New Zealand Fisheries
Assessment Report
2008/60
October 2008
ISSN 1175-1584

Catch-at-age for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) in the 2006–07 fishing year and from trawl surveys in summer 2007–08, with a summary of all available data sets

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New Zealand Fisheries Assessment Report 2008/60
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Published by Ministry of Fisheries
Wellington
2008

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New Zealand Fisheries Assessment Report 2008/60. 54 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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This report describes catch-at-age distributions for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) estimated from commercial fisheries for these species in the 2006–07 fishing year (using data and otoliths collected at sea by observers), and from trawl surveys of hoki and middle depth species on the Campbell Plateau in December 2007 (TAN0714) and the Chatham Rise in January 2008 (TAN0801). For each estimated catch at age distribution there is a target coefficient of variation (c.v.) of 30 % (mean weighted c.v. across all age classes).

For hake, the mean weighted c.v. targets were met for two of the commercial fishery samples (WCSI and Chatham Rise area 404), but not for the two trawl surveys or the Sub-Antarctic commercial fishery sample. However, all available information was used to calculate the survey and Sub-Antarctic catch-at-age distributions, so there is no way to improve the c.v.s.

For ling, the mean weighted c.v. targets were met for both trawl survey samples and for the trawl fisheries in the Chatham Rise and Sub-Antarctic areas. The targets were not met in the WCSI or Cook Strait commercial trawl fisheries, owing largely to relatively low levels of observer sampling in these fisheries in winter 2007. Of the three ling longline fisheries for which catch at age distributions were produced for 2006–07, only the distribution from the Sub-Antarctic spawning fishery met the c.v. target. However, the targets were almost met for the Chatham Rise and Cook Strait longline fisheries.

In all distributions for both species where the target c.v. was not met it was not possible to improve the precision as all available data and otoliths had been used in the analyses.

This report also provides summaries of all catch at age distributions available for hake and ling from the various trawl survey and fisheries series. In addition, the definitions of any stratification used in the analyses of the commercial fisheries are defined.

1. INTRODUCTION

The work presented here aimed to determine catch-at-age from the main fisheries for hake and ling in the 2006–07 fishing year, and for hake and ling from trawl surveys conducted during the summer of 2007–08. Catch-at-age data are a vital input into the stock assessment process as they provide important information on the year class strength of recruited cohorts, and enable calculation of selectivity ogives for the trawl surveys and commercial fisheries for these species. This report describes the resulting catch-at-age distributions for hake and ling; the new data extend existing series of catch-at-age data in all cases. It fulfils the first year's reporting requirements for Objectives 4 and 5 of Project MID2007-01 "Determination of catch at age in hoki, hake and ling fisheries", funded by the Ministry of Fisheries. Those objectives are:

4. To determine the catch at age from hake fisheries in HAK 1, 4 and 7 from samples collected at sea by the Observer Programme, by trawl surveys and from other sources in 2006/07, with a target coefficient of variation (c.v.) of 30 % for each fishstock (mean weighted c.v. across all age classes).

5. To determine the catch at age from ling fisheries in LIN 3 & 4, 5 & 6 and 7 in 2006/07 from samples collected at sea by the Observer Programme, by trawl surveys and from other sources, with a target coefficient of variation (c.v.) of 30 % for each fishstock (mean weighted c.v. across all age classes).

The report also summarises all the available catch at age data sets for hake and ling from trawl surveys and commercial fisheries. In recent years, for both species, stratification of the data from the commercial trawl fisheries has been refined. Some of these stratifications have been well described in the formal literature (e.g., ling off west coast South Island (Horn 2008a)), but others are undescribed or have been reported only in Final Research Reports to MFish. Consequently, it is considered desirable to have all stratifications for both species described in a single accessible document, and these are presented below.

2. METHODS

For hake, it was proposed to age the following samples under this project (with the number of aged otoliths in square brackets):

HAK 1 — trawl survey, Dec 2007 (project MDT2007/01) [all available]
HAK 1 — commercial trawl fishery, Sep 2006–May 2007 [600]
HAK 4 — trawl survey, Jan 2008 (project HOK2007/02) [all available]
HAK 4 — commercial trawl fishery, Oct 2006–April 2007 [500]
HAK 7 — commercial trawl fishery, Jun–Sep 2007 [500]

For ling, it was proposed to age the following samples under this project (with the number of aged otoliths in square brackets):

LIN 3&4 — trawl survey, Jan 2008 (project HOK2007/02) [640]
LIN 3&4 — commercial longline fishery, Jun–Oct 2007 [580]
LIN 5&6 — trawl survey, Dec 2007 (project MDT2007/01) [570]
LIN 5&6 — commercial longline fishery, spawning, Puysegur, Oct–Dec 2006 [500]
LIN 5&6 — commercial longline fishery, non-spawning, Campbell, Feb–Jul 2007 [500]
LIN 7 — commercial trawl fishery, west coast South Island, Jun–Sep 2007 [600]
LIN 7&2 — commercial trawl fishery, Cook Strait, Jun–Sep 2007 [500]

Also, the following additional commercial fishery catch-at-age distributions were estimated using age-length keys derived previously from the January 2007 Chatham Rise trawl survey (LIN 3&4) and the December 2006 Sub-Antarctic trawl survey (LIN 5&6).

LIN 3&4 — commercial trawl fishery, Oct 2006–May 2007
LIN 5&6 — commercial trawl fishery, Sep 2006–Apr 2007

A catch-at-age model describing the age structure of each of the commercial fisheries and surveyed areas was developed as in previous years for both species. For each of the samples, otoliths (for each sex separately) from each 1 cm length class were selected in proportion to their occurrence in the scaled length frequency, with the constraint that the number of otoliths in each length class (where available) was at least one. In addition, all otoliths from fish in the extreme right hand tail of the scaled length frequency (constituting about 2% of that length frequency) were fully sampled. This provides a sample with a mean weighted c.v. similar to that from proportional sampling, but does better than uniform sampling for the older age classes (A. Dunn, NIWA, pers. comm.). Otoliths were prepared and read using the validated ageing technique for hake (Horn 1997) or ling (Horn 1993). Catch-at-age was calculated by constructing age-length keys separately for each sex and applying them to the scaled length frequency data derived from each fishery or survey separately using software developed specifically for this task by NIWA (Bull & Dunn 2002).

Observer sampling of the HAK 1 and HAK 4 commercial trawl fisheries sometimes provides only small numbers of otoliths. Consequently, catch-at-age distributions for these fisheries are estimated using age-length keys combining commercial fishery and trawl survey age data. For example, the age-length key for the 2006–07 HAK 4 fishery includes otoliths from observer sampling from October 2006 to May 2007 plus age data from the TAN0701 trawl survey in January 2007.

The mean weighted c.v. targets for hake from previous trawl surveys have often not been met. To maximise the chances of meeting the target, all hake from the trawl shots used in the biomass (and scaled length-frequency) calculations were measured and had their otoliths collected. Also, any additional hake caught in survey tows not used for biomass calculations (i.e., foul shots, midwater tows, or night tows) were measured, sexed, and had their otoliths removed. These extra fish were aged, and the data incorporated into the age-length key. Consequently, in the data summaries shown below, the number of aged hake from the trawl surveys is often greater than the number of measured fish (i.e., the fish used to calculate the catch-at-length and catch-at-age).

3. RESULTS

3.1 Observer catch at age data from hake trawl fisheries

3.1.1 Chatham Rise

The fishery on the Chatham Rise had previously been stratified using a tree-based regression on mean lengths of hake in tows where observers had measured five or more hake in all observed trawls from 1989 to 2006 (Horn & Dunn 2007). The resulting fishery strata are shown in Figure 1, and defined as follows:

1. West shallow (longitude ≤ 178.1° E, and bottom depth ≤ 530 m)
2. West deep (longitude ≤ 178.1° E, and bottom depth > 530 m)
3. East excl. area 404 (longitude > 178.1° E, and excluding Statistical Area 404)
4. Area 404 (178° W ≤ longitude ≤ 179.5° W, 42° S ≤ latitude ≤ 43.75° S)

A tow was included in the catch at age analysis if it occurred between 1 October and 30 April, and if at least five hake had been measured from it.

Mean fish length tends to increase from west to east, and with increasing depth. Area 404 is a known spawning ground. Because landings and intensity of observer effort varied markedly over the four strata between years it was considered necessary to model the Chatham Rise stock with four separate fisheries, each with its own selectivity ogives. Consequently, it was necessary to develop catch-at-length and catch-at-age series separately for each fishery.

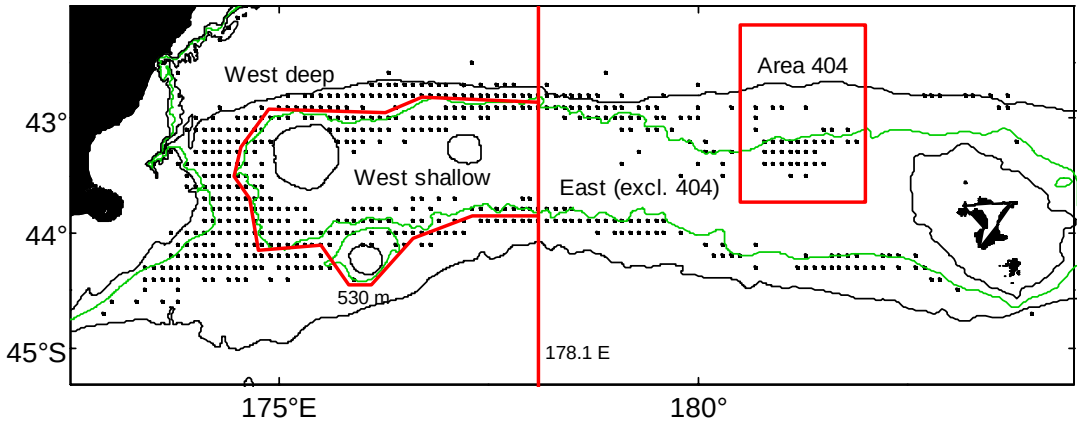

Figure 1: Fishery strata defined for the Chatham Rise hake fishery. Dots show positions of tows included in the tree regression analysis; one point may represent many tows. The stratum boundary defined by depth (530 m) is shown only approximately. Isobaths at 1000, 500, and 250 m are also shown.

