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The stock affinity of hake (*Merluccius australis*) from Puysegur Bank, and catch-at-age data and revised productivity parameters for hake stocks HAK 1, 4, and 7

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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.

The stock affinity of hake (*Merluccius australis*) from Puysegur Bank, and catch-at-age data and revised productivity parameters for hake stocks HAK 1, 4, and 7

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1. EXECUTIVE SUMMARY

The stock affinity of hake on the Puysegur Bank was examined by comparing growth rates and catch-at-age data from Puysegur, WCSI, and Sub-Antarctic. Puysegur hake appear most similar to those from the Sub-Antarctic, but the data are not unequivocal so their stock affinity is still open to some doubt. It is quite possible that this is an area of stock mixing.

Catch-at-age data are presented for samples of hake collected from the three hake stocks (WCSI, Chatham Rise, Sub-Antarctic) in 1997 and 1998. All available catch-at-age data for hake are summarised. Mean weighted *c.v.s* across all age classes are generally unsatisfactory (i.e., > 35%) from trawl surveys, but satisfactory for WCSI commercial catch samples. Revised von Bertalanffy growth parameters and length-weight parameters are presented for the three stocks.

2. INTRODUCTION

The three main hake stocks (HAK 1, 4, and 7) were assessed in 1997 using, for the first time, the MIAEL estimation technique of Cordue (1993, 1996). The assessments and the model inputs (which included biological data, catch histories, estimates of catch-at-age, and series of relative abundance indices from trawl surveys) were reported by Colman (1997) and updated by Dunn (1998). Since those assessments, additional age data have enabled the generation of new catch-at-age distributions which are presented below. For completeness, all catch-at-age data available for hake are included in this document.

Information on the stock structure of hake was summarised by Colman (1997, 1998). Based on known spawning areas, the presence of juveniles, and differences in morphometric characteristics, parasite faunas, length-frequency distributions, and growth rates, it appears likely that there are three stocks of hake in New Zealand waters. They are the west coast South Island (WCSI), the Chatham Rise (and including fish off the east coast North Island), and the Sub-Antarctic (Campbell Plateau and Stewart-Snares shelf). The stock affinity of hake on the Puysegur Bank was complicated, however. Using morphometric data, Colman (1997) found that Puysegur fish were most similar to those from WCSI but, depending on which variables were used, could not always be distinguished from Sub-Antarctic hake. Horn (1996, 1997) showed that there were significant differences in growth parameters for hake from WCSI and Sub-Antarctic, but he included data from Puysegur fish in the Sub-Antarctic sample. In this document, age-length data are re-examined to compare growth parameters and mean lengths at age from Puysegur fish with those from WCSI and Sub-Antarctic hake. Age-frequency distributions from these three areas are also compared.

Colman & Vignaux (1992) calculated von Bertalanffy parameters for WCSI hake only. Horn (1996) presented a validated ageing methodology and separate sets of growth parameters for the three hake stocks. However, since that time a large quantity of new age data have been generated. There is also a need to re-calculate the parameters for the Sub-Antarctic stock excluding Puysegur fish, which, as noted above, may derive from a different stock. The revised parameters are presented below.

Length-weight parameters for hake have also been poorly described. Colman *et al.* (1991) calculated parameters for hake off WCSI based on data collected in 1976 during a survey by *Shinkai Maru*. Equations for Chatham Rise and Sub-Antarctic hake were reported in the 1997 plenary document (Annala & Sullivan 1997) but with no supporting documentation. No new length-weight data are available for WCSI hake, but parameters for Chatham Rise and Sub-Antarctic hake (HAK 1 and HAK 4) are revised below following the availability of a considerable quantity of new data from recent trawl surveys.

3. STOCK AFFINITY OF PUYSEGUR HAKE

3.1 Comparison of growth

Samples of hake obtained from either research or commercial trawl operations seldom comprise juvenile fish, so von Bertalanffy curves calculated from these samples poorly describe juvenile growth. The best descriptors of hake growth were considered to be those obtained using a combination of age-length data from otoliths for ages 3 and older, and a set of points describing likely fish length at ages 0.6, 1.6, and 2.6 years derived from length-frequency distributions (Horn 1996, 1997). All von Bertalanffy parameters presented in this document were calculated including the length-based data set to define juvenile growth. Curves were fitted to the age-length data using a non-linear least-squares regression procedure (Ralston & Jennrich 1978).

Otoliths, and subsequent age-length data, were obtained from the following sources:

WCSI: Collections by observers from the winter fishery in QMA 7, from 1990 to 1997.

Puysegur Bank: Collections by observers and from trawl survey tows in an area defined by latitudes 45° 30' to 47° 10' S and longitudes 165° and 166° 40' E, at various times of the year, from 1988 to 1997.

Sub-Antarctic: Collections from trawl survey tows on the Campbell Plateau and the eastern and southern margins of the Stewart-Snares shelf, at various times of the year, from 1989 to 1996.

Von Bertalanffy parameters (with 95% confidence intervals), by area and sex, using all available data points are given in Table 1. Based on a comparison of these parameters, Sub-Antarctic hake grow faster and larger than WCSI fish (as shown by Horn 1997), and Puysegur Bank fish appear to have growth parameters more comparable to WCSI, rather than Sub-Antarctic, hake. However, it was apparent that the length-frequency distributions of the aged fish differed between areas (Figure 1). In general, larger fish of both sexes were

relatively less abundant on the Puysegur Bank than in the two other areas. Hence, the growth of larger fish on the Puysegur Bank will be relatively poorly defined and a comparison of L_{∞} and k between samples is probably not valid.

To better compare growth of fish from the three areas, modified data sets were created for WCSI and Sub-Antarctic fish. Data points for fish over 70 cm TL were randomly deleted from these samples to create length-frequency distributions of aged fish identical in shape over the 70–120 cm length range to the Puysegur samples. Von Bertalanffy parameters calculated from these samples were compared with the original Puysegur parameters (see Table 1). Significant differences (based on there being no overlap of the 95% confidence intervals presented in Table 1) in the L_{∞} parameters for both sexes are still apparent between WCSI and Sub-Antarctic hake. The L_{∞} and k parameters for the Puysegur sample fall between those from the other two areas, but appear to be more similar to the Sub-Antarctic values. This is particularly apparent for males, where there is a statistically significant difference between the L_{∞} values for Puysegur and WCSI fish.

