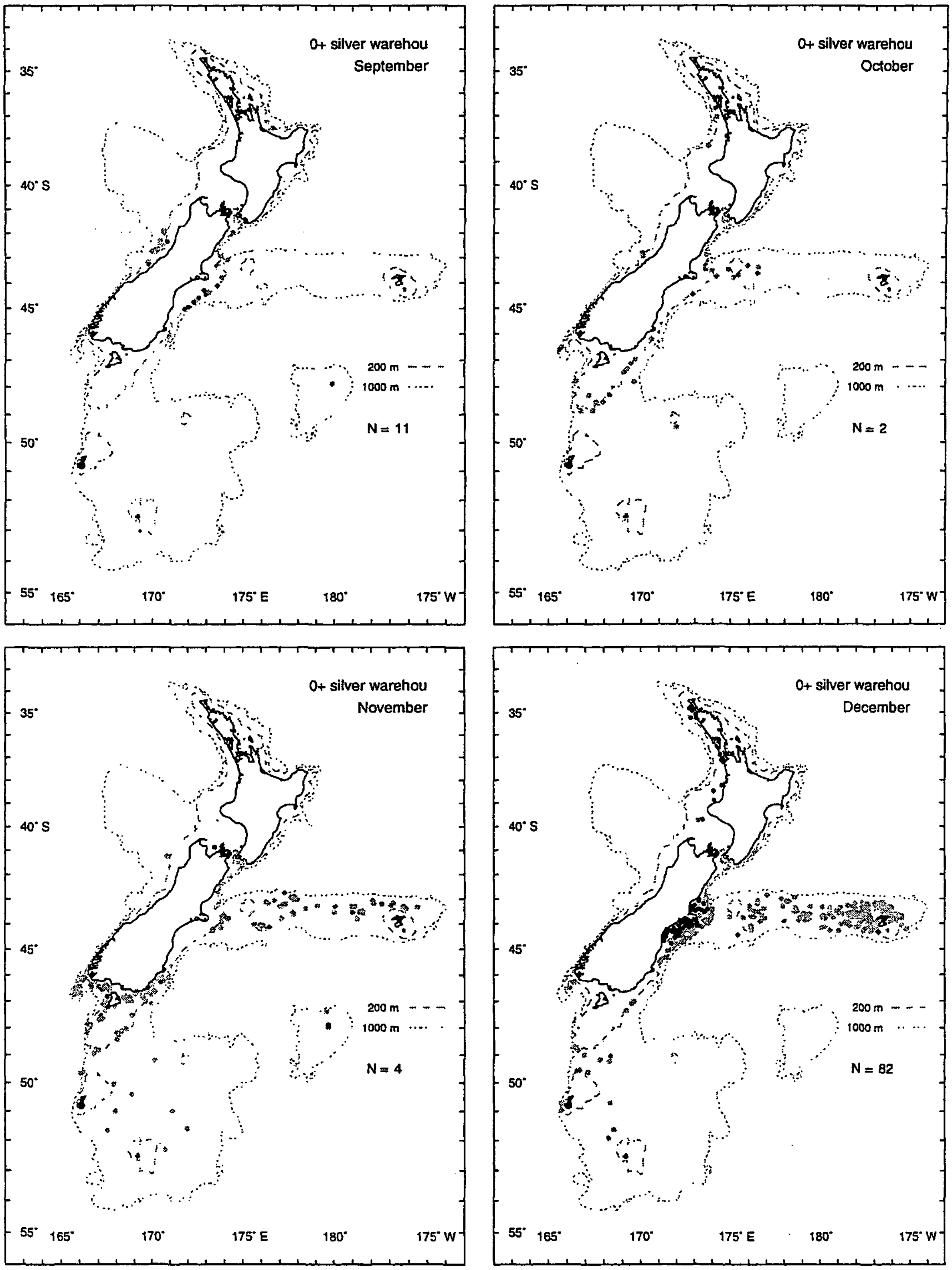


Figure 10 ctd.

Appendix A

Table A1: Calculated numbers-at-age (scaled to reported landings) and proportion-at-age, by sex, with coefficients of variation (c.v.), and proportion-at-age with sexes combined, from sampled commercial landings of silver warehou. Data are grouped by fishing year (Fish yr) in three areas (Southern Plateau, WCSI, Chatham Rise). N, number at age; P, proportion at age; mal, males; fem, females; tot, sexes combined. For each sample, the numbers of fish measured and aged (by sex), and the mean weighted c.v. over all age classes are also presented.