Observer data from each fishery stratum were converted into catch-at-age distributions if there were at least 400 length measurements and the mean weighted c.v. over all age classes was less than 30%. Any data sets not meeting these criteria were accepted as catch-at-length distributions if they contained at least 278 length measurements. Table 1 summarises the quantities of useful data, and the outcome for each data set (i.e., whether it was converted to catch-at-age or catch-at-length). Note that the 1991 data sets are generally large, but could not be converted to catch-at-age because no age data (or otoliths) are available from that year. The two western fisheries have been generally well sampled, but both eastern fisheries (and particularly the Area 404 fishery) have been poorly sampled. Consequently, for stock modelling, observer data from the western fisheries have been combined to produce a more extensive set of catch-at-age and length distributions (Horn & Dunn 2007).

Although the observer length data from each year were partitioned into fisheries, the age data from each year were not (i.e., a single age-length key was constructed for each year and applied to all available sets of length data from that year). Horn & Dunn (2007) showed that mean age at length did not differ between fisheries, so the use of a single age-length key per year has probably not biased the age distributions.

In the 2006–07 fishing year, sufficient length data and otoliths were available to calculate a catch at age distribution for the Area 404 fishery only (see Table 1). Details of that estimated distribution are given in Table 2. Although the sample sizes of measured fish are relatively small, the mean weighted c.v. of 28% was within the 30% target.

All estimated proportion at age distributions from the four Chatham Rise trawl fisheries are presented in Appendix A (Figures A1, A2, A3, and A4).

Table 1: Numbers of measured and aged male (Mal) and female (Fem) hake contributing to samples of proportion at age or proportion at length from the four commercial trawl fisheries on the Chatham Rise. The number of tows sampled by observers and the estimated mean weighted c.v. (%) by age when a proportion at age distribution was produced are also listed. A dash in the c.v. column indicates that only a proportion-at-length distribution was produced.

Fishing year	Measured																Aged	
	West shallow				West deep				East excl. 404				Area 404					
	Mal	Fem	Tows	c.v.	Mal	Fem	Tows	c.v.	Mal	Fem	Tows	c.v.	Mal	Fem	Tows	c.v.	Mal	Fem
1990–91					642	471	58	–	747	818	94	–	902	156	23	–		
1991–92	696	1 221	79	26.6	1 416	1 415	84	21.0	260	417	28	28.6					233	230
1992–93																		
1993–94	226	310	55	–					151	203	35	–					181	217
1994–95	257	495	54	34.4									210	68	7	–	170	191
1995–96	468	569	67	33.0	334	348	36	27.7									113	165
1996–97	304	174	23	–									344	69	22	–	145	149
1997–98	2 081	1 835	209	15.3	1 080	1 211	181	17.1									393	393
1998–99	460	902	119	22.7	252	377	52	26.9	205	274	45	27.9					290	440
1999–2000	173	362	61	24.1	634	539	103	18.3									442	499
2000–01	396	633	90	21.7	434	502	95	21.0					940	212	18	25.2	317	426
2001–02	216	326	53	23.1	170	166	36	–	239	219	53	23.9					455	419
2002–03	122	184	33	–													256	345
2003–04	271	133	39	–	326	305	62	29.1	269	53	23	–					364	304
2004–05	232	187	35	–	664	250	47	24.7									391	343
2005–06	144	248	37	–													189	255
2006–07									161	202	48	–	318	173	25	28.0	368	388

Table 2: Calculated numbers at age, separately by sex, with c.v.s, for hake caught during commercial trawl operations on the Chatham Rise (Area 404 fishery) during October 2006–April 2007, and in the Sub-Antarctic during September 2006–May 2007. Summary statistics for the samples are also presented.

	Chatham Rise					Sub-Antarctic			
Age	Male	c.v.	Female	c.v.	Age	Male	c.v.	Female	c.v.
3	277	0.962	80	1.447	3	295	1.290	38	1.864
4	1 179	0.569	199	0.858	4	815	0.581	204	0.908
5	3 037	0.327	874	0.522	5	2 297	0.642	244	0.868
6	4 830	0.256	2 206	0.354	6	7 757	0.533	3 999	0.656
7	7 467	0.255	2 607	0.360	7	21 217	0.365	5 273	0.557
8	6 282	0.309	2 030	0.397	8	21 573	0.314	9 030	0.353
9	9 474	0.238	2 760	0.443	9	28 715	0.273	9 496	0.380
10	4 359	0.314	3 077	0.354	10	14 448	0.368	7 413	0.456
11	6 518	0.267	1 949	0.475	11	11 918	0.505	9 066	0.479
12	4 979	0.382	1 765	0.482	12	18 291	0.408	8 590	0.465
13	2 134	0.529	1 587	0.496	13	6 394	0.886	3 346	0.755
14	2 237	0.453	2 237	0.408	14	4 975	0.693	3 127	0.871
15	3 348	0.486	1 287	0.573	15	5 086	0.641	3 932	0.725
16	845	0.695	163	1.186	16	1 327	1.444	2 187	1.209
17	1 013	0.781	1 048	0.628	17	4 325	0.733	1 090	1.186
18	749	0.869	166	1.822	18	1 736	1.042	3 171	1.216
19	0	–	320	1.113	19	1 081	1.134	0	–
20	0	–	0	–	20	1 327	1.304	0	–
21	0	–	0	–	21	0	–	3 037	1.431
22	215	1.375	0	–	22	1 616	1.340	0	–
					23	1 155	1.479	0	–

Measured males	318	547
Measured females	173	666
Aged males	368	224
Aged females	388	351
No. of tows sampled	25	73
Mean weighted c.v. (sexes pooled)	28.0	38.5

3.1.2 Sub-Antarctic

A tree-based regression on mean fish length was able to logically stratify the fisheries on the Chatham Rise likely owing to the shape and orientation of this geological feature, i.e., a relatively flat-topped ridge running consistently along a degree of latitude. However, the Sub-Antarctic area comprises numerous island plateaus, under-sea ridges, and steep drop-offs, so it was considered less likely that a regression analysis primarily based on latitude and longitude would logically stratify the fisheries. Consequently, an initial investigation of mean fish length by depth and sub-area was conducted (Horn 2008b). There were no obvious trends in mean fish length by depth. Mean length, by sex, for hake in sub-areas of 2° latitude/longitude, did show some clear trends. Fish from the Puysegur Bank were the smallest. Relatively small fish were also concentrated around and to the east of Auckland Islands, and to the west of Campbell Island. The remaining sub-areas all had relatively large fish. It was noted that the density of males in the sub-area southwest of the Snares shelf is greater (by at least a factor of 2) than in any other rectangle, and that the percentage of males declines as you radiate out from that sub-area (Horn 2008b).

On the basis of mean fish size, four fishery areas were defined (Figure 2). The length-frequency distributions from the four areas exhibited clear differences (Horn 2008b). Most of the hake target fishing occurs in the Snares-Pukaki area (i.e., an average of 94% per year). Puysegur is the next most important area with about 3% of the catch. Available observer data are also concentrated in the Snares-Pukaki region, but it is clear that the other three fisheries have been highly over-sampled in some years (Horn 2008b). The conclusion from that analysis was that there is one major and three very

minor hake fisheries in the Sub-Antarctic area, so a single fishery ogive should be suitable for this stock. However, because of the clear differences in mean fish length between the fisheries, it is important to use the four fishery strata when calculating catch at age distributions. Without stratification, the frequent over-sampling in the minor fisheries could strongly bias the catch at age distributions. However, as shown for the Chatham Rise stock (Horn & Dunn 2007), it is probably satisfactory to apply a single age-length key to the scaled length-frequency distributions for each fishery to produce the catch at age data. Consequently, commercial age frequencies were developed using the four fishery strata shown in Figure 2, and defined as follows:

1. Puysegur Bank (165° E ≤ longitude ≤ 168° E, 46° S ≤ latitude ≤ 48° S)
2. Snares-Pukaki (165° E ≤ longitude ≤ 175° E, 46° S ≤ latitude ≤ 50.25° S, but excluding the Puysegur Bank stratum)
3. Auckland Island (165° E ≤ longitude ≤ 169° E, 50.25° S < latitude ≤ 54° S)
4. Campbell Island (169° E < longitude ≤ 174° E, 50.25° S < latitude ≤ 54° S)

A tow was included in the catch at age analysis if it occurred between 1 September and 31 May, and if at least five hake had been measured from it. The start of the fishing year was not used as the start of the time stratum because a descriptive analysis of this fishery indicated a landings peak from September to February (Devine 2008), so it is logical to include the September catch with landings from the five months immediately following it, rather than with catches taken about seven months previously.

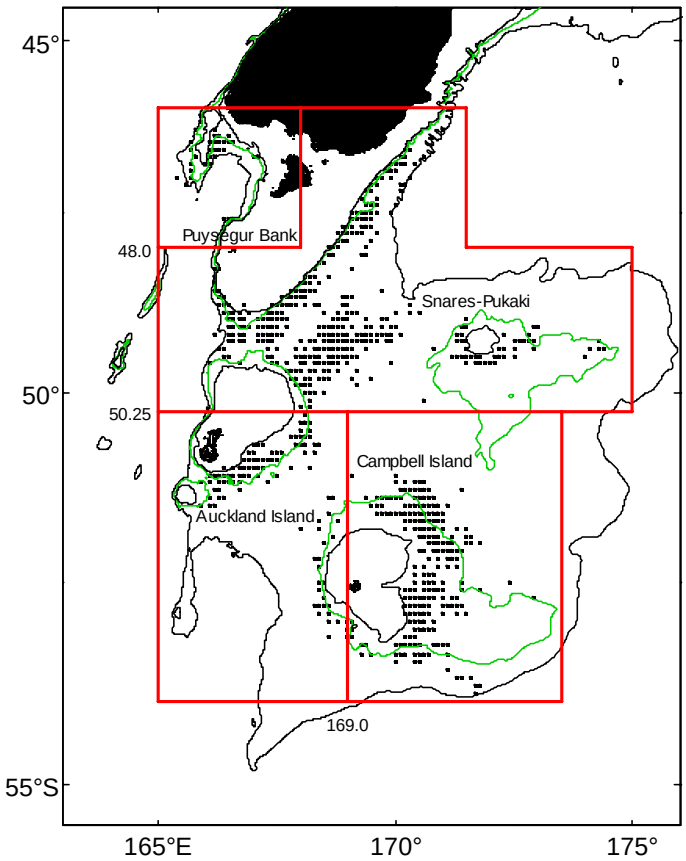

Figure 2: Fishery strata defined for the Sub-Antarctic hake fishery. Dots show positions of tows included in the stratum analysis; one point may represent many tows. Numbers show latitudes/longitudes of fishery boundaries. Isobaths at 1000, 500, and 250 m are also shown.