It could be argued that parameter comparisons between the modified data sets described above are still not valid because the length-frequency distributions of aged fish are not identical where lengths are less than 70 cm. Consequently, as a further check on differences in growth between areas, mean lengths at age were compared. This comparison also posed problems because otolith collections in the three areas were not all made at the same time of the year. Thus, the effects of seasonal growth could complicate comparisons, particularly for the younger age classes which have the most rapid growth. In an attempt to overcome these problems, only fish 3.5 years or older sampled during the months of March to August were included in the analysis. Unfortunately, this resulted in a relatively small sample being available from the Puysegur Bank.

Mean lengths at age, separately by sex, were compared using pairwise t -tests, where $n \geq 3$ in each of the three areas (Table 2). Most comparisons for male hake were non-significant. The few significant differences suggested that Puysegur fish had growth rates intermediate to those of Sub-Antarctic and WCSI hake. Of the significantly different comparisons for female hake, all but one indicated that the growth rate of Puysegur fish was slower than on both the other grounds. However, there was a general trend for the growth of Puysegur females to be more closely aligned with WCSI fish, particularly at the older ages.

3.2 Comparison of age-frequency distributions

Calculated age-frequency distributions from Sub-Antarctic, Puysegur, and WCSI, from two years, were compared. Sample details are given in Table 3. Although the WCSI samples were taken 6–8 months after the Puysegur and Sub-Antarctic samples, and in a different calendar year, the distributions are still directly comparable because of the chosen birthday for hake (1 September).

The age-frequency comparisons are complicated by having different length distributions of hake on the grounds. Also, the WCSI samples are from a spawning fishery, while those from the two southern grounds are sampled in the dispersed phase. Puysegur fish are generally small and young, while the WCSI and Sub-Antarctic populations have a greater proportion of older fish (Figure 2). However, comparisons of the distributions in Figure 2 show some

similarities to be apparent. The 1991 Sub-Antarctic and Puysegur distributions both have a weak age class 6; the same year class is probably not fully recruited to the WCSI fishery in 1992, and it does not appear particularly weak there. However, the weak 1991 6-year-olds do not manifest as weak 8-year-olds in 1993. Instead, age class 7 appears to be relatively weak in 1993 on both the southern grounds. Both 7 and 8-year-olds are relatively strong on the WCSI in 1994. Strong classes of 4- and 5-year-olds are apparent in 1993 on the two southern grounds, but do not appear as strong on WCSI in 1994 (although again, these year classes would not be recruiting strongly to the spawning fishery). A strong 1979 year class is apparent as 12- and 14-year-olds on the two Sub-Antarctic distributions. There is tentative evidence that this year class is also abundant (relative to year classes of fish older than 6 years) on the Puysegur Bank in 1993. The comparable age classes appear relatively weak in both the WCSI samples.

When planning for Project MID9701 it was expected that the very strong 1993 year class identified off WCSI as 1+ fish (Horn 1996) would start to appear strongly in the 1997 commercial length-frequencies, and could indicate whether Puysegur fish derive from the WCSI or Campbell Plateau spawning ground. However, it was not possible to complete this task in 1998 because only 22 hake from Puysegur were measured by observers in 1997. Also, the 1993 year class did not appear to have recruited strongly to the WCSI spawning fishery by winter 1997 (Table 4), when they would have been 3+ fish about to have their fourth birthday. It will still be possible for this comparison to be conducted in later years.

In the April 1998 survey of the Puysegur and Sub-Antarctic region, the 1993 year class (4+ fish) does appear to be stronger than average, though it is not exceptional (Table 5). Most of the 3-5 year-old fish caught in this survey (including 83% of those aged as 4+) were from the Puysegur Bank region. However, as younger age classes tend to be more abundant on the Puysegur Bank relative to the rest of the Sub-Antarctic region (*see* Figure 1), it can still not be concluded that the Puysegur 4-year-olds derive from WCSI rather than from a possible successful spawning in 1993 on the Campbell Plateau. Only sampling in future years will indicate the strength of the 1993 year class in the Sub-Antarctic. It is also possible that the relatively greater abundance of young fish on the Puysegur Bank could have resulted from local spawnings.

3.3 Conclusion

None of the comparisons of growth parameters, mean lengths at age, or age-frequency distributions convincingly indicate the likely stock affinity of Puysegur Bank hake. Growth parameters of male Puysegur hake are quite similar to those for Sub-Antarctic fish, but a comparison of mean lengths at age suggests that growth rates on Puysegur Bank are intermediate to those in the other areas: female fish are more comparable to WCSI hake. Where comparisons of adult year class strengths are possible, the Puysegur samples are more closely aligned with those from the Sub-Antarctic. Thus, on current evidence, Puysegur hake are more likely to be part of the Sub-Antarctic stock, although some mixing of this and the WCSI stocks in the Puysegur region is also likely. Puysegur Bank could also be a nursery area for hake from both the WCSI and Sub-Antarctic stocks.

In the longer term, the collection of more age data from the Puysegur Bank in autumn-winter should enable a more powerful comparison of mean length at age. Larger collections of

Puysegur age data from single years would also enable more comprehensive comparisons of catch at age between areas, particularly once the presumed strong 1993 WCSI year class has recruited to the spawning fishery off that coast.

Until more convincing evidence is available, Puysegur hake should be modelled as part of the Sub-Antarctic stock.

4. REVISED PARAMETERS

4.1 Growth parameters

Von Bertalanffy growth parameters, by sex, for hake from the three stocks were first presented by Horn (1996), with each equation being based on about 300–500 data points. The parameters have been recalculated using all existing data (and excluding Puysegur fish from the Sub-Antarctic data set). Data sources for the WCSI and Sub-Antarctic samples are described in Section 3.1 above. Chatham Rise data were from trawl survey samples collected in December 1989 and in January 1992–97. Revised parameters for all stocks are presented in the “All data” section of Table 1.

Horn (1996, 1997) found statistically significant differences between parameters for the three stocks. The revised parameters in Table 1 still show male and female WCSI hake to grow at a slower rate than those from the other two stocks, but the equations for the Chatham Rise and Sub-Antarctic stocks are now not significantly different (based on there being an overlap of the 95% confidence intervals presented in Table 1).

4.2 Length-weight parameters

Annala & Sullivan (1997) presented length-weight parameters for Fishstocks HAK 1 and 4 based on “MAF unpublished data”, and for HAK 7 from Colman *et al.* (1991) based on data collected in 1976. There are no new data available for HAK 7, but the parameters for HAK 1 and HAK 4 have been recalculated (Table 6) using all existing data from the Ministry of Fisheries’ research trawl database. The vast majority of the data were collected since 1989, and mainly during surveys by *Tangaroa* since 1991.