Fish yr	Age	N.mal	c.v.	P.mal	N.fem	c.v.	P.fem	P.tot		
Southern Plateau										
1992–93	2	148 315	0.101	9.72	246 651	0.115	16.16	25.88	Meas.mal	1 192
	3	125 217	0.147	8.20	34 853	0.455	2.28	10.49	Meas.fem	1 330
	4	58 147	0.243	3.81	92 019	0.180	6.03	9.84	Aged.mal	190
	5	27 349	0.314	1.79	12 973	0.456	0.85	2.64	Aged.fem	223
	6	36 066	0.301	2.36	57 436	0.228	3.76	6.13	Mean c.v.	26.1
	7	21 991	0.400	1.44	30 522	0.348	2.00	3.44		
	8	15 196	0.447	1.00	75 594	0.210	4.95	5.95		
	9	34 225	0.341	2.24	47 269	0.288	3.10	5.34		
	10	24 061	0.440	1.58	44 710	0.303	2.93	4.51		
	11	10 080	0.578	0.66	38 686	0.338	2.53	3.20		
	12	30 944	0.361	2.03	44 706	0.310	2.93	4.96		
	13	76 320	0.216	5.00	33 886	0.367	2.22	7.22		
	14	11 371	0.604	0.75	30 419	0.371	1.99	2.74		
	15	18 504	0.441	1.21	6 580	0.659	0.43	1.64		
	16	15 555	0.489	1.02	2 773	1.075	0.18	1.20		
	17	13 621	0.596	0.89	14 900	0.543	0.98	1.87		
	18	0	0.000	0.00	5 461	0.839	0.36	0.36		
	19	18 233	0.341	1.19	1 374	2.741	0.09	1.28		
	20	3 014	1.078	0.20	2 773	1.075	0.18	0.38		
	21	0	0.000	0.00	0	0.000	0.00	0.00		
	22	0	0.000	0.00	14 395	0.581	0.94	0.94		
1993–94	2	26 002	0.738	1.66	8 655	1.608	0.55	2.21	Meas.mal	924
	3	70 897	0.330	4.53	59 471	0.319	3.80	8.33	Meas.fem	1 045
	4	297 734	0.129	19.03	277 900	0.120	17.76	36.79	Aged.mal	175
	5	91 397	0.242	5.84	125 195	0.211	8.00	13.84	Aged.fem	191
	6	101 866	0.245	6.51	62 606	0.298	4.00	10.51	Mean c.v.	28.1
	7	36 570	0.367	2.34	43 884	0.374	2.80	5.14		
	8	45 992	0.347	2.94	6 957	0.750	0.44	3.38		
	9	25 474	0.473	1.63	67 858	0.299	4.34	5.96		
	10	16 412	0.492	1.05	11 660	0.530	0.75	1.79		
	11	23 676	0.486	1.51	29 307	0.374	1.87	3.39		
	12	18 576	0.501	1.19	22 600	0.408	1.44	2.63		
	13	12 162	0.596	0.78	16 555	0.443	1.06	1.84		
	14	21 143	0.420	1.35	7 180	0.614	0.46	1.81		
	15	4 207	0.944	0.27	5 272	0.614	0.34	0.61		
	16	0	0.000	0.00	2 116	0.881	0.14	0.14		
	17	2 048	1.501	0.13	14 071	0.665	0.90	1.03		
	18	1 745	1.734	0.11	3 604	1.083	0.23	0.34		
	19	0	0.000	0.00	408	1.432	0.03	0.03		
	20	0	0.000	0.00	495	1.213	0.03	0.03		

Fish yr	Age	N.mal	c.v.	P.mal	N.fem	c.v.	P.fem	P.tot		
1994–95	2	40 497	0.409	3.76	20 769	1.047	1.93	5.68	Meas.mal	727
	3	16 270	0.638	1.51	497	6.202	0.05	1.56	Meas.fem	682
	4	54 319	0.247	5.04	25 649	0.519	2.38	7.42	Aged.mal	156
	5	82 962	0.190	7.70	138 745	0.149	12.87	20.57	Aged.fem	186
	6	47 778	0.290	4.43	76 611	0.212	7.11	11.54	Mean c.v.	31.6