Table 3 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for

trawl-caught hake in the 2006–07 fishing year are given in Table 2. The mean weighted c.v. of 38.5% did not meet the target of 30%. However, this value cannot be improved as all available length data and otoliths were used in the analysis.

All estimated proportion at age distributions from the Sub-Antarctic trawl fishery are presented in Appendix A (Figure A5).

Table 3: Numbers of measured and aged male and female hake, and the number of sampled tows and estimated mean weighted c.v. (%) by age, for the Sub-Antarctic trawl fishery.

	Males		Females		Tows	Mean c.v.
Year	Measured	Aged	Measured	Aged		
1989–90	269	47	548	71	74	42.0
1990–91	175	–	588	–	64	–
1991–92	557	215	1 363	409	151	24.9
1992–93	833	183	1 218	518	171	27.6
1993–94	512	87	609	173	119	47.8
1994–95	167	–	597	–	92	–
1995–96	289	65	435	110	75	50.0
1996–97	84	–	219	–	54	–
1997–98	390	82	1 018	193	154	37.7
1998–99	463	174	1 077	322	199	27.4
1999–2000	3 007	259	2 526	421	307	22.5
2000–01	527	388	1 648	698	216	29.6
2001–02	921	333	2 026	874	320	23.4
2002–03	271	258	908	739	197	40.4
2003–04	1 309	350	969	518	165	24.7
2004–05	179	185	424	305	82	40.1
2005–06	1 906	218	1 094	506	153	23.2
2006–07	547	224	666	351	73	38.5

3.1.3 West coast South Island

The fishery off WCSI was stratified using a tree-based regression on mean lengths of hake, by sex, in tows where observers had measured five or more hake between 1 June and 30 September in all years from 1989 to 2007. The trees tended to be small (two or three branches), and explained little of the variance (less than 13% in all cases). Mean fish length is greater in shallower than deeper water, and (for females) tends to increase from north to south. For males, two strata based on bottom depth were indicated, with the split at 629 m; mean fish lengths were 73.6 and 75.5 cm in the deep and shallow strata, respectively. For females, a depth boundary also at 629 m was indicated (mean length 80.9 cm in the deep stratum), and the shallow area was divided at a latitude of 42.55° S (mean lengths of 85.3 and 88.9 cm for the northern and southern areas, respectively). Consequently, tows occurring between 1 June and 30 September each year, and with at least five measured hake, were allocated to the following three strata:

1. Deep (bottom depth ≥ 629 m)
2. North shallow (latitude < 42.55° S)
3. South shallow (latitude ≥ 42.55° S)

Table 4 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for trawl-caught hake in the 2006–07 fishing year are given in Table 5. The measured sample size was large, and the mean weighted c.v. of 17% was well within the target of 30%.

All estimated proportion at age distributions from the WCSI trawl fishery are presented in Appendix A (Figure A6).

Table 4: Numbers of measured and aged male and female hake, and the number of sampled tows and estimated mean weighted c.v. (%) by age, for the WCSI trawl fishery.

	Males		Females		Tows	Mean c.v.
Year	Measured	Aged	Measured	Aged		
1989–90	578	210	567	261	57	23.1
1990–91	2 288	286	1 653	358	146	18.4
1991–92	2 592	196	1 193	261	121	22.5
1992–93	2 129	188	979	163	93	29.1
1993–94	1 598	151	1 643	272	174	32.5
1994–95	2 528	271	2 769	342	152	29.2
1995–96	2 862	287	1 753	326	193	28.9
1996–97	3 286	262	1 720	198	234	21.3
1997–98	2 339	257	1 497	253	237	21.4
1998–99	4 186	270	3 744	240	307	18.3
1999–2000	2 705	258	2 330	269	285	18.9
2000–01	1 529	176	1 723	280	192	23.9
2001–02	2 281	93	2 434	385	380	33.8
2002–03	1 917	227	2 063	234	296	20.0
2003–04	2 702	303	2 181	193	353	16.5
2004–05	2 305	238	2 324	280	217	23.8
2005–06	5 502	276	4 231	298	395	16.3
2006–07	3 385	248	3 258	257	132	16.7

Table 5: Calculated numbers at age, separately by sex, with c.v.s, for hake caught during commercial trawl operations off the west coast of the South Island (WCSI) during June–September 2007. Summary statistics for the samples are also presented.

			WCSI	
Age	Male	c.v.	Female	c.v.
2	259 654	0.171	195 025	0.233
3	67 346	0.226	57 351	0.258
4	51 552	0.291	24 834	0.350
5	271 640	0.115	42 240	0.251
6	202 063	0.155	123 775	0.181
7	162 207	0.161	131 938	0.181
8	37 668	0.355	178 364	0.157
9	35 452	0.358	154 921	0.166
10	17 614	0.540	62 383	0.260
11	20 558	0.466	47 892	0.290
12	8 844	0.790	19 626	0.457
13	6 614	0.802	23 398	0.394
14	11 641	0.628	17 277	0.429
15	0	–	4 594	1.179
16	0	–	6 417	0.875
17	2 621	1.144	2 293	0.894
18	0	–	2 260	1.139
19	7 934	0.635	705	1.038

Measured males	3 385
Measured females	3 258
Aged males	248
Aged females	257
No. of tows sampled	132
Mean weighted c.v. (sexes pooled)	16.7

3.2 Trawl survey catch at age data for hake

3.2.1 Chatham Rise

Trawl survey catch at age distributions are estimates of the numbers of hake, by sex and age, available to the trawl in the survey area between 200 and 800 m. In some years an additional deeper stratum (800–1000 m) on the north Rise is surveyed. However, to ensure comparability, the distributions presented here are for the 'core' strata only, i.e., 200–800 m.

Table 6 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for hake caught in the January 2008 trawl survey are given in Table 7. The mean weighted c.v. of 38% did not meet the target of 30%. However, this value cannot be improved as all available length data and otoliths were used in the analysis. The 30% target has been met in only one of the 18 surveys (TAN9106, see Table 6).

All estimated proportion at age distributions from the Chatham Rise trawl surveys are presented in Appendix A (Figure A7).

Table 6: Numbers of measured and aged male and female hake, and the number of sampled tows and estimated mean weighted c.v. (%) by age, for the Chatham Rise resource surveys.

	Males		Females			Mean c.v.
Source	Measured	Aged	Measured	Aged	Tows	
AEX8903	220	154	212	179	63	39.5
TAN9106	322	233	305	230	122	30.0
TAN9212	243	200	275	225	121	32.7
TAN9401	293	181	355	217	123	33.1
TAN9501	201	170	229	191	87	38.7
TAN9601	149	113	200	165	56	36.4
TAN9701	149	145	159	149	77	36.1
TAN9801	137	135	142	139	55	39.0
TAN9901	94	103	142	157	62	44.1
TAN0001	177	177	178	177	72	35.9
TAN0101	104	112	148	150	66	37.3
TAN0201	104	177	121	172	61	36.4
TAN0301	33	34	69	71	46	61.4
TAN0401	94	82	110	105	53	49.4
TAN0501	115	134	107	113	55	45.3
TAN0601	109	123	126	138	56	33.8
TAN0701	133	158	136	142	61	32.6
TAN0801	55	65	87	99	60	38.0

Table 7: Calculated numbers at age in the survey area, separately by sex, with c.v.s, for hake caught during trawl surveys of the Chatham Rise in January 2008 (survey TAN0801) and the Sub-Antarctic in November-December 2007 (survey TAN0714). Summary statistics for the samples are also presented.

	TAN0801			
Age	Male	c.v.	Female	c.v.
2	2 740	1.261	0	–
3	4 411	0.866	0	–
4	24 988	0.410	4 223	0.804
5	20 234	0.418	14 587	0.502
6	28 567	0.397	67 258	0.233
7	1 470	1.566	24 935	0.421
8	7 714	0.632	24 667	0.432
9	4 204	0.979	4 593	0.770
10	2 338	0.955	24 932	0.401
11	1 690	1.451	3 679	0.839
12	1 184	1.411	4 976	0.751
13	979	1.749	4 433	1.307
14	0	–	3 992	0.82
15	1 656	1.417	3 330	0.713
16	0	–	0	–
17	0	–	2 778	0.908
18	0	–	1 759	1.321

	TAN0714			
Age	Male	c.v.	Female	c.v.
2	779	1.212	260	1.463
3	20 939	0.218	33 317	0.219
4	26 752	0.503	35 608	0.279
5	33 536	0.62	22 996	0.31
6	16 247	0.638	23 856	0.388
7	25 855	0.484	23 918	0.335
8	16 994	0.496	32 845	0.333
9	20 621	0.468	28 527	0.38
10	8 400	0.715	33 885	0.357
11	7 684	0.800	22 106	0.355
12	7 750	0.778	27 446	0.427
13	8 546	0.765	10 695	0.650
14	8 205	0.557	15 221	0.552
15	565	1.909	10 655	0.757
16	3 089	0.999	3 780	0.919
17	1 245	1.614	7 483	0.826
18	0	–	1 383	1.014
19	0	–	3 194	1.572
20	0	–	0	–
21	0	–	0	–
22	0	–	0	–
23	2 682	1.450	0	–

Measured males	55	166
Measured females	87	352
Aged males	65	217
Aged females	99	423
No. of tows sampled	60	47
Mean weighted c.v. (sexes pooled)	38.0	35.4

3.2.2 Sub-Antarctic

Trawl survey catch at age distributions are estimates of the numbers of hake, by sex and age, available to the trawl in the survey. The main survey series has been conducted in summer. Those surveys have sampled depths from 300 to 800 m, plus an 800–1000 m stratum at Puysegur, and, in some years, other 800–1000 m strata off the Campbell Plateau. However, to ensure comparability, the distributions presented here are for the 'core' 300–800 m strata plus the deep Puysegur stratum only. The catch at age distributions from the spring and autumn surveys are derived from the 'core' 300–800 m strata only.

Table 8 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for hake caught in the November–December 2007 trawl survey are given in Table 7. The mean weighted c.v. of 35% did not meet the target of 30%. However, this value cannot be improved as all available length data and otoliths were used in the analysis. The 30% target has never been met in any of the Sub-Antarctic surveys (see Table 8).

All estimated proportion at age distributions from the Sub-Antarctic trawl surveys are presented in Appendix A (Figure A8).