5. CATCH-AT-AGE DATA

Some calculated age-frequency distributions were presented for the three hake stocks by Horn (1996) and Colman (1997). Ageing has now been completed for hake from all the *Tangaroa* trawl surveys of the Chatham Rise and Sub-Antarctic from 1991 to 1998, and all observer samples from the WCSI from 1990 to 1997. In addition, one sample each from the Chatham Rise and Sub-Antarctic is available from 1989.

Catch-at-age distributions were calculated separately by sex for each sample using the total scaled length-frequency and the otoliths read, in the following manner:

$$A_t = \sum_x (L_x p_{tx})$$

where A_t = the estimated proportion of fish of age t in the population, L_x = the proportion of fish of length x in the length-frequency sample, and p_{tx} = the proportion of fish of length x which were age t .

Catch-at-age data specifically required under project MID9701 are from the commercial trawl fishery for hake off WCSI in winter 1997, from a trawl survey of the Sub-Antarctic in April-May 1998 (TAN9805), and from trawl surveys of the Chatham Rise in January 1997 and 1998 (TAN9701, TAN9801). These data are presented in detail in Tables 4, 5, 7, and 8.

All available age-frequency data are presented by stock in Tables 9–11. For the Chatham Rise and Sub-Antarctic, numbers represent the estimated population available to the trawl in the survey areas. For WCSI, numbers represent the total catch by the commercial fleet.

Mean weighted *c.v.s* across all age classes of individual samples are unsatisfactory (i.e., over 35%) from trawl surveys of the Sub-Antarctic and Chatham Rise (Tables 9 and 10). This is due to the relatively small number of fish caught and aged, and the few shots catching hake. Annual samples from the WCSI commercial fishery comprise large numbers of measured fish and more sampled shots than the trawl surveys (Table 11). Consequently, the mean weighted *c.v.s* for these samples are generally satisfactory.

6. ACKNOWLEDGMENTS

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Table 1: Von Bertalanffy parameters (with 95% confidence intervals) for hake from the west coast of the South Island (WC), Puysegur Bank (PB), Sub-Antarctic (SA), and Chatham Rise (CR), by sex. N , number of sample points, which in every case includes the 300 length-based data points included to define juvenile growth. The formulation of the modified data sets for WC, PB, and SA hake is described in the text

Area	N	L_{∞}	k	t_0
All data				
Female				
WC	2 329	101.0 (100.1–101.9)	0.236 (0.226–0.245)	-0.08 (-0.16 to -0.01)
PB	821	99.9 (98.3–101.4)	0.242 (0.231–0.252)	-0.03 (-0.10 to 0.03)
SA	1 214	115.0 (113.8–116.3)	0.188 (0.180–0.196)	-0.13 (-0.21 to -0.05)
CR	1 629	113.4 (111.9–114.9)	0.202 (0.193–0.211)	-0.20 (-0.29 to -0.10)
Male				
WC	2 021	83.1 (82.6–83.6)	0.309 (0.299–0.318)	-0.02 (-0.07 to 0.03)
PB	581	85.3 (83.7–86.9)	0.313 (0.296–0.330)	0.04 (-0.01 to 0.10)
SA	822	90.8 (90.0–91.6)	0.263 (0.250–0.276)	-0.06 (-0.13 to 0.01)
CR	1 467	90.3 (89.4–91.2)	0.277 (0.266–0.288)	-0.11 (-0.18 to -0.04)
Modified data sets				
Female				
WC	1 440	97.3 (96.3–98.4)	0.257 (0.245–0.269)	-0.02 (-0.09 to 0.06)
PB	821	99.9 (98.3–101.4)	0.242 (0.231–0.252)	-0.03 (-0.10 to 0.03)
SA	748	102.7 (101.4–104.0)	0.237 (0.227–0.248)	-0.00 (-0.06 to 0.06)
Male				
WC	1 369	81.6 (81.0–82.2)	0.313 (0.300–0.325)	-0.03 (-0.09 to 0.02)
PB	581	85.3 (83.7–86.9)	0.313 (0.296–0.330)	0.04 (-0.01 to 0.10)
SA	518	85.6 (84.5–86.8)	0.297 (0.281–0.312)	-0.00 (-0.07 to 0.06)

Table 2: Comparisons of mean length at age (Lgth) of hake from the Sub-Antarctic, Puysegur Bank, and WCSI, by sex. Results of pairwise *t*-tests between Sub-Antarctic and Puysegur Bank (S:P), and between Puysegur Bank and WCSI (P:W) have the following significance levels: ns, not significant; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$

Age	Sub-Antarctic			S:P	Puysegur Bank			P:W	WCSI		
	Lgth	s.d.	<i>n</i>		Lgth	s.d.	<i>n</i>		Lgth	s.d.	<i>n</i>
Male											
3.7	60.6	2.27	6	ns	60.6	3.43	10	*	57.6	4.17	19
4.7	66.5	6.55	6	ns	65.9	5.35	17	ns	65.8	6.45	21
5.7	71.1	4.52	12	ns	68.8	6.02	15	ns	71.7	5.40	80
6.7	76.0	4.95	16	*	71.2	6.66	14	ns	73.9	5.05	165
7.7	78.0	4.26	11	ns	80.6	6.23	8	ns	75.8	5.01	221
8.7	79.9	5.19	34	ns	79.4	4.64	10	ns	76.8	5.09	235
9.7	80.1	5.44	28	ns	82.3	5.18	12	**	77.5	4.98	229
10.7	83.6	6.98	47	ns	84.5	4.69	6	*	78.6	5.41	150
11.7	86.6	7.80	39	**	79.1	4.30	8	ns	80.2	5.75	117
12.7	88.5	7.58	67	ns	91.7	10.55	5	ns	80.9	5.05	101
14.7	89.9	5.37	29	ns	92.8	8.25	3	ns	84.0	4.46	55
Female											
3.7	62.2	3.35	14	ns	60.7	4.45	11	ns	61.3	5.05	52
4.7	68.0	5.07	14	ns	66.1	4.25	34	*	69.3	6.75	50
5.7	74.7	5.98	15	**	68.6	6.54	27	***	79.9	7.05	71
6.7	78.2	5.66	16	ns	73.9	8.46	12	**	82.4	8.20	135
7.7	86.3	8.24	22	ns	80.2	7.75	7	ns	85.6	7.28	233
8.7	90.6	7.29	36	ns	86.8	8.11	13	ns	88.7	7.69	261
9.7	94.2	9.13	38	ns	89.6	7.65	17	ns	89.7	8.78	222
10.7	97.8	9.15	56	**	90.7	9.12	27	ns	90.7	8.78	192
11.7	101.5	8.22	40	ns	95.0	8.21	13	ns	92.9	9.07	148
12.7	105.1	8.19	115	***	98.2	4.94	11	*	94.6	10.52	127
13.7	106.4	8.44	78	*	100.0	7.07	10	ns	97.3	9.73	115
14.7	108.3	8.61	65	*	99.5	7.74	8	ns	99.2	10.60	92
15.7	110.4	7.96	42	ns	103.4	11.41	6	ns	99.4	8.10	53
16.7	110.5	8.62	39	***	96.3	4.29	7	*	101.7	10.03	58
17.7	113.0	6.21	24	*	99.2	7.90	4	ns	99.4	10.07	29