	7	19 024	0.429	1.76	66 280	0.214	6.15	7.91		
	8	54 431	0.274	5.05	53 554	0.272	4.97	10.02		
	9	25 334	0.377	2.35	42 832	0.291	3.97	6.32		
	10	38 446	0.303	3.57	22 464	0.391	2.08	5.65		
	11	26 037	0.320	2.42	46 230	0.309	4.29	6.70		
	12	25 934	0.373	2.41	28 573	0.384	2.65	5.06		
	13	8 854	0.687	0.82	36 817	0.333	3.42	4.24		
	14	7 179	0.703	0.67	20 957	0.469	1.94	2.61		
	15	25 717	0.351	2.39	21 117	0.484	1.96	4.34		
	16	0	0.000	0.00	3 808	0.980	0.35	0.35		
	17	219	2.971	0.02	0	0.000	0.00	0.02		
1995–96	1	4 216	2.345	0.24	2 321	3.615	0.13	0.37	Meas.mal	845
	2	157 746	0.239	8.97	97 377	0.428	5.53	14.50	Meas.fem	769
	3	30 505	0.567	1.73	29 102	0.774	1.65	3.39	Aged.mal	150
	4	101 424	0.230	5.77	74 516	0.299	4.24	10.00	Aged.fem	171
	5	96 497	0.238	5.48	232 579	0.166	13.22	18.70	Mean c.v.	31.8
	6	200 237	0.149	11.38	258 100	0.147	14.67	26.05		
	7	44 139	0.358	2.51	92 907	0.241	5.28	7.79		
	8	9 445	0.720	0.54	10 741	0.741	0.61	1.15		
	9	15 549	0.592	0.88	43 984	0.403	2.50	3.38		
	10	42 793	0.422	2.43	9 800	1.021	0.56	2.99		
	11	45 661	0.352	2.60	24 449	0.563	1.39	3.99		
	12	43 642	0.417	2.48	8 238	1.132	0.47	2.95		
	13	14 521	0.633	0.83	881	5.185	0.05	0.88		
	14	0	0.000	0.00	1 734	2.169	0.10	0.10		
	15	0	0.000	0.00	5 787	1.156	0.33	0.33		
	16	9 328	0.981	0.53	6 488	1.223	0.37	0.90		
	17	24 661	0.588	1.40	2 485	1.700	0.14	1.54		
	18	0	0.000	0.00	13 342	0.726	0.76	0.76		
	19	0	0.000	0.00	14	278.994	0.00	0.00		
	20	4 119	1.797	0.23	0	0.000	0.00	0.23		
WCSI										
1991–92	2	13 679	0.126	2.48	319	4.378	0.06	2.53	Meas.mal	1 507
	3	1 589	1.019	0.29	1 149	1.367	0.21	0.50	Meas.fem	1 856
	4	12 598	0.266	2.28	8 583	0.451	1.55	3.83	Aged.mal	215
	5	33 226	0.172	6.02	22 022	0.249	3.99	10.00	Aged.fem	229
	6	32 345	0.205	5.86	75 261	0.129	13.63	19.48	Mean c.v.	25.1
	7	35 028	0.198	6.34	44 321	0.178	8.02	14.37		
	8	21 085	0.272	3.82	32 531	0.211	5.89	9.71		
	9	18 538	0.285	3.36	25 983	0.241	4.70	8.06		
	10	14 373	0.271	2.60	18 190	0.283	3.29	5.90		
	11	18 581	0.240	3.36	26 032	0.241	4.71	8.08		
	12	10 906	0.301	1.97	21 098	0.253	3.82	5.79		
	13	9 442	0.321	1.71	15 504	0.312	2.81	4.52		
	14	4 150	0.522	0.75	6 328	0.466	1.15	1.90		
	15	1 950	0.757	0.35	4 108	0.564	0.74	1.10		
	16	975	1.070	0.18	4 523	0.594	0.82	1.00		
	17	0	0.000	0.00	12 996	0.369	2.35	2.35		
	18	1 497	0.992	0.27	891	1.027	0.16	0.43		
	19	1 101	0.957	0.20	493	0.678	0.09	0.29		
	20	0	0.000	0.00	891	1.027	0.16	0.16		