Table 8: Numbers of measured and aged male and female hake, and the number of sampled tows and estimated mean weighted c.v. (%) by age for the Sub-Antarctic resource surveys.

	Males		Females		Tows	Mean c.v.
Survey	Measured	Aged	Measured	Aged		
Summer surveys						
AEX8902	45	43	76	66	34	52.7
TAN9105	337	117	332	217	61	65.1
TAN9211	14	46	133	168	48	48.6
TAN9310	57	93	181	182	59	47.2
TAN0012	348	239	392	352	56	37.3
TAN0118	219	212	351	349	44	35.6
TAN0219	331	191	490	377	38	36.1
TAN0317	126	186	175	220	30	41.0
TAN0414	178	245	225	283	39	42.8
TAN0515	88	146	265	274	39	39.9
TAN0617	188	190	487	460	39	33.6
TAN0714	166	217	352	423	47	35.4
Autumn surveys						
TAN9204	60	58	113	107	48	46.8
TAN9304	36	36	124	122	54	49.5
TAN9605	32	86	93	137	45	61.9
TAN9805	49	94	146	189	31	52.0
Spring surveys						
TAN9209	76	68	141	113	44	43.8

3.3 Observer catch at age data from ling longline fisheries

3.3.1 Chatham Rise

The line fishery data from the Chatham Rise are analysed using a single area stratum (i.e., FMAs 3 and 4 between 42° and 46° S), and a time stratum of 1 June to 31 October.

Table 9 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for Chatham Rise line-caught ling in the 2006–07 fishing year are given in Table 10. Despite a relatively small sample size, the mean weighted c.v. of 31.1% was just above the target value of 30%. This value cannot be improved as all available length data and otoliths were used in the analysis.

Table 9: Numbers of measured and aged male and female ling, and the number of sampled sets and estimated mean weighted c.v. (%) by age, for the Chatham Rise longline fishery.

	Males		Females			Mean c.v.
Year	Measured	Aged	Measured	Aged	Sets	
2002	4 966	284	2 998	309	538	20.4
2003	3 038	337	2 071	289	429	19.1
2004	1 066	302	747	293	139	21.8
2005	889	356	479	234	137	21.6
2006	266	95	294	141	48	36.6
2007	351	174	268	139	62	31.1

Table 10: Calculated numbers at age, separately by sex, with c.v.s, for ling caught during commercial longline operations on the Chatham Rise (LIN 3&4) in June–October 2007, and in the Sub-Antarctic spawning fishery (LIN 5&6) in October–December 2006. Summary statistics for the samples are also presented.

	Chatham Rise					Sub-Antarctic spawning			
Age	Male	c.v.	Female	c.v.	Age	Male	c.v.	Female	c.v.
5	138	1.858	0	–	5	71	1.967	133	1.347
6	176	1.186	44	1.682	6	856	0.808	285	0.864
7	603	0.694	461	0.898	7	783	0.775	1 203	0.620
8	1 612	0.441	132	1.116	8	3 637	0.357	2 841	0.378
9	3 151	0.345	418	0.768	9	3 324	0.344	3 299	0.270
10	3 232	0.350	1 271	0.474	10	4 073	0.240	5 418	0.253
11	3 300	0.309	2 963	0.313	11	6 131	0.196	7 837	0.161
12	4 118	0.274	3 590	0.246	12	4 318	0.279	4 203	0.245
13	4 020	0.353	2 798	0.291	13	2 321	0.346	3 403	0.269
14	2 796	0.326	2 725	0.320	14	3 015	0.309	2 933	0.298
15	1 749	0.446	1 609	0.419	15	1 717	0.400	2 635	0.325
16	2 057	0.333	1 911	0.353	16	1 115	0.455	1 709	0.366
17	2 447	0.363	788	0.601	17	2 364	0.330	1 422	0.398
18	1 499	0.401	1 560	0.434	18	1 775	0.367	0	–
19	1 297	0.498	469	0.743	19	902	0.502	1 297	0.430
20	382	0.771	157	1.148	20	1 200	0.505	674	0.623
21	136	1.053	0	–	21	586	0.679	535	0.830
22	562	0.691	0	–	22	122	1.053	699	0.606
23	237	1.001	125	1.263	23	540	0.694	208	1.117
24	167	1.188	608	0.750	24	652	0.749	1 073	0.590
25	716	0.685	0	–	25	437	0.685	0	–
26	247	1.241	0	–	26	0	–	112	1.432
27	383	0.966	0	–	27	617	0.704	0	–
28	243	1.075	0	–	28	0	–	0	–
29	0	–	0	–	29	0	–	133	1.617
30	418	0.948	0	–					

Measured males	351	412
Measured females	268	418
Aged males	174	191
Aged females	139	217
No. of sets sampled	62	82
Meanweighted c.v. (sexes pooled)	31.1	25.1

All estimated proportion at age distributions from the Chatham Rise longline fishery are presented in Appendix B (Figure B1).

3.3.2 Sub-Antarctic

The line fishery data from the Sub-Antarctic stock are analysed as two separate fisheries, one spawning and one non-spawning. The spawning fishery was defined as a single stratum comprising the Puysegur Bank and Solander Corridor (i.e., Statistical Area 30), with a time stratum of October to December. The non-spawning fishery was defined as a single stratum comprising all of FMAs 5 and 6, excluding Statistical Area 30 and the Bounty Plateau, with a time stratum of 1 February to 31 July.

Table 11 summarises the quantities of data used each year to produce the catch at age distributions for the two Sub-Antarctic longline fisheries, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for spawning Sub-Antarctic line-caught ling in the 2006–07 fishing year are given in Table 10. The mean weighted c.v. of 25% was within the target value of 30%.

There was no observer sampling of non-spawning Sub-Antarctic line-caught ling in the 2006–07 fishing year.

Table 11: Numbers of measured and aged male and female ling, and the number of sampled sets and estimated mean weighted c.v. (%) by age, for the Sub-Antarctic spawning and non-spawning longline fisheries.

	Males		Females			Mean c.v.
Fishery & year	Measured	Aged	Measured	Aged	Sets	
Spawning line fishery						
2000	4 044	242	4 231	278	83	20.6
2001	2 084	131	1 962	143	55	28.7
2002	670	197	898	284	157	22.6
2003	1 250	211	1 687	307	214	20.0
2004	887	208	1 129	289	168	22.5
2005	193	88	362	179	54	28.6
2006	233	108	707	345	94	23.3
2007	412	191	418	217	82	25.1
Non-spawning line fishery						
1998	608	73	2 763	395	34	23.1
1999	3 316	214	7 535	428	136	18.3
2001	674	103	2 040	235	58	25.3
2003	304	128	611	273	43	29.3
2005	413	114	716	307	113	25.9

All estimated proportion at age distributions from the spawning and non-spawning Sub-Antarctic longline fisheries are presented in Appendix B (Figures B2 and B3).

3.3.3 Cook Strait

The line fishery data from Cook Strait are analysed using a single area stratum (i.e., those parts of FMAs 2, 7, and 8 between 41° and 42° S and 174° and 175.4° E, equating approximately to Statistical Areas 16 and 17), and a time stratum of 1 June to 30 September.

Table 12 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for Cook Strait line-caught ling in the 2006–07 fishing year are given in Table 13. (These otoliths were not scheduled to be processed under this project, but resources that would have been used to process a Sub-Antarctic non-spawning fishery sample, had one been available, were transferred to this task.) The mean weighted c.v. of 34% did not meet the usual target value of 30%. However, this value cannot be improved as all available length data and otoliths were used in the analysis.

All estimated proportion at age distributions from the Cook Strait longline fishery are presented in Appendix B (Figure B4).

Table 12: Numbers of measured and aged male and female ling, and the number of sampled sets and estimated mean weighted c.v. (%) by age, for the Cook Strait longline fishery.

	Males		Females			Mean c.v.
Year	Measured	Aged	Measured	Aged	Sets	
2006	607	319	538	275	116	19.3
2007	238	125	180	92	43	33.8

Table 13: Calculated numbers at age, separately by sex, with c.v.s, for ling caught by commercial longline in Cook Strait in June–September 2007. Summary statistics for the samples are also presented.

	Cook Strait			
Age	Male	c.v.	Female	c.v.
6	148	1.006	214	1.203
7	251	0.782	596	0.494
8	2 027	0.310	1 143	0.416
9	662	0.595	1 098	0.401
10	2 024	0.294	1 388	0.407
11	1 493	0.343	603	0.496
12	1 603	0.360	1 246	0.419
13	1 097	0.315	912	0.396
14	621	0.618	1 347	0.308
15	652	0.486	372	0.595
16	785	0.497	238	0.759
17	0	–	124	1.284
18	320	0.689	0	–
19	486	0.673	0	–
20	0	–	0	–
21	109	1.309	0	–
22	0	–	0	–
23	0	–	0	–
24	40	1.482	0	–
25	0	–	0	–
26	0	–	0	–
27	230	1.180	0	–
28	101	1.127	68	1.407
29	30	1.739	0	–

Measured males	238
Measured females	180
Aged males	125
Aged females	92
No. of sets sampled	43
Meanweighted c.v. (sexes pooled)	33.8

3.3.4 Bounty Plateau

The line fishery data from the Bounty Plateau are analysed using a single area stratum (i.e., that part of FMA 6 east of 176° E), and a time stratum of 1 November to 28 February.

Table 14 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. There was no observer sampling of Bounty Plateau line-caught ling in the 2006–07 fishing year. All estimated proportion at age distributions from the Bounty Plateau longline fishery are presented in Appendix B (Figure B5).

Table 14: Numbers of measured and aged male and female ling, and the number of sampled sets and estimated mean weighted c.v. (%) by age, for the Bounty Plateau longline fishery.