Table 3: Details of samples of hake from the Sub-Antarctic, Puysegur Bank, and WCSI, used to construct comparable age-length distributions

Sample		Number measured			Number aged		
		Male	Female	Total	Male	Female	Total
Sub-Antarctic	Dec 1991	247	154	401	38	84	122
Puysegur Bank	Dec 1991	90	178	268	72	129	201
WCSI	Jun-Aug 1992	2 620	1 228	3 848	176	237	413
Sub-Antarctic	Dec 1993	33	90	123	33	79	112
Puysegur Bank	Dec 1993	136	287	423	54	100	154
WCSI	Jun-Aug 1994	1 631	1 724	3 355	135	258	393

Table 4: Catch-at-age data, by sex, for hake sampled from the commercial trawl fishery off WCSI during the period June-September 1997 (HAK 7). Numbers represent the estimated total catch by the commercial fishery

Age	Males			Females		
	<i>N</i>	%	<i>c.v.</i>	<i>N</i>	%	<i>c.v.</i>
1	6 162	0.57	0.876	13 163	1.66	0.306
2	155	0.01	2.227	2 257	0.29	0.318
3	4 603	0.43	0.945	17 453	2.21	0.385
4	14 657	1.36	0.486	53 974	6.82	0.330
5	75 313	7.01	0.240	74 509	9.42	0.259
6	207 586	19.33	0.130	70 170	8.87	0.252
7	227 631	21.19	0.126	145 092	18.34	0.180
8	190 336	17.72	0.140	104 954	13.27	0.203
9	117 450	10.94	0.188	91 313	11.54	0.216
10	63 858	5.95	0.268	74 275	9.39	0.251
11	36 219	3.37	0.361	18 642	2.36	0.556
12	38 167	3.55	0.363	36 510	4.62	0.338
13	20 217	1.88	0.467	24 526	3.10	0.405
14	21 512	2.00	0.477	29 392	3.72	0.253
15	18 162	1.69	0.489	12 724	1.61	0.495
16	7 533	0.70	0.694	4 041	0.51	0.958
17	10 091	0.94	0.781	8 596	1.09	0.789
18	722	0.07	2.185	272	0.03	0.000
19	3 792	0.35	0.977	498	0.06	0.762
20	5 207	0.48	0.985	240	0.03	0.000
21	0	0.00	0.000	0	0.00	0.000
22	0	0.00	0.000	7 992	1.01	0.892
23	0	0.00	0.000	496	0.06	2.685
24	4 678	0.44	0.985	0	0.00	0.000
Number males measured			3 359			
Number females measured			1 784			
Number males aged			240			
Number females aged			180			
Number shots sampled			279			
Mean weighted <i>c.v.</i>			24.6			

Table 5: Catch-at-age data, by sex, for hake from a trawl survey (TAN9805) of the Sub-Antarctic region including Puysegur Bank (HAK 1), conducted in April–May 1998. Numbers represent the estimated total population in the survey area available to the trawl

Age	Males			Females		
	<i>N</i>	%	<i>c.v.</i>	<i>N</i>	%	<i>c.v.</i>
1	0	0.00	0.000	0	0.00	0.000
2	0	0.00	0.000	0	0.00	0.000
3	11 318	4.21	0.202	44 579	7.24	0.255
4	21 888	8.14	0.400	75 498	12.25	0.240
5	14 494	5.39	0.886	53 714	8.72	0.262
6	24 593	9.15	0.393	55 359	8.98	0.367
7	10 643	3.96	0.623	90 149	14.63	0.340
8	27 364	10.18	0.357	25 412	4.12	0.695
9	9 103	3.39	0.726	52 121	8.46	0.406
10	20 144	7.49	0.470	42 516	6.90	0.437
11	13 527	5.03	0.639	42 199	6.85	0.467
12	13 369	4.97	0.721	39 385	6.39	0.419
13	13 541	5.04	1.144	4 802	0.78	1.256
14	6 112	2.27	0.703	0	0.00	0.000
15	3 306	1.23	1.009	32 585	5.29	0.541
16	23 190	8.62	0.631	6 948	1.13	0.859
17	14 236	5.29	0.761	9 551	1.55	0.565
18	11 851	4.41	0.730	18 645	3.03	0.726
19	6 762	2.51	0.981	4 802	0.78	1.256
20	9 471	3.52	0.877	11 823	1.92	0.533
21	0	0.00	0.000	0	0.00	0.000
22	5 963	2.22	1.272	0	0.00	0.000
23	0	0.00	0.000	0	0.00	0.000
24	4 015	1.49	2.946	2 460	0.40	2.839
25	0	0.00	0.000	3 584	0.58	1.383
26	0	0.00	0.000	0	0.00	0.000
27	0	0.00	0.000	0	0.00	0.000
28	4 015	1.49	2.946	0	0.00	0.000
Number males measured			104			
Number females measured			214			
Number males aged			89			
Number females aged			186			
Number shots sampled			46			
Mean weighted <i>c.v.</i>			50.7			

Table 6: Length-weight parameters, by sex, for hake from the Sub-Antarctic (HAK 1) and the Chatham Rise (HAK 4). Parameters are for the equation $Weight = a.(Length)^b$, with weight in g and length in cm total length. Range, length range of sample ; N , sample size

Fishstock	Sex	a	b	N	R^2	Range
HAK 1	Male	0.00395	3.130	850	0.93	47-119
	Female	0.00186	3.313	1879	0.97	46-131
HAK 4	Male	0.00249	3.234	1626	0.98	35-123
	Female	0.00170	3.328	1694	0.98	36-130