Fish yr	Age	N.mal	c.v.	P.mal	N.fem	c.v.	P.fem	P.tot		
1992–93	2	6 347	0.130	1.50	531	0.703	0.13	1.62	Meas.mal	503
	3	3 661	0.372	0.86	177	1.255	0.04	0.90	Meas.fem	663
	4	39 008	0.179	9.19	31 768	0.216	7.48	16.67	Aged.mal	75
	5	8 029	0.573	1.89	3 776	0.824	0.89	2.78	Aged.fem	91
	6	34 246	0.269	8.07	16 270	0.367	3.83	11.90	Mean c.v.	35.5
	7	24 627	0.310	5.80	24 996	0.305	5.89	11.69		
	8	9 292	0.500	2.19	37 807	0.250	8.91	11.10		
	9	14 644	0.434	3.45	17 653	0.337	4.16	7.61		
	10	13 426	0.395	3.16	27 283	0.299	6.43	9.59		
	11	390	2.084	0.09	13 117	0.444	3.09	3.18		
	12	18 352	0.372	4.32	17 293	0.377	4.07	8.40		
	13	988	2.007	0.23	8 195	0.507	1.93	2.16		
	14	16 639	0.325	3.92	5 417	0.702	1.28	5.20		
	15	1 854	0.987	0.44	10 616	0.487	2.50	2.94		
	16	1 854	0.987	0.44	2 711	1.005	0.64	1.08		
	17	7 744	0.468	1.82	2 835	0.961	0.67	2.49		
	18	0	0.000	0.00	2 983	0.985	0.70	0.70		
1993–94	2	945	1.763	0.07	0	0.000	0.00	0.07	Meas.mal	3 451
	3	6 070	0.563	0.44	14 198	0.456	1.03	1.47	Meas.fem	5 600
	4	173 819	0.060	12.59	280 829	0.057	20.34	32.92	Aged.mal	336
	5	48 231	0.170	3.49	105 929	0.131	7.67	11.16	Aged.fem	491
	6	35 057	0.196	2.54	65 487	0.185	4.74	7.28	Mean c.v.	15.3
	7	49 599	0.159	3.59	92 734	0.142	6.72	10.31		
	8	32 801	0.196	2.38	61 701	0.172	4.47	6.84		
	9	39 274	0.171	2.84	83 173	0.135	6.02	8.87		
	10	25 921	0.217	1.88	43 228	0.180	3.13	5.01		
	11	24 559	0.228	1.78	35 047	0.189	2.54	4.32		
	12	20 874	0.247	1.51	21 245	0.236	1.54	3.05		
	13	8 545	0.358	0.62	30 678	0.191	2.22	2.84		
	14	15 024	0.272	1.09	22 604	0.238	1.64	2.72		
	15	10 960	0.357	0.79	13 526	0.307	0.98	1.77		
	16	2 176	0.720	0.16	2 732	0.569	0.20	0.36		
	17	3 541	0.785	0.26	2 639	0.627	0.19	0.45		
	18	0	0.000	0.00	3 176	0.586	0.23	0.23		
	19	1 190	0.997	0.09	839	1.024	0.06	0.15		
	20	0	0.000	0.00	1 055	0.914	0.08	0.08		
	21	0	0.000	0.00	939	1.011	0.07	0.07		
1994–95	1	216	1.898	0.02	216	1.898	0.02	0.04	Meas.mal	1 184
	2	5 127	1.246	0.49	3 052	1.951	0.29	0.79	Meas.fem	1 252
	3	5 702	0.354	0.55	2 084	2.671	0.20	0.75	Aged.mal	223
	4	81 272	0.152	7.84	72 785	0.168	7.02	14.86	Aged.fem	221
	5	143 014	0.121	13.79	127 889	0.121	12.34	26.13	Mean c.v.	24.8
	6	52 250	0.223	5.04	136 894	0.147	13.20	18.24		
	7	48 109	0.235	4.64	31 812	0.309	3.07	7.71		
	8	27 126	0.319	2.62	46 993	0.294	4.53	7.15		
	9	35 463	0.252	3.42	33 452	0.286	3.23	6.65		
	10	11 255	0.428	1.09	20 871	0.378	2.01	3.10		
	11	25 817	0.283	2.49	20 437	0.378	1.97	4.46		