	Males		Females			Mean c.v.
Year	Measured	Aged	Measured	Aged	Sets	
1993	201	52	237	69	24	50.4
2000	1 102	106	2 184	185	41	26.9
2001	405	50	713	66	20	43.6
2004	1 155	200	1 628	300	272	20.0

3.4 Observer catch at age data from ling trawl fisheries

3.4.1 Chatham Rise

The trawl fishery data from the Chatham Rise were stratified using a tree-based regression on mean lengths of ling measured in all observed trawls from 1 October to 31 May in all years from 1989 to 2007. Most observed trips were on vessels targeting finfish, but a significant number were on scampi trawlers. Previous investigations had indicated that the length distributions of ling taken in scampi trawls were quite different to those produced when targeting other species (Horn 2002). However, the tree-based regression did not select target species into the stratification. For both sexes, there was an east-west split through the Mernoo Gap (about 174° E), followed by a north-south split along the top of the Chatham Rise (about 43.5° S). Fish were, on average, smaller in coastal waters than on the Rise, and smaller on the south Rise than on the north (Figure 3). The ling caught by the scampi fishery were not selected as a separate stratum in the regression analysis because that fishery catches both the largest and the smallest ling (see Figure 3). However, because observer coverage on scampi vessels has been extensive in some years, a scampi fishery stratum was added to ensure that data from that fishery (which produces a relatively small proportion of the Chatham trawl catch) does not exert a disproportionate influence on the estimated catch-at-length. Consequently, data from 1 October to 31 May in each fishing year were stratified using the following four strata:

- Coast (longitude ≤ 174° E, target not scampi)
- Scampi (all tows targeting scampi)
- North Rise (latitude < 43.55° S, longitude > 174° E, target not scampi)
- South Rise (latitude ≥ 43.55° S, longitude > 174° E, target not scampi)

Table 15 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for trawl-caught ling in the 2006–07 fishing year are given in Table 16. The mean weighted c.v. of 23% was better then the value of 30% that is usually used as a target for ling catch at age distributions.

All estimated proportion at age distributions from the Chatham Rise trawl fishery are presented in Appendix B (Figure B6).

Table 15: Numbers of measured and aged male and female ling, and the number of sampled tows and estimated mean weighted c.v. (%) by age, for the Chatham Rise trawl fishery.

	Males		Females			Mean c.v.
Source	Measured	Aged	Measured	Aged	Tows	
1991–92	2 151	252	2 653	281	143	27.0
1993–94	1 127	302	768	302	126	32.9
1994–95	359	236	302	201	59	45.1
1995–96	453	306	399	284	87	30.0
1996–97	162	317	240	242	31	41.1
1997–98	3 463	348	3 117	280	497	18.7
1998–99	3 306	336	2 469	318	312	20.0
1999–2000	887	322	1 013	326	161	24.8
2000–01	1 000	312	988	341	188	21.0
2001–02	642	294	708	334	129	23.8
2002–03	694	317	764	347	114	24.3
2003–04	356	303	600	302	99	30.1
2004–05	869	310	666	326	194	27.9
2005–06	251	328	291	330	54	34.5
2006–07	699	310	687	330	135	22.9

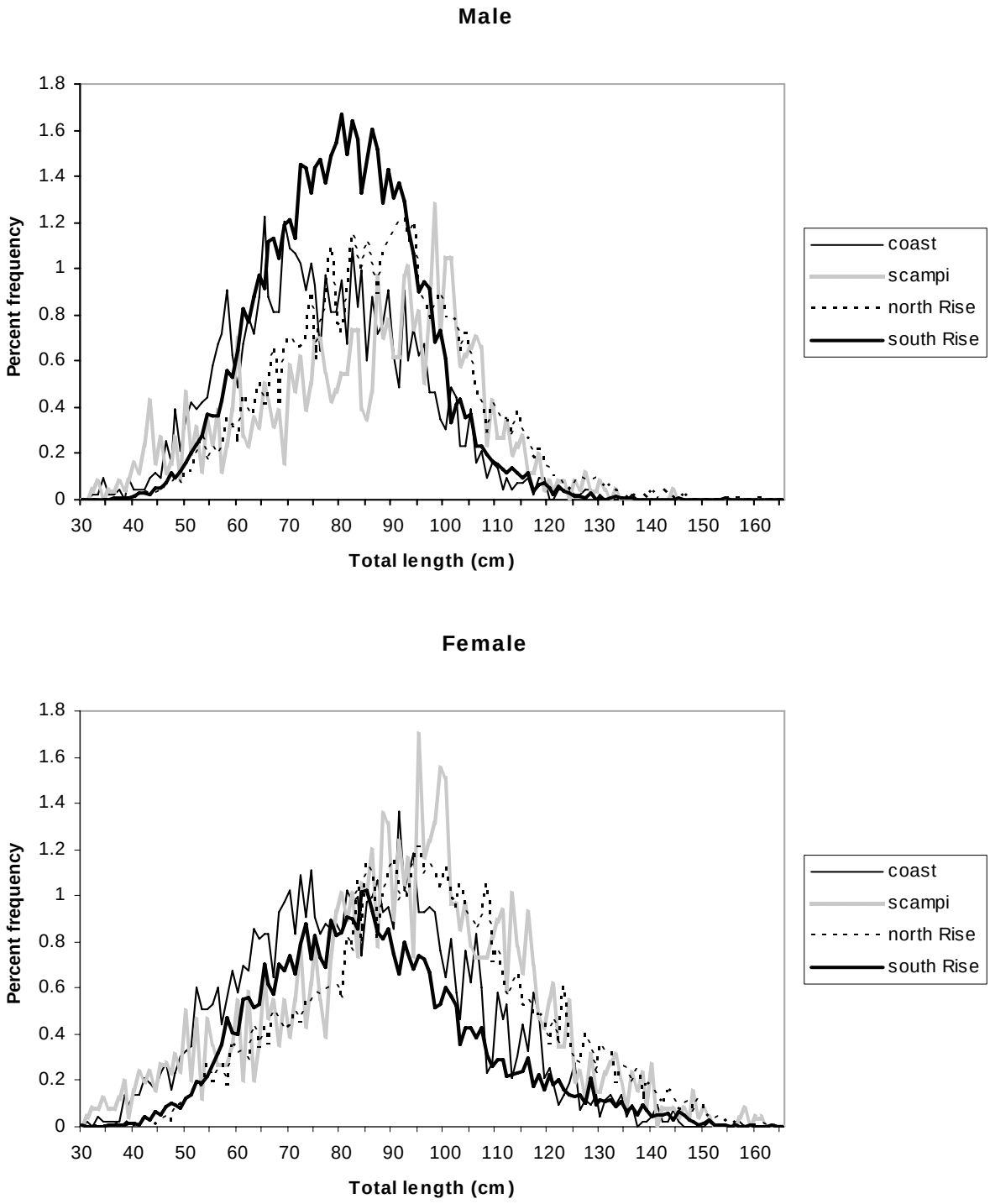

Figure 3: Length-frequency distributions of ling from four trawl fisheries (defined by area or target species) on the Chatham Rise. Plots are of raw data in 1 cm bins, with sexes shown separately.

Table 16: Calculated numbers at age, separately by sex, with c.v.s, for ling caught during commercial trawl operations on the Chatham Rise during October 2006–May 2007, and in the Sub-Antarctic during September 2006–April 2007. Summary statistics for the samples are also presented.

	Chatham Rise				Sub-Antarctic				
Age	Male	c.v.	Female	c.v.	Age	Male	c.v.	Female	c.v.
2	1 438	1.194	250	1.693	2	1 289	0.961	0	–
3	3 030	0.713	15 339	0.408	3	7 730	0.714	6 804	0.644
4	21 672	0.307	23 557	0.291	4	7 952	0.510	9 512	0.450
5	36 123	0.234	34 935	0.245	5	45 486	0.285	55 655	0.360
6	33 649	0.226	27 039	0.257	6	84 926	0.278	59 974	0.286
7	40 820	0.205	45 138	0.200	7	160 497	0.206	82 885	0.237
8	35 858	0.227	29 794	0.253	8	132 650	0.237	119 737	0.215
9	32 629	0.254	27 850	0.245	9	143 048	0.258	125 390	0.193
10	23 606	0.306	26 452	0.238	10	113 606	0.265	105 199	0.221
11	23 825	0.280	16 700	0.352	11	174 591	0.219	121 423	0.200
12	16 918	0.362	21 372	0.311	12	94 992	0.351	107 411	0.215
13	7 117	0.444	14 453	0.375	13	44 889	0.522	68 619	0.252
14	6 633	0.518	14 811	0.358	14	38 877	0.538	67 281	0.278
15	8 583	0.488	3 439	0.599	15	14 775	0.720	46 228	0.374
16	8 866	0.502	5 080	0.493	16	15 773	0.871	36 332	0.417
17	7 049	0.518	818	1.078	17	9 366	1.185	19 464	0.489
18	3 455	0.748	2 096	1.048	18	44 424	0.543	19 262	0.632
19	1 694	0.788	465	1.343	19	13 597	1.017	10 864	0.522
20	385	1.613	0	–	20	10 439	0.916	6 994	0.733
21	2 141	1.076	1 212	1.231	21	8 496	0.985	17 601	0.594
22	1 041	1.368	0	–	22	0	–	13 983	0.612
23	693	1.107	0	–	23	36 271	0.741	1 063	1.633
24	1 808	0.782	0	–	24	0	–	0	–
25	510	1.383	0	–	25	9 605	0.708	640	1.789
26	607	1.203	907	0.904	26	22 639	0.983	0	–
27	0	–	0	–					
28	0	–	1 212	1.313					
29	0	2.318	0	–					

Measured males	699	1 644
Measured females	687	1 446
Aged males	310	225
Aged females	330	382
No. of tows sampled	135	191
Mean weighted c.v. (sexes pooled)	22.9	24.3

3.4.2 Sub-Antarctic

The fishery in the Sub-Antarctic was initially investigated using a tree-based regression on mean lengths of ling measured in observed trawls in all years from 1989 to 2007. Strata were determined for the data sets separated by sex. This analysis indicated that ling of both sexes caught as a bycatch of the scampi fishery were markedly smaller than those taken in other trawl fisheries. For all other ling, strata based on bottom depth were indicated, with likely stratum boundaries being at about 140 and 450–500 m. An examination of mean size of ling by 25 m depth bins indicated that very large ling were most abundant in depths shallower than 150 m (Figure 4), but that ling measured from these depths made up only about 2% of the total observed (non-scampi target) data. For female ling, there was a clear shift in mean size between the 425 and 450 m depth bins; ling were smaller in the shallower depths. There was no clear depth delineation for males; they tended to decrease in average size as depths increased to about 400 m, and then increase in size as depth further increased (see Figure 5). Consequently, data from 1 September to 30 April (the months producing most of the observer data) were stratified using the following four strata:

1. Scampi (all tows targeting scampi)
2. Shallow (bottom depth ≤ 450 m, and target not scampi)
3. Deep (bottom depth > 450 m, and target not scampi)

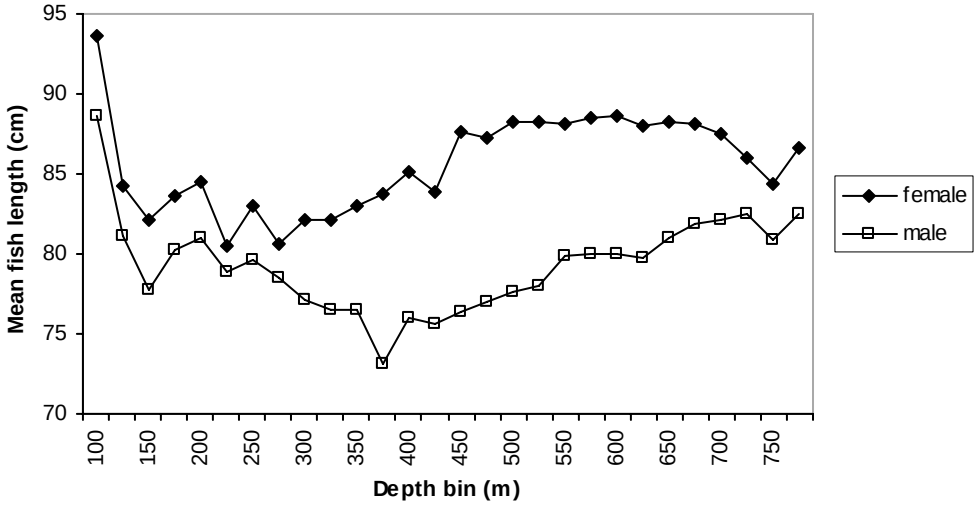

Figure 4: Mean length (cm TL) of ling, by sex, in 25 m depth bins in the Sub-Antarctic.