Table 7: Catch-at-age data, by sex, for hake from a trawl survey (TAN9701) of the Chatham Rise (HAK 4), conducted in January 1998. Numbers represent the estimated total population in the survey area available to the trawl

Age	Males			Females		
	N	%	$c.v.$	N	%	$c.v.$
1	0	0.00	0.000	0	0.00	0.000
2	33 085	9.49	0.314	21 459	5.85	0.258
3	61 202	17.56	0.273	75 255	20.52	0.258
4	52 978	15.20	0.311	45 642	12.44	0.297
5	38 420	11.02	0.362	61 970	16.89	0.218
6	32 980	9.46	0.369	54 858	14.96	0.298
7	20 880	5.99	0.471	15 024	4.10	0.523
8	34 676	9.95	0.352	15 693	4.28	0.763
9	2 865	0.82	1.329	12 213	3.33	0.644
10	12 315	3.53	0.611	4 623	1.26	1.221
11	5 957	1.71	0.847	0	0.00	0.000
12	9 985	2.86	0.460	1 803	0.49	0.481
13	6 075	1.74	0.818	19 694	5.37	0.408
14	14 768	4.24	0.559	8 049	2.19	0.543
15	0	0.00	0.000	10 321	2.81	0.604
16	1 203	0.35	1.056	0	0.00	0.000
17	10 677	3.06	0.624	10 294	2.81	0.522
18	0	0.00	0.000	4 080	1.11	0.990
19	7 344	2.11	0.710	0	0.00	0.000
20	0	0.00	0.000	2 292	0.62	1.509
21	3 198	0.92	1.092	3 582	0.98	1.208

Number males measured	149
Number females measured	159
Number males aged	141
Number females aged	147
Number shots sampled	77
Mean weighted $c.v.$	39.3

Table 8: Catch-at-age data, by sex, for hake from a trawl survey (TAN9801) of the Chatham Rise (HAK 4), conducted in January 1997. Numbers represent the estimated total population in the survey area available to the trawl

Age	Males			Females		
	<i>N</i>	%	<i>c.v.</i>	<i>N</i>	%	<i>c.v.</i>
1	4 194	1.27	1.417	3 269	0.93	2.061
2	13 620	4.12	0.505	16 973	4.83	0.677
3	25 878	7.83	0.295	12 757	3.63	0.443
4	43 374	13.13	0.382	39 392	11.20	0.373
5	55 726	16.87	0.301	43 335	12.32	0.273
6	29 421	8.90	0.525	53 878	15.32	0.252
7	42 770	12.95	0.340	46 228	13.14	0.310
8	22 067	6.68	0.398	33 883	9.63	0.325
9	14 150	4.28	1.191	18 586	5.28	0.445
10	14 384	4.35	0.675	11 043	3.14	0.564
11	5 587	1.69	0.717	22 787	6.48	0.553
12	11 603	3.51	0.758	13 920	3.96	0.699
13	4 372	1.32	1.122	6 194	1.76	0.985
14	16 667	5.04	0.547	3 040	0.86	0.939
15	4 358	1.32	0.848	2 871	0.82	0.564
16	5 450	1.65	0.841	2 528	0.72	1.440
17	2 672	0.81	0.960	6 662	1.89	1.315
18	7 593	2.30	1.274	4 532	1.29	0.777
19	0	0.00	0.000	0	0.00	0.000
20	4 372	1.32	1.122	6 473	1.84	1.129
21	0	0.00	0.000	0	0.00	0.000
22	0	0.00	0.000	0	0.00	0.000
23	0	0.00	0.000	3 393	0.96	1.649
24	2 132	0.65	0.839	0	0.00	0.000
Number males measured			151			
Number females measured			147			
Number males aged			132			
Number females aged			137			
Number shots sampled			54			
Mean weighted <i>c.v.</i>			49.7			

Table 9: Catch-at-age data, by sex, for hake from trawl surveys of the Sub-Antarctic region (including the Puysegur Bank) (HAK 1)

Age	Trip code									
	aex8902	tan9105	tan9204	tan9209	tan9211	tan9304	tan9310	tan9605	tan9805	
Male	1	0	0	0	0	0	0	0	0	
	2	0	0	0	0	0	0	0	0	
	3	0	3 834	868	9 970	5 814	5 514	7 519	12 692	11 318
	4	1 427	11 763	933	3 078	5 102	5 993	22 266	23 388	21 888
	5	5 709	10 634	918	2 110	7 680	4 367	19 865	21 647	14 494
	6	4 996	3 269	0	686	3 135	10 865	9 558	21 315	24 593
	7	6 448	5 988	3 130	0	4 019	5 205	2 044	3 931	10 643
	8	3 574	26 179	2 247	2 382	691	6 573	8 545	31 744	27 364
	9	10 684	65 308	15 332	12 799	7 770	4 543	0	2 818	9 103
	10	26 939	109 235	8 966	11 074	208	0	6 580	2 818	20 144
	11	14 794	40 476	30 471	22 499	0	14 769	3 435	8 035	13 527
	12	7 842	196 434	52 813	23 589	0	11 371	5 973	6 068	13 369
	13	15 224	43 440	24 972	37 128	3 879	11 798	3 462	21 685	13 541
	14	6 180	43 814	6 364	9 459	0	3 134	23 963	10 398	6 112
	15	4 836	30 226	8 064	14 909	0	3 341	3 462	8 979	3 306
	16	0	16 015	13 860	2 817	0	3 134	9 659	25 492	23 190
	17	0	0	0	2 817	0	0	2 683	22 574	14 236
	18	0	0	5 911	6 444	0	3 518	4 306	17 591	11 851
	19	0	0	0	0	0	0	2 683	3 585	6 762
	20	0	0	6 106	0	0	0	2 153	0	9 471
	21	0	0	0	3 024	0	0	0	5 458	0
	22	0	0	0	0	0	3 526	0	3 183	5 963
	23	0	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	3 392	4 015
	25	0	0	0	0	0	0	0	0	0
	26	0	0	3 048	0	4 127	0	0	0	0
	27	0	0	0	0	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	4 015
	29	0	0	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	2 153	0	0
Female	1	0	0	0	0	0	0	0	0	0
	2	0	404	0	0	205	0	311	0	0
	3	624	16 696	4 445	0	1 668	18 295	14 654	11 032	44 579
	4	6 805	21 971	9 800	6 957	17 653	16 654	71 024	33 797	75 498
	5	4 249	30 548	5 625	15 378	21 076	14 217	52 549	50 390	53 714
	6	714	6 926	8 560	22 410	20 798	8 193	11 571	33 928	55 359
	7	13 820	19 356	10 342	0	13 514	11 671	5 006	17 610	90 149
	8	14 104	18 168	13 288	24 983	10 792	39 205	12 880	24 786	25 412
	9	25 190	29 328	17 631	23 648	16 295	13 411	17 064	19 051	52 121
	10	65 851	25 128	29 261	14 096	15 191	43 698	20 045	34 962	42 516
	11	31 773	21 363	23 307	21 914	12 554	26 437	19 663	20 253	42 199
	12	28 304	89 405	66 248	22 768	21 721	22 612	7 889	4 141	39 385
	13	30 271	40 827	21 993	74 975	43 735	68 984	10 927	13 038	4 802
	14	2 418	29 779	83 226	13 051	23 776	13 047	41 028	4 395	0
	15	4 494	19 123	34 236	20 065	18 728	32 811	36 901	2 152	32 585
	16	0	2 731	14 708	16 314	8 215	28 946	17 289	11 858	6 948
	17	4 460	12 217	23 172	26 554	4 200	15 173	18 113	14 637	9 551
	18	3 908	0	23 377	9 064	0	16 914	12 014	17 938	18 645
	19	4 052	0	11 239	2 674	1 569	0	8 431	8 496	4 802
	20	0	0	4 769	0	1 643	0	0	8 458	11 823
	21	4 052	0	0	0	0	2 989	0	6 583	0
	22	0	0	0	0	0	0	0	2 567	0
	23	0	0	0	0	0	0	0	9 881	0
	24	0	0	0	0	0	0	0	5 340	2 460
	25	0	0	0	0	0	0	0	0	3 584
	26	0	0	0	0	0	0	0	6 583	0
Measured male		45	337	60	76	113	36	169	127	104
Measured female		75	332	113	141	262	124	377	253	214
Aged male		43	110	54	60	40	36	87	74	89
Aged female		64	213	103	108	166	113	179	129	186
Sampled shots		34	62	48	44	54	54	64	59	46
Mean weighted c.v. (%)		55.0	43.3	48.1	48.1	40.1	51.7	40.6	48.3	50.7
Sample period		Nov 89	Dec 91	May 92	Sep 92	Dec 92	May 93	Dec 93	Apr 96	Apr 98