	12	7 286	0.466	0.70	7 561	0.587	0.73	1.43		
	13	14 259	0.409	1.38	13 239	0.403	1.28	2.65		
	14	6 119	0.573	0.59	8 928	0.520	0.86	1.45		
	15	11 005	0.428	1.06	10 731	0.439	1.04	2.10		
	16	0	0.000	0.00	10 966	0.534	1.06	1.06		
	17	1 540	1.034	0.15	1 965	1.008	0.19	0.34		
	18	1 294	1.261	0.12	0	0.000	0.00	0.12		
	19	532	2.405	0.05	8 974	0.957	0.87	0.92		

Fish yr	Age	N.mal	c.v.	P.mal	N.fem	c.v.	P.fem	P.tot		
1995–96	2	4 527	0.254	0.35	1 497	1.381	0.11	0.46	Meas.mal	1730
	3	18 921	0.302	1.44	363	12.453	0.03	1.47	Meas.fem	1979
	4	34 668	0.174	2.64	13 052	0.427	1.00	3.64	Aged.mal	148
	5	64 669	0.233	4.93	68 739	0.195	5.24	10.17	Aged.fem	211
	6	129 774	0.168	9.90	244 301	0.114	18.63	28.53	Mean c.v.	23.3
	7	110 818	0.189	8.45	179 846	0.138	13.72	22.17		
	8	43 590	0.308	3.32	90 436	0.203	6.90	10.22		
	9	37 582	0.345	2.87	35 800	0.323	2.73	5.60		
	10	46 802	0.288	3.57	42 301	0.293	3.23	6.80		
	11	6 250	0.617	0.48	24 644	0.350	1.88	2.36		
	12	11 428	0.526	0.87	23 034	0.378	1.76	2.63		
	13	12 023	0.498	0.92	9 785	0.541	0.75	1.66		
	14	17 657	0.392	1.35	9 404	0.567	0.72	2.06		
	15	6 829	0.646	0.52	8 538	0.557	0.65	1.17		
	16	682	1.376	0.05	1 220	1.437	0.09	0.15		
	17	2 853	0.875	0.22	7 068	0.685	0.54	0.76		
	18	0	0.000	0.00	54	16.466	0.00	0.00		
	19	0	0.000	0.00	54	16.466	0.00	0.00		
	20	0	0.000	0.00	0	0.000	0.00	0.00		
	21	1 428	0.899	0.11	0	0.000	0.00	0.11		
	22	682	1.376	0.05	0	0.000	0.00	0.05		
Chatham Rise										
1992–93	2	408 120	0.063	22.71	200 760	0.104	11.17	33.88	Meas.mal	866
	3	185 458	0.135	10.32	170 129	0.105	9.47	19.79	Meas.fem	793
	4	37 964	0.502	2.11	54 389	0.348	3.03	5.14	Aged.mal	100
	5	43 177	0.357	2.40	89 947	0.281	5.01	7.41	Aged.fem	91
	6	53 537	0.423	2.98	13 924	0.714	0.77	3.75	Mean c.v.	27.9
	7	31 198	0.568	1.74	77 075	0.308	4.29	6.02		
	8	44 691	0.472	2.49	57 751	0.419	3.21	5.70		
	9	32 347	0.546	1.80	54 143	0.450	3.01	4.81		
	10	31 534	0.631	1.75	32 844	0.654	1.83	3.58		
	11	12 712	0.799	0.71	13 281	0.714	0.74	1.45		
	12	3 063	1.514	0.17	19 556	0.621	1.09	1.26		
	13	43 849	0.537	2.44	20 585	0.820	1.15	3.59		
	14	0	0.000	0.00	10 747	0.876	0.60	0.60		
	15	23 702	0.384	1.32	5 376	1.440	0.30	1.62		
	16	0	0.000	0.00	6 362	1.868	0.35	0.35		
	17	18 853	0.856	1.05	0	0.000	0.00	1.05		
1993–94	1	14 003	1.361	0.62	4 202	5.044	0.19	0.81	Meas.mal	571
	2	199 786	0.146	8.85	141 680	0.224	6.27	15.12	Meas.fem	472
	3	189 879	0.111	8.41	84 528	0.270	3.74	12.15	Aged.mal	87