The resulting overall length-frequency distributions from the three chosen strata show the clear difference between the scampi and non-scampi target catches, and also show that females are, on average, smaller in shallower waters (Figure 5). The distribution of males has a more clearly defined peak in the deeper, relative to the shallower, stratum.

Table 17 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for trawl-caught ling in the 2006–07 fishing year are given in Table 16. The mean weighted c.v. of 24% was better then the value of 30% that is usually used as a target for ling catch at age distributions.

All estimated proportion at age distributions from the Sub-Antarctic trawl fishery are presented in Appendix B (Figure B7).

Table 17: Numbers of measured and aged male and female ling, and the number of sampled tows and estimated mean weighted c.v. (%) by age, for the Sub-Antarctic trawl fishery.

	Males		Females			Mean c.v.
Source	Measured	Aged	Measured	Aged	Tows	
1991–92	1 466	437	1 652	667	141	22.0
1992–93	1 337	235	1 615	363	164	28.3
1993–94	686	256	1 059	357	129	29.2
1995–96	881	366	779	297	83	24.5
1997–98	1 408	274	1 717	302	218	29.0
2000–01	2 192	247	1 947	351	267	28.1
2001–02	1 887	264	2 579	327	424	24.8
2002–03	1 164	434	1 828	625	263	20.9
2003–04	853	246	1 397	337	202	22.9
2004–05	2 324	254	2 415	339	218	21.5
2005–06	2 739	288	2 618	305	252	20.4
2006–07	1 644	225	1 446	382	191	24.3

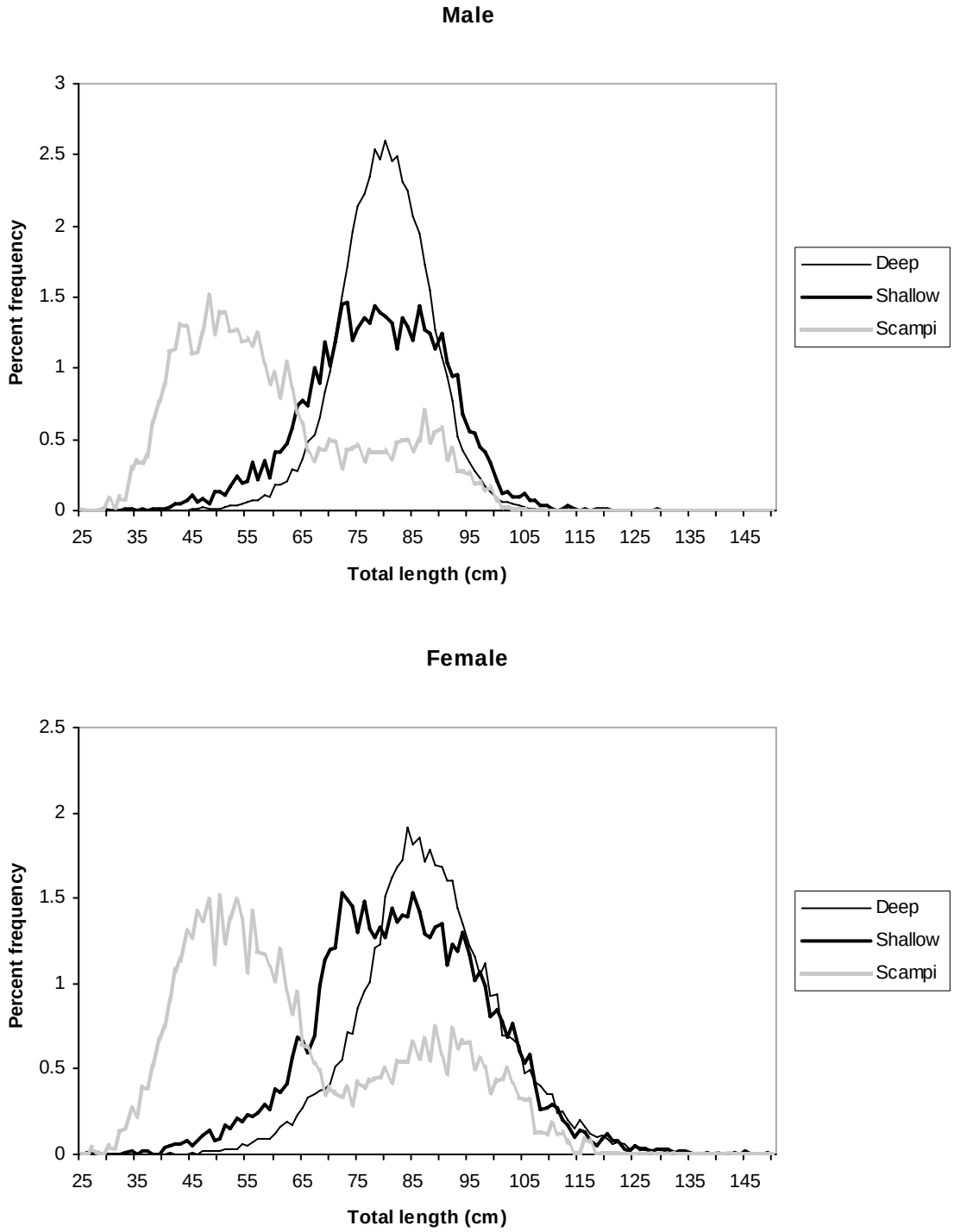

Figure 5: Length-frequency distributions of ling from the three trawl strata (defined by bottom depth or target species) in the Sub-Antarctic. Plots are of raw data in 1 cm bins, with sexes shown separately.

3.4.3 West coast South Island

The trawl fishery data off WCSI were stratified using a tree-based regression on mean lengths of ling measured from observed trawls from 1 June to 30 September in all years from 1991 to 2005 (Horn 2008a). Strata were determined for the data sets of both sexes combined, and each sex separately. The trees tended to be small (two or three branches), and explained little of the variance (less than 7% in all cases). A bottom depth split at 498 m was chosen first in the combined sexes and female

regressions. For males, a latitude split (42.42°) was chosen first, followed by a depth variable. Consequently, data from 1 June to 30 September each year were stratified using the following three strata:

- Deep (bottom depth ≥ 498 m)
- North shallow (bottom depth < 498 m, latitude < 42.42° S)
- South shallow (bottom depth < 498 m, latitude ≥ 42.42° S)

Table 18 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for trawl-caught ling in the 2006–07 fishing year are given in Table 19. Observer sampling in winter 2007 produced fewer otoliths and length measurements than in any other sampled year (see Table 18). Consequently, the mean weighted c.v. of 39% did not meet the target of 30%, but this value can not be improved as all available length data and otoliths were used in the analysis.

All estimated proportion at age distributions from the WCSI trawl fishery are presented in Appendix B (Figure B8).

Table 18: Numbers of measured and aged male and female ling, and the number of sampled tows and estimated mean weighted c.v. (%) by age, for the WCSI trawl fishery.

	Males		Females			Mean c.v.
Year	Measured	Aged	Measured	Aged	Tows	
1991	563	176	440	220	65	34.8
1994	873	172	1 096	221	141	27.9
1995	1 051	238	794	268	111	24.3
1996	485	247	448	201	83	28.0
1997	1 532	442	901	399	173	19.5
1998	1 063	349	700	279	155	23.6
1999	1 862	285	1 126	263	221	23.7
2000	829	269	783	264	168	26.8
2001	1 106	256	924	307	178	29.6
2002	1 401	283	1 405	321	332	21.4
2003	1 157	293	1 290	302	286	23.3
2004	1 003	243	1 540	352	334	21.4
2005	908	282	899	355	184	24.9
2006	763	276	844	361	154	29.0
2007	228	148	258	158	65	38.7

Table 19: Calculated numbers at age, separately by sex, with c.v.s, for ling caught during commercial trawl operations off WCSI during June–September 2007, and in Cook Strait during June–September 2007. Summary statistics for the samples are also presented.