Table 10: Catch-at-age data, by sex, for hake from trawl surveys of the Chatham Rise (HAK 4)

Age	Trip code							
	aex8903	tan9106	tan9212	tan9401	tan9501	tan9601	tan9701	tan9801
Male								
1	0	0	0	0	0	0	0	4 194
2	4 575	0	52 542	40 852	18 401	31 820	33 085	13 620
3	65 007	12 960	24 424	82 556	57 732	34 790	61 202	25 878
4	54 636	16 611	21 057	30 959	49 899	33 967	52 978	43 374
5	52 125	19 265	19 788	32 493	25 139	59 273	38 420	55 726
6	33 327	30 106	5 542	21 138	8 444	31 080	32 980	29 421
7	31 955	39 215	15 267	13 980	24 253	14 683	20 880	42 770
8	25 253	49 424	11 538	13 680	20 696	20 804	34 676	22 067
9	22 470	32 256	15 236	13 094	11 836	4 220	2 865	14 150
10	56 264	51 447	8 276	14 755	9 209	9 509	12 315	14 384
11	24 414	40 018	16 382	23 273	10 698	2 402	5 957	5 587
12	14 498	52 657	15 616	19 470	19 316	2 381	9 985	11 603
13	2 945	22 905	36 421	9 483	21 350	2 987	6 075	4 372
14	18 375	10 059	15 159	14 825	32 474	6 945	14 768	16 667
15	4 144	16 195	11 437	13 854	8 675	2 987	0	4 358
16	12 838	6 237	5 030	12 683	0	6 705	1 203	5 450
17	0	11 058	9 403	15 810	9 505	5 347	10 677	2 672
18	3 113	0	2 048	9 478	2 170	1 891	0	7 593
19	0	3 834	3 143	12 144	0	0	7 344	0
20	208	0	1 657	1 914	0	0	0	4 372
21	3 113	2 159	0	4 935	0	0	3 198	0
22	0	0	0	1 718	0	0	0	0
23	0	0	0	0	0	0	0	0
24	0	0	0	2 048	0	0	0	2 132
Female								
1	0	0	0	0	0	0	0	3 269
2	6 035	0	36 429	34 926	14 085	22 938	21 459	16 973
3	33 459	4 343	30 395	93 150	52 394	45 878	75 255	12 757
4	34 085	19 227	12 986	37 410	42 105	95 755	45 642	39 392
5	22 737	15 645	24 210	34 439	33 061	91 758	61 970	43 335
6	33 342	24 764	15 864	39 559	23 860	51 529	54 858	53 878
7	43 513	20 732	15 454	20 647	25 367	29 556	15 024	46 228
8	40 673	30 814	22 500	27 047	18 619	16 701	15 693	33 883
9	29 836	19 788	6 521	7 282	2 953	8 819	12 213	18 586
10	51 450	41 629	21 438	11 602	30 715	18 291	4 623	11 043
11	23 500	27 391	15 085	4 246	13 921	0	0	22 787
12	20 301	32 886	29 030	20 267	15 528	10 864	1 803	13 920
13	9 037	38 354	37 714	6 377	12 842	18 660	19 694	6 194
14	6 363	23 344	6 855	24 063	24 057	8 774	8 049	3 040
15	10 769	15 616	22 138	5 207	9 495	6 629	10 321	2 871
16	9 950	12 300	17 865	12 058	11 029	3 199	0	2 528
17	2 007	11 077	8 799	20 579	3 998	3 301	10 294	6 662
18	0	9 584	3 846	16 292	12 859	3 159	4 080	4 532
19	3 591	2 984	4 675	4 366	2 130	0	0	0
20	1 409	1 612	0	3 685	3 884	0	2 292	6 473
21	0	1 612	0	5 061	0	0	3 582	0
22	0	0	759	5 342	0	0	0	0
23	0	0	1 746	2 171	0	0	0	3 393
24	0	0	0	4 702	0	0	0	0
25	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0
27	0	0	1 929	2 932	0	0	0	0
Measured male	220	322	243	293	201	149	149	151
Measured female	212	305	275	355	229	200	159	147
Aged male	146	228	199	178	166	109	141	132
Aged female	173	225	221	216	188	160	147	137
Sampled shots	68	124	127	125	88	56	77	54
Mean weighted c.v. (%)	39.8	34.0	36.3	40.6	42.2	39.7	39.3	49.7
Sample period	Dec 89	Jan 92	Jan 93	Jan 94	Jan 95	Jan 96	Jan 97	Jan 98