	4	442 819	0.065	19.61	331 097	0.067	14.66	34.27	Aged.fem	88
	5	35 802	0.538	1.59	83 366	0.268	3.69	5.28	Mean c.v.	26.6
	6	157 812	0.190	6.99	172 813	0.177	7.65	14.64		
	7	25 501	0.638	1.13	39 413	0.678	1.75	2.87		
	8	20 191	0.957	0.89	192 155	0.157	8.51	9.40		
	9	9 391	1.665	0.42	14 089	1.181	0.62	1.04		
	10	14 130	1.662	0.63	18 866	0.908	0.84	1.46		
	11	10 199	1.833	0.45	16 246	0.989	0.72	1.17		
	12	6 538	2.028	0.29	3 348	2.803	0.15	0.44		
	13	4 652	2.252	0.21	9 878	1.219	0.44	0.64		
	14	2 188	2.891	0.10	2 936	4.372	0.13	0.23		
	15	4 559	1.138	0.20	802	6.885	0.04	0.24		
	16	1 094	3.458	0.05	845	3.868	0.04	0.09		
	17	2 439	5.715	0.11	697	7.481	0.03	0.14		

Fish yr	Age	N.mal	c.v.	P.mal	N.fem	c.v.	P.fem	P.tot		
1994–95	2	365	46.594	0.03	0	0.000	0.00	0.03	Meas.mal	320
	3	18 688	0.143	1.74	7 923	0.237	0.74	2.47	Meas.fem	302
	4	88 539	0.310	8.22	91 146	0.271	8.47	16.69	Aged.mal	90
	5	72 404	0.371	6.73	32 792	0.198	3.05	9.77	Aged.fem	77
	6	59 278	0.388	5.51	24 227	0.734	2.25	7.76	Mean c.v.	45
	7	63 639	0.356	5.91	2 642	2.139	0.25	6.16		
	8	49 604	0.347	4.61	66 824	0.481	6.21	10.81		
	9	65 524	0.350	6.09	26 965	0.599	2.50	8.59		
	10	49 203	0.413	4.57	67 613	0.367	6.28	10.85		
	11	32 315	0.513	3.00	95 667	0.349	8.89	11.89		
	12	46	28.170	0.00	27 841	0.604	2.59	2.59		
	13	9 867	0.907	0.92	9 869	0.681	0.92	1.83		
	14	7 360	2.519	0.68	50 528	0.377	4.69	5.38		
	15	5 608	1.352	0.52	22 313	0.514	2.07	2.59		
	16	0	0.000	0.00	6 855	0.889	0.64	0.64		
	17	0	0.000	0.00	11 371	0.993	1.06	1.06		
	18	3 559	1.251	0.33	4 302	0.292	0.40	0.73		
	19	0	0.000	0.00	1 743	6.360	0.16	0.16		
1995–96	1	125	29.272	0.01	326	22.693	0.03	0.04	Meas.mal	611
	2	37 305	0.448	3.04	15 610	0.777	1.27	4.31	Meas.fem	778
	3	40 988	0.273	3.34	14 331	0.702	1.17	4.51	Aged.mal	79
	4	108 809	0.198	8.87	57 574	0.273	4.69	13.56	Aged.fem	92
	5	61 593	0.415	5.02	52 646	0.314	4.29	9.31	Mean c.v.	43.4
	6	104 546	0.264	8.52	118 840	0.244	9.69	18.21		
	7	63 620	0.471	5.19	38 633	0.453	3.15	8.34		
	8	18 640	0.673	1.52	47 528	0.494	3.87	5.39		
	9	51 792	0.366	4.22	50 309	0.423	4.10	8.32		
	10	19 948	0.691	1.63	61 934	0.423	5.05	6.68		
	11	8 836	0.920	0.72	73 104	0.374	5.96	6.68		
	12	37 192	0.703	3.03	30 258	0.653	2.47	5.50		
	13	849	2.339	0.07	28 526	0.681	2.33	2.39		
	14	7 187	0.964	0.59	20 456	0.847	1.67	2.25		
	15	18 717	0.586	1.53	11 607	0.822	0.95	2.47		
	16	1 576	1.556	0.13	278	8.129	0.02	0.15		
	17	18 888	0.538	1.54	859	2.934	0.07	1.61		