	WCSI				Cook Strait				
Age	Male	c.v.	Female	c.v.	Age	Male	c.v.	Female	c.v.
3	1 634	1.242	32	3.156	3	0	–	0	–
4	3 937	0.670	333	1.569	4	592	0.702	592	0.728
5	7 486	0.483	2 149	0.603	5	2 113	0.577	1 361	0.533
6	6 486	0.609	3 827	0.534	6	2 206	0.554	1 806	0.609
7	13 256	0.338	7 932	0.504	7	1 356	0.474	1 372	0.456
8	3 830	0.528	7 800	0.497	8	941	0.437	1 617	0.481
9	9 255	0.384	7 524	0.507	9	1 116	0.437	1 214	0.433
10	6 732	0.399	3 859	0.680	10	938	0.424	929	0.429
11	7 187	0.437	6 890	0.505	11	1 419	0.371	474	0.608
12	7 251	0.378	6 357	0.462	12	973	0.410	1 393	0.386
13	7 835	0.427	9 448	0.337	13	737	0.500	638	0.475
14	5 981	0.575	5 283	0.514	14	898	0.428	741	0.504
15	2 588	0.783	5 312	0.440	15	499	0.569	1 255	0.430
16	3 252	0.674	8 843	0.391	16	643	0.532	808	0.626
17	600	1.120	5 372	0.426	17	552	0.617	182	0.996
18	0	–	2 922	0.527	18	0	–	341	0.706
19	0	–	1 206	0.890	19	427	0.644	0	–
20	346	1.373	1 656	1.166	20	0	–	80	1.237
21	0	–	1 419	0.713	21	67	1.236	0	–
22	0	–	90	2.006	22	28	1.513	0	–
23	54	1.978	635	1.414	23	0	–	0	–
24	0	–	0	–	24	61	1.142	0	–
25	0	–	0	–	25	0	–	0	–
26	574	1.795	164	1.866	26	0	–	0	–
27	858	1.346	507	1.319	27	27	1.634	70	1.306
28	0	–	0	–	28	0	–	0	–
29	1 211	1.539	0	–	29	0	–	0	–
					31	76	1.441	0	–
					32	194	0.984	0	–

	WCSI	Cook Strait
Measured males	228	327
Measured females	258	300
Aged males	148	143
Aged females	158	137
No. of tows sampled	65	19
Mean weighted c.v. (sexes pooled)	38.7	42.0

3.4.4 Cook Strait

The trawl fishery in Cook Strait is analysed using a single area stratum (i.e., those parts of FMAs 2, 7, and 8 between 41° and 42° S and 174° and 175.4° E, equating approximately to Statistical Areas 16 and 17), and a time stratum of 1 June to 30 September.

Table 20 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for Cook Strait trawl-caught ling in the 2006–07 fishing year are given in Table 19. The mean weighted c.v. of 42% did not meet the target value of 30%. However, this value cannot be improved as all available length data and otoliths were used in the analysis.

All estimated proportion at age distributions from the Cook Strait trawl fishery are presented in Appendix B (Figure B9).

Table 20: Numbers of measured and aged male and female ling, and the number of sampled tows and estimated mean weighted c.v. (%) by age, for the Cook Strait trawl fishery.

	Males		Females			Mean c.v.
Year	Measured	Aged	Measured	Aged	Tows	
1999	226	75	189	54	59	47.9
2000	197	95	191	93	62	40.9
2001	610	205	550	208	72	24.5
2002	583	219	644	241	58	27.9
2003	430	282	437	308	56	24.2
2004	609	269	645	241	48	27.2
2005	617	272	561	264	75	26.4
2006	729	248	539	226	26	26.4
2007	327	143	300	137	19	42.0

3.5 Trawl survey catch at age data for ling

3.5.1 Chatham Rise

Trawl survey catch at age distributions are estimates of the numbers of ling, by sex and age, available to the trawl in the survey area between 200 and 800 m. In some years an additional deeper stratum (800–1000 m) on the north Rise is surveyed. However, to ensure comparability, the distributions presented here are for the 'core' strata only, i.e., 200–800 m.

Table 21 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for ling caught in the January 2008 trawl survey are given in Table 22. The mean weighted c.v. of 22% was well within the target of 30%, as it has been in all surveys in this series.

All estimated proportion at age distributions from the Chatham Rise trawl surveys are presented in Appendix B (Figure B10).

Table 21: Numbers of measured and aged male and female ling, and the number of sampled tows and estimated mean weighted c.v. (%) by age, for the Chatham Rise trawl surveys.

	Males		Females			Mean c.v.
Survey	Measured	Aged	Measured	Aged	Tows	
AEX8903	743	303	613	296	130	26.0
TAN9106	1 208	252	1 189	281	174	22.4
TAN9212	1 229	286	1 108	313	177	21.7
TAN9401	1 541	302	1 349	302	157	21.5
TAN9501	583	236	578	201	114	28.1
TAN9601	556	306	509	284	79	27.7
TAN9701	837	317	601	242	98	24.3
TAN9801	665	348	492	280	88	24.5
TAN9901	1 071	336	848	318	111	23.8
TAN0001	1 080	322	969	326	113	22.0
TAN0101	1 145	312	1 084	341	108	20.5
TAN0201	1 053	294	1 170	334	102	19.7
TAN0301	813	317	808	347	98	20.6
TAN0401	865	303	752	302	101	20.2
TAN0501	845	310	801	326	98	22.5
TAN0601	1 007	328	880	330	90	21.0
TAN0701	733	310	732	330	94	21.0
TAN0801	610	317	623	325	92	22.3

Table 22: Calculated numbers at age in the survey area, separately by sex, with c.v.s, for ling caught during trawl surveys of the Chatham Rise in January 2008 (survey TAN0801) and the Sub-Antarctic in November-December 2007 (survey TAN0714). Summary statistics for the samples are also presented.

	TAN0801			
Age	Male	c.v.	Female	c.v.
2	3 895	1.724	9 351	0.975
3	63 443	0.364	82 325	0.339
4	195 853	0.196	144 896	0.219
5	100 374	0.297	175 945	0.222
6	138 484	0.262	137 156	0.278
7	209 252	0.208	155 081	0.234
8	155 676	0.219	136 343	0.216
9	73 001	0.287	92 072	0.241
10	109 240	0.250	75 592	0.283
11	118 696	0.240	69 830	0.290
12	63 613	0.349	72 396	0.276
13	33 487	0.434	29 524	0.450
14	59 865	0.319	32 926	0.372
15	11 920	0.610	27 977	0.424
16	21 581	0.545	13 964	0.628
17	23 194	0.503	24 289	0.600
18	13 148	0.642	10 917	0.908
19	7 238	0.976	13 021	0.573
20	10 098	0.610	0	–
21	9 304	0.721	1 704	1.225
22	0	–	14 321	0.674
23	5 733	1.201	0	–
24	5 701	1.017	2 126	1.348
25	2 518	1.217	0	–
26	0	–	3 611	0.979
27	0	–	0	–
28	8 707	0.926	2 126	1.397
29	2 362	1.461	2 126	1.313
30	0	–	5 229	1.454

	TAN0714			
Age	Male	c.v.	Female	c.v.
2	0	–	0	–
3	56 998	0.688	96 004	0.488
4	608 797	0.205	450 905	0.293
5	750 438	0.235	776 532	0.248
6	532 460	0.240	899 017	0.199
7	559 285	0.232	1 048 631	0.166
8	363 266	0.293	680 866	0.200
9	199 111	0.313	441 056	0.234
10	242 989	0.326	407 076	0.249
11	192 896	0.347	586 769	0.214
12	197 564	0.351	427 431	0.261
13	209 929	0.314	391 548	0.256
14	78 300	0.563	247 327	0.293
15	106 662	0.469	103 217	0.517
16	25 479	1.003	126 378	0.417
17	68 008	0.639	66 490	0.674
18	13 887	1.145	68 325	0.665
19	20 522	1.291	54 704	0.541
20	5 241	1.347	75 252	0.534
21	23 247	0.840	40 281	0.748
22	0	–	12 640	1.250
23	0	–	0	–
24	31 041	0.799	9 010	1.360
25	0	–	10 054	1.163
26	5 241	1.602	0	–
27	14 145	1.261	0	–
28	11 634	1.345	9 220	1.765
29	0	–	0	–
30	0	–	0	–
33	782	1.705	0	–

Measured males	610	1 014
Measured females	623	1 288
Aged males	317	229
Aged females	325	353
No. of tows sampled	92	79
Mean weighted c.v. (sexes pooled)	22.3	21.7

3.5.2 Sub-Antarctic

Trawl survey catch at age distributions are estimates of the numbers of ling, by sex and age, available to the trawl in the survey. The main survey series has been conducted in summer. Those surveys have sampled depths from 300 to 800 m, plus an 800–1000 m stratum at Puysegur, and, in some years, other 800–1000 m strata off the Campbell Plateau. However, to ensure comparability, the distributions presented here are for the 'core' 300–800 m strata plus the deep Puysegur stratum only. The catch at age distributions from the spring and autumn surveys are derived from the 'core' 300–800 m strata only.

Table 23 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution

for ling caught in the November–December 2007 trawl survey are given in Table 22. The mean weighted c.v. of 22% was well within the target of 30%, as it has been in all surveys in this series.

All estimated proportion at age distributions from the Sub-Antarctic trawl surveys are presented in Appendix B (Figure B12).

Table 23: Numbers of measured and aged male and female ling, and the number of sampled tows and estimated mean weighted c.v. (%) by age, for the Sub-Antarctic trawl surveys.

	Males		Females			Mean c.v.
Survey	Measured	Aged	Measured	Aged	Tows	
Summer surveys						
AEX8902	760	160	1 067	234	133	29.0
TAN9105	1 563	213	2 079	348	151	19.6
TAN9211	1 249	227	1 668	354	146	21.1
TAN9310	1 520	254	1 894	351	127	22.3
TAN0012	1 761	244	1 696	351	85	18.8
TAN0118	1 316	268	1 290	326	95	19.6
TAN0219	1 661	224	1 606	350	88	20.6
TAN0317	1 270	243	1 156	333	70	22.1
TAN0414	1 433	256	1 146	339	79	27.0
TAN0515	1 095	279	988	300	82	22.0
TAN0617	969	250	1 011	355	80	23.1
TAN0714	1 014	229	1 288	353	79	21.7
Autumn surveys						
TAN9204	1 570	221	1 498	310	90	21.5
TAN9304	1 353	261	1 344	373	97	21.1
TAN9605	1 129	325	902	303	88	21.9
TAN9805	809	271	765	296	64	22.9

4. DISCUSSION

4.1 Hake

For hake, sufficient otoliths and length-frequency data to produce catch at age distributions that met the target mean weighted c.v.s. were available from the HAK 7 fishery off WCSI and the 'Area 404' section of the HAK 4 fishery on the Chatham Rise. The target has almost always been met for samples in the WCSI fishery (see Table 4). It is pleasing that a catch at age distribution was derived for Area 404 of the Chatham Rise as this has been the main commercial fishing area in most years, but only one catch at age distribution had previously been derived for it (see Table 1). Sampling in previous years on the Chatham Rise tends to have been concentrated on the western Chatham Rise, but in 2006–07, sufficient data were available to produce a length-frequency distribution only for the 'East excluding area 404' section. For the HAK 1 (Sub-Antarctic) commercial trawl fishery, sample sizes of lengths (1213) and aged fish (575) were relatively small. All available data and otoliths were used to calculate the catch at age distribution, but the mean weighted c.v. (38.5%) did not meet the target of 30%. Sampling intensity in the Sub-Antarctic has varied considerably between years, with consequent wide variation in the mean weighted c.v.s (see Table 3).