Table 11: Catch-at-age data, by sex, for hake sampled from the commercial trawl fishery off WCSI during the period June–September each year (HAK 7)

	Age	Sample year							
		1990	1991	1992	1993	1994	1995	1996	1997
Male	1	0	0	620	38 800	2 955	281 367	56 091	6 162
	2	606	0	3 037	7 656	563	34 018	27 253	155
	3	0	479	4 257	9 475	2 028	47 186	6 502	4 603
	4	1 624	5 402	12 799	8 547	2 277	45 219	6 256	14 657
	5	16 365	31 379	7 027	33 168	4 447	88 777	41 023	75 313
	6	34 539	62 553	38 645	60 479	19 974	121 782	106 612	207 586
	7	76 005	122 225	67 507	62 224	33 626	184 451	204 791	227 631
	8	82 401	165 749	92 587	64 385	37 711	139 382	164 355	190 336
	9	88 738	235 215	73 404	133 284	29 189	119 535	174 883	117 450
	10	37 322	159 927	56 126	178 202	35 358	46 015	117 164	63 858
	11	43 680	77 819	69 532	173 916	27 046	32 862	68 783	36 219
	12	35 953	108 648	14 263	161 446	17 094	46 113	52 763	38 167
	13	17 200	64 921	31 234	47 413	11 819	10 429	68 440	20 217
	14	19 894	33 518	18 934	31 344	2 070	26 857	46 553	21 512
	15	18 890	42 111	3 035	56 791	10 889	19 193	7 136	18 162
	16	19 480	31 281	17 025	37 066	5 349	15 349	25 735	7 533
	17	0	15 028	2 648	24 298	4 011	12 098	48 744	10 091
	18	3 613	11 727	4 095	27 409	8 000	4 543	13 327	722
	19	2 303	8 405	1 104	14 355	3 028	9 016	28 296	3 792
	20	0	2 641	0	9 656	1 268	0	7 477	5 207
	21	0	0	2 648	5 919	0	9 653	29 888	0
	22	0	0	0	0	0	6 996	6 720	0
	23	0	0	0	4 314	0	0	0	0
	24	617	0	0	0	0	0	8 598	4 678
	25	0	0	0	0	1 054	0	0	0
	26	0	9 321	2 377	0	0	724	0	0
	27	0	0	0	0	0	0	0	0
	28	2 234	0	5 253	0	0	0	0	0
	29	0	2 657	0	0	0	0	0	0
	30	0	0	0	0	0	0	0	0
	31	0	0	0	0	0	0	3 653	0
Female	1	1 727	5 258	883	89 556	189	268 875	35 326	13 163
	2	606	67	6 174	21 895	6 348	33 862	38 354	2 257
	3	303	931	2 266	29 412	4 743	52 676	22 016	17 453
	4	31 858	4 310	387	13 971	5 529	17 661	12 919	53 974
	5	24 194	26 359	2 491	22 709	9 517	44 962	58 059	74 509
	6	68 470	67 401	11 253	7 071	15 994	50 639	83 297	70 170
	7	73 713	123 617	22 892	36 456	44 695	85 680	110 429	145 092
	8	58 808	141 297	38 766	71 969	42 068	84 587	124 429	104 954
	9	62 832	120 213	29 321	59 870	24 550	61 220	98 600	91 313
	10	73 641	116 811	23 244	53 689	26 348	34 160	92 449	74 275
	11	26 372	80 739	16 612	56 569	33 323	33 540	43 021	18 642
	12	37 900	58 698	8 642	27 448	35 526	23 152	54 880	36 510
	13	56 618	46 426	6 963	11 657	29 702	25 341	34 827	24 526
	14	19 995	41 071	8 120	17 221	14 674	10 686	14 812	29 392
	15	9 294	23 276	4 453	24 850	2 471	4 310	14 864	12 724
	16	10 403	15 498	2 557	28 408	7 106	4 375	14 608	4 041
	17	22 723	9 978	209	1 382	7 115	8 611	2 201	8 596
	18	9 279	5 078	81	1 910	4 742	2 765	18 689	272
	19	0	2 390	153	616	13 788	3 162	1 663	498
	20	165	8 296	0	0	1 509	1 103	1 266	240
	21	0	2 024	0	3 923	6 326	692	1 766	0
	22	0	0	0	0	491	1 398	0	7 992
	23	34	0	0	1 884	0	1 217	0	496
	24	0	0	0	0	0	0	476	0
Measured male		587	2 316	2 620	2 520	1 631	2 543	2 874	3 359
Measured female		586	1 679	1 228	1 212	1 724	2 805	1 774	1 784
Aged male		205	280	176	160	135	254	271	240
Aged female		255	346	237	133	258	322	310	180
Sampled shots		70	166	144	125	223	171	205	279
Mean weighted c.v.		31.8	22.6	25.1	30.8	30.5	31.1	28.0	24.6