	18	0	0.000	0.00	859	2.934	0.07	0.07		
	19	0	0.000	0.00	2 440	1.466	0.20	0.20		

Appendix B

Table B1: Mean length at age, by sex, with associated data, for silver warehou from three areas. YC Age, year class age; SD, standard deviation; *N*, sample size; Sou, Southern Plateau; WSI, west coast South Island; Chat, Chatham Rise; –, no data available or sample size less than 5

YC Age	Mean true age			Mean length (cm)			SD of length			*N*		
	Sou	WSI	Chat	Sou	WSI	Chat	Sou	WSI	Chat	Sou	WSI	Chat
Male												
1	0.5	–	0.5	20.1	–	21.3	2.27	–	1.21	18	–	6
2	1.5	1.8	1.5	30.7	33.1	32.3	2.64	3.34	2.37	114	20	40
3	2.5	2.9	2.6	37.3	38.5	36.0	2.42	2.52	3.06	62	24	24
4	3.5	3.9	3.5	42.3	42.7	42.4	2.02	1.62	1.81	91	165	24
5	4.6	4.9	4.8	45.3	45.8	44.8	1.52	1.60	1.29	67	136	26
6	5.6	5.9	5.7	46.5	46.6	45.8	1.74	1.73	1.59	75	102	38
7	6.6	6.9	6.7	48.1	48.0	47.1	1.92	1.90	1.56	29	113	24
8	7.5	7.9	7.7	49.4	49.1	47.8	1.39	1.61	1.42	26	63	25
9	8.5	8.9	8.6	50.5	49.6	48.6	1.72	1.76	2.33	24	75	28
10	9.5	9.9	9.7	51.3	50.6	50.1	2.11	1.62	2.30	26	59	28
11	10.6	10.9	10.6	51.6	51.6	50.4	1.61	1.75	2.22	24	59	16
12	11.5	11.9	11.7	51.2	51.5	51.6	1.65	1.84	3.26	25	42	11
13	12.5	12.9	12.6	52.0	52.1	51.5	1.75	1.73	2.07	28	33	14
14	13.5	13.9	13.8	52.3	52.3	52.4	2.27	1.41	2.07	12	35	5
15	14.5	14.9	14.6	53.4	53.0	52.7	1.39	1.51	3.06	14	22	10
16	15.6	15.9	–	53.0	52.2	–	2.19	1.92	–	6	5	–
17	16.6	16.9	16.7	53.5	54.3	52.1	1.20	2.38	3.58	8	8	7
Female												
1	0.5	–	–	20.2	–	–	2.49	–	–	14	–	–
2	1.5	1.6	1.5	30.9	32.8	32.2	2.84	2.59	2.87	102	17	25
3	2.5	2.8	2.5	37.9	38.9	35.6	2.08	1.76	3.70	54	19	20
4	3.5	3.9	3.6	42.3	43.5	42.6	1.82	2.20	2.22	89	137	10
5	4.6	4.9	4.7	45.5	46.1	45.7	1.79	1.79	2.63	90	126	19
6	5.6	5.9	5.7	47.7	48.1	48.1	1.68	1.49	2.52	78	167	30
7	6.5	6.9	6.7	49.9	49.4	48.6	2.07	1.92	2.09	54	135	23
8	7.5	7.9	7.7	50.4	50.7	49.3	1.92	1.76	3.06	37	109	29
9	8.5	8.9	8.8	51.1	51.4	51.3	2.02	1.75	1.56	48	103	23
10	9.5	9.9	9.7	52.7	52.5	51.9	1.84	1.99	2.15	25	82	32
11	10.5	10.9	10.7	53.8	53.0	52.7	2.03	1.98	2.79	34	73	32
12	11.5	11.9	11.6	53.9	53.6	53.9	1.71	1.86	2.86	29	59	18
13	12.5	12.9	12.7	54.3	54.4	53.5	2.30	1.65	3.16	30	60	15
14	13.5	13.9	13.6	54.3	54.8	53.6	1.80	2.02	2.03	19	44	19
15	14.5	14.9	14.6	56.2	54.7	54.8	1.21	2.48	2.27	15	35	11
16	15.5	15.9	15.8	56.0	56.0	55.8	1.91	2.11	1.30	12	18	5
17	16.5	16.9	–	56.1	55.4	–	1.38	1.74	–	13	19	–
18	17.6	17.9	–	54.2	55.9	–	2.14	2.70	–	6	8	–