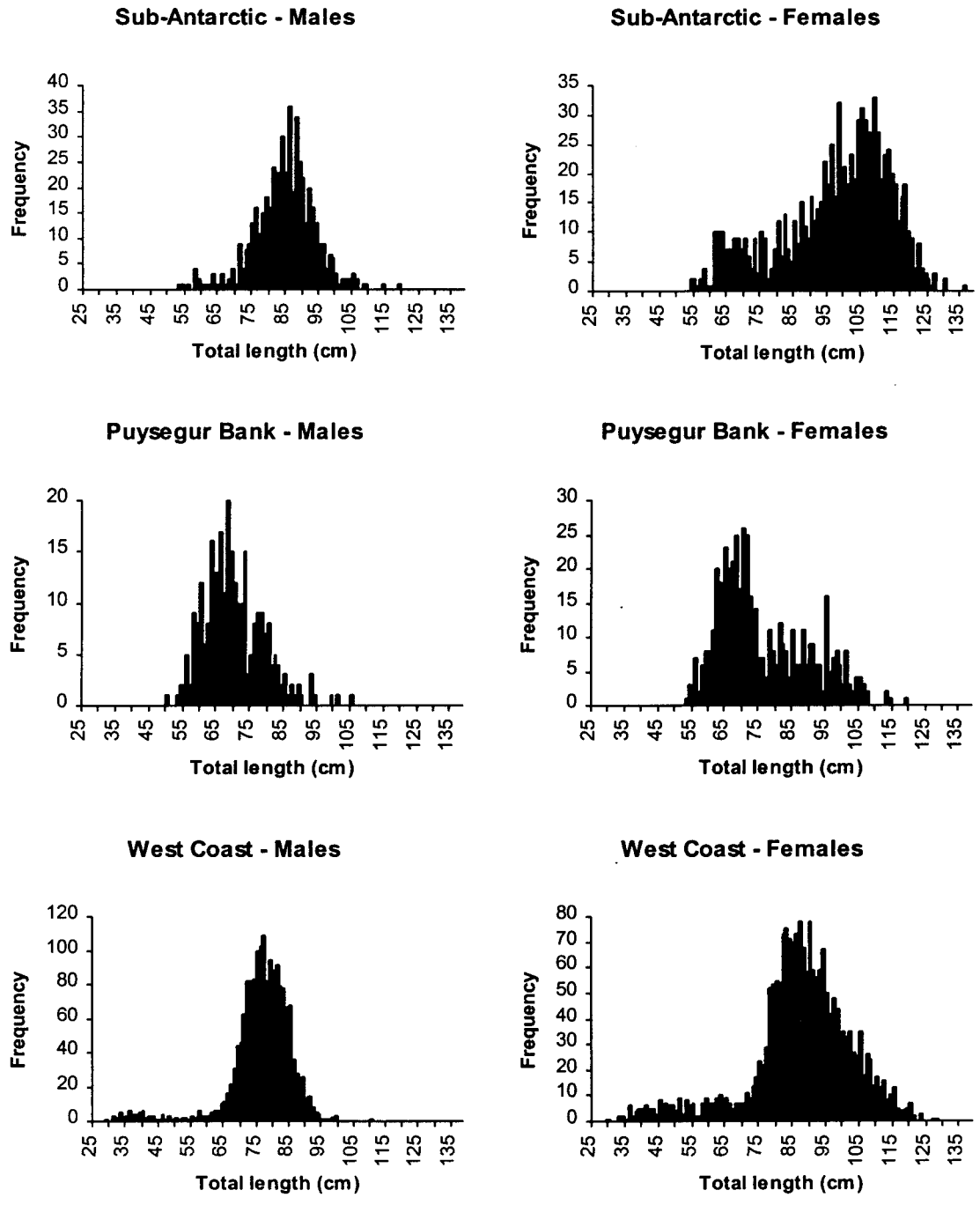


Figure 1: Length-frequency distributions, by sex, of aged fish from the Sub-Antarctic, Puysegur Bank, and west coast South Island regions.

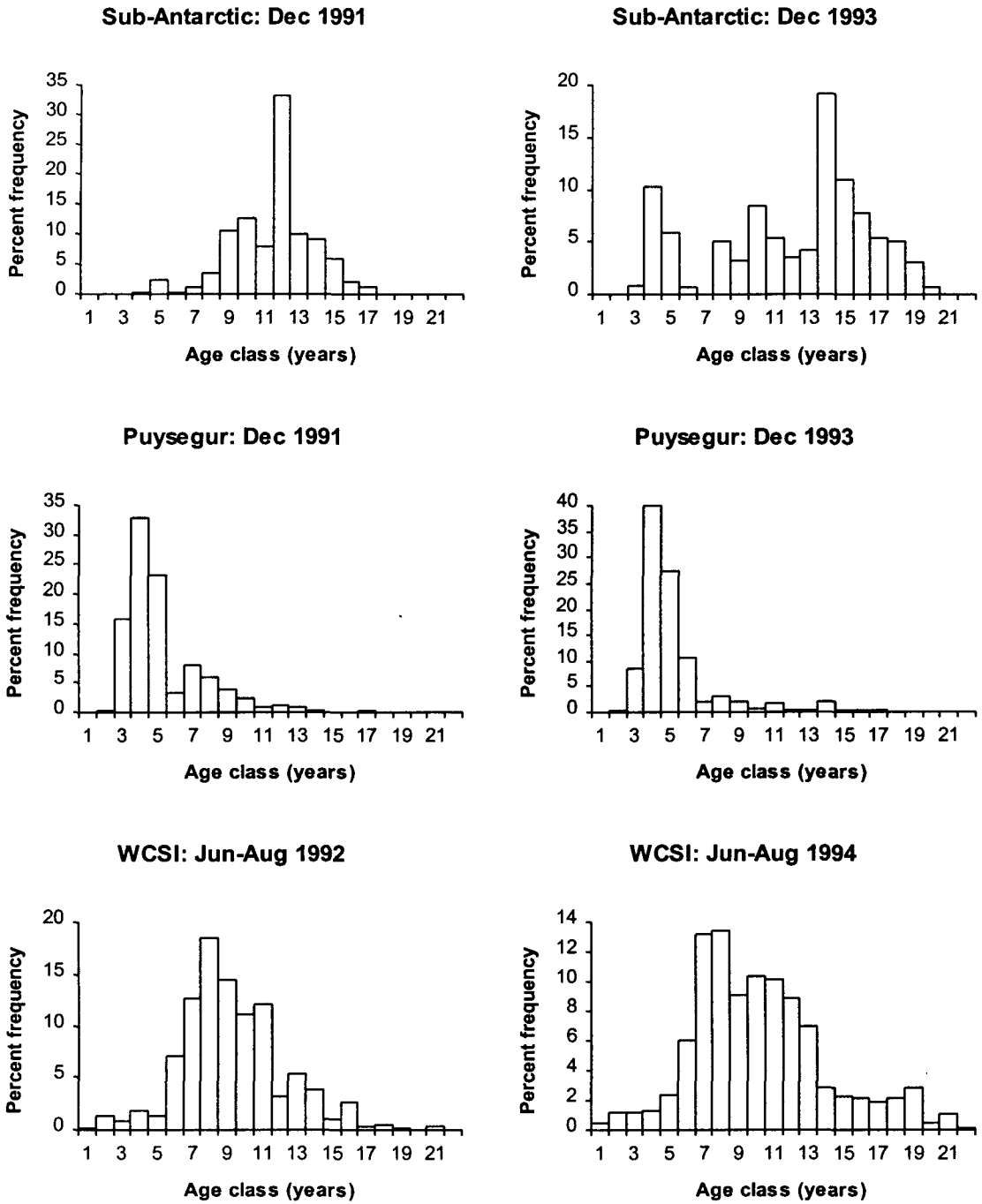


Figure 2: Age-frequency distributions (sexes combined) from the Sub-Antarctic, Puysegur bank, and west coast South Island, calculated for the years 1991–92 and 1993–94.