The Sub-Antarctic trawl survey produced a good sample of aged fish (640), but the Chatham Rise survey was less productive (164 age estimates). Catch-at-age distributions were produced for both the trawl surveys, but neither of the estimated mean weighted c.v.s met the target of 30%. However, no improvements in the precision can be achieved, as all available data and otoliths were included in the analyses.

On the Chatham Rise, catches of younger hake tend to be concentrated in the west, particularly in the late 1990s (see Appendix A, Figures A1–A2). Throughout the 2000s there has been an apparent increase in the mean age of hake caught in that area. Middle-aged and older hake tend to dominate catches in the eastern Rise (see Figures A3–A4). Males and females appear to be about evenly abundant in all areas except Statistical Area 404, where males clearly dominate the catch. No clear year class progressions are apparent in any of the distribution series from the Chatham Rise.

In the Sub-Antarctic, there are some clear year class progressions, particularly in the male distributions. Figure A5 shows the progressions of hake aged 10 in 1990 through to age 16 in 1996, and aged 6 in 1998 through to age 12 in 2004.

The WCSI trawl catch is dominated by hake aged 6–12 years, with no clearly apparent year class progressions (see Figure A6). In some years, large numbers of 1- or 2-year-old fish are taken by the fishery, but these do not manifest as strong cohorts in later years. A characteristic of most of the WCSI distributions is that numbers of fish aged 3 and 4 are generally very low. It seems likely that fish of this age are much less vulnerable or available to the trawl during the winter months of the fishery than younger or older hake..

4.2 Ling

Of the three ling longline fisheries for which catch at age distributions were produced for 2006–07, only the distribution from the Sub-Antarctic spawning fishery met the c.v. target. However, the targets were almost met for the Chatham Rise and Cook Strait longline fisheries. A catch at age distribution was scheduled to be produced for the Sub-Antarctic non-spawning fishery, but it was not sampled by observers in 2006–07. The resources intended to be used to analyse the non-spawning Sub-Antarctic fishery were transferred to the Cook Strait fishery. Only one year's catch at age data was previously available for that fishery, so it was considered desirable to add to that series.

Catch at age distributions were produced for trawl fisheries catching ling in four areas. The Chatham Rise and Sub-Antarctic distributions used observer length data applied to age-length keys obtained from trawl surveys, e.g., Chatham Rise length data collected from October 2006 to May 2007 were applied to the age-length key from the January 2007 (TAN0701) trawl survey of the Chatham Rise. The estimated catch at age distributions from both these areas had mean weighted c.v.s well within the usual target of 30%. Most distributions calculated for these fisheries in previous years had also been within the target. Estimates of catch at age were also produced for the ling taken as bycatch in the WCSI and Cook Strait hoki spawning fisheries. Neither of these estimated distributions met the target c.v. of 30% owing to small available sample sizes of length data and otoliths. For the WCSI fishery, fewer than 500 length measurements and 300 otoliths were collected by observers, the lowest level of sampling since 1994. All available data were used in the analysis, so the mean weighted c.v. of 39% cannot be improved. The Cook Strait catch at age distribution is reliant on a mix of observer and on-shore market sampling. Data from both these sources were at their lowest levels since sampling began. Only six trawl tows were sampled for ling by observers, and only 13 of the programmed 18 ling market samples were obtained. Market sampling of this fishery began in 2001, and the target number and size of samples has generally been met. However, in 2007 there was a greater reticence to land sample of green ling, and the numbers of fish in the samples that were landed tended to be small. Steps have been taken that will hopefully get around this problem in 2008.

Sufficient ling otoliths and length-frequency data were available from the Sub-Antarctic and Chatham Rise trawl surveys to easily meet the mean weighted c.v. target. The target has been met in all surveys from these two areas.

The ling longline fisheries catch few fish younger than 7 years, and much of the catch is older than 12 years. Sex ratios of the longline catch are about 1:1 on the Chatham Rise and in Cook Strait, but tend to be biased towards females in the other fisheries. This is particularly apparent in the Sub-Antarctic

non-spawning fishery (see Figure B3). No clear year class progressions are apparent in any of the longline series.

Recruitment to the trawl fisheries is generally about two years earlier than to the line fisheries (i.e., at about 5 years), and most of the catch is 12 years or younger. No clear year class progressions are apparent in any of the trawl series. The ling trawl catch at age distributions from the WCSI fishery often exhibit a trough at about age 6 or 7. This is consistent with an inflexion point in the length-frequency distributions at lengths of about 72 cm for males and 77 cm for females (see figure 3 of Horn 2008a). It seems likely that fish of this size are less vulnerable or available to the trawl during the winter months of the fishery.

5. ACKNOWLEDGMENTS

This work was funded by the Ministry of Fisheries under Project MID2007-01.

6. REFERENCES

Bull, B.; Dunn, A. (2002). Catch-at-age: User Manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. (Unpublished report held in NIWA Library, Wellington.)

Devine, J. (2008). Descriptive analysis of the commercial catch and effort data for New Zealand hake (*Merluccius australis*) for the 1989–90 to 2004–05 fishing years. *New Zealand Fisheries Assessment Report 2008/60*. 73 p.

Horn, P.L. (1993). Growth, age structure, and productivity of ling, *Genypterus blacodes* (Ophidiidae), in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 27*: 385–397.

Horn, P.L. (1997). An ageing methodology, growth parameters, and estimates of mortality for hake (*Merluccius australis*) from around the South Island, New Zealand. *Marine and Freshwater Research 48*: 201–209.

Horn, P.L. (2002). Stock assessment of ling (*Genypterus blacodes*) around the South Island (Fishstocks LIN 3, 4, 5, 6, and 7) for the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2002/20*. 53 p.

Horn, P.L. (2008a). Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise, Campbell Plateau, and in Cook Strait for the 2007–08 fishing year. *New Zealand Fisheries Assessment Report 2008/24*. 76 p.

Horn, P.L. (2008b). Stock assessment of hake (*Merluccius australis*) in the Sub-Antarctic for the 2007–08 fishing year. *New Zealand Fisheries Assessment Report 2008/49*. 66 p.

Horn, P.L.; Dunn, A. (2007). Stock assessment of hake (*Merluccius australis*) on the Chatham Rise for the 2006–07 fishing year. *New Zealand Fisheries Assessment Report 2007/44*. 62 p.

Appendix A: Summaries of the proportions-at-age data for hake from resource surveys and trawl fishery observer sampling

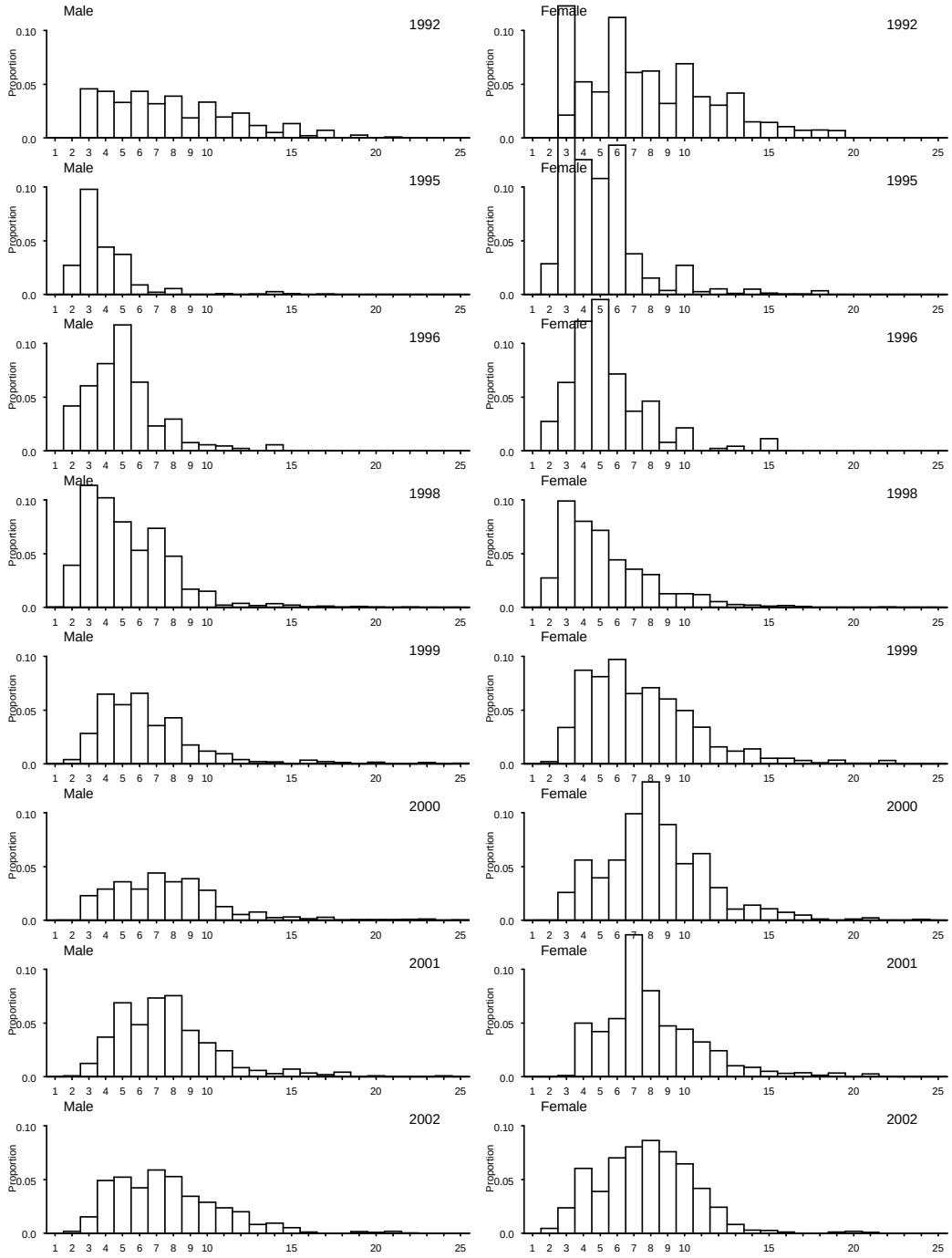

Figure A1: Age frequencies of hake from commercial catch-at-age data in the Chatham Rise (west shallow) trawl fishery, 1992 to 2007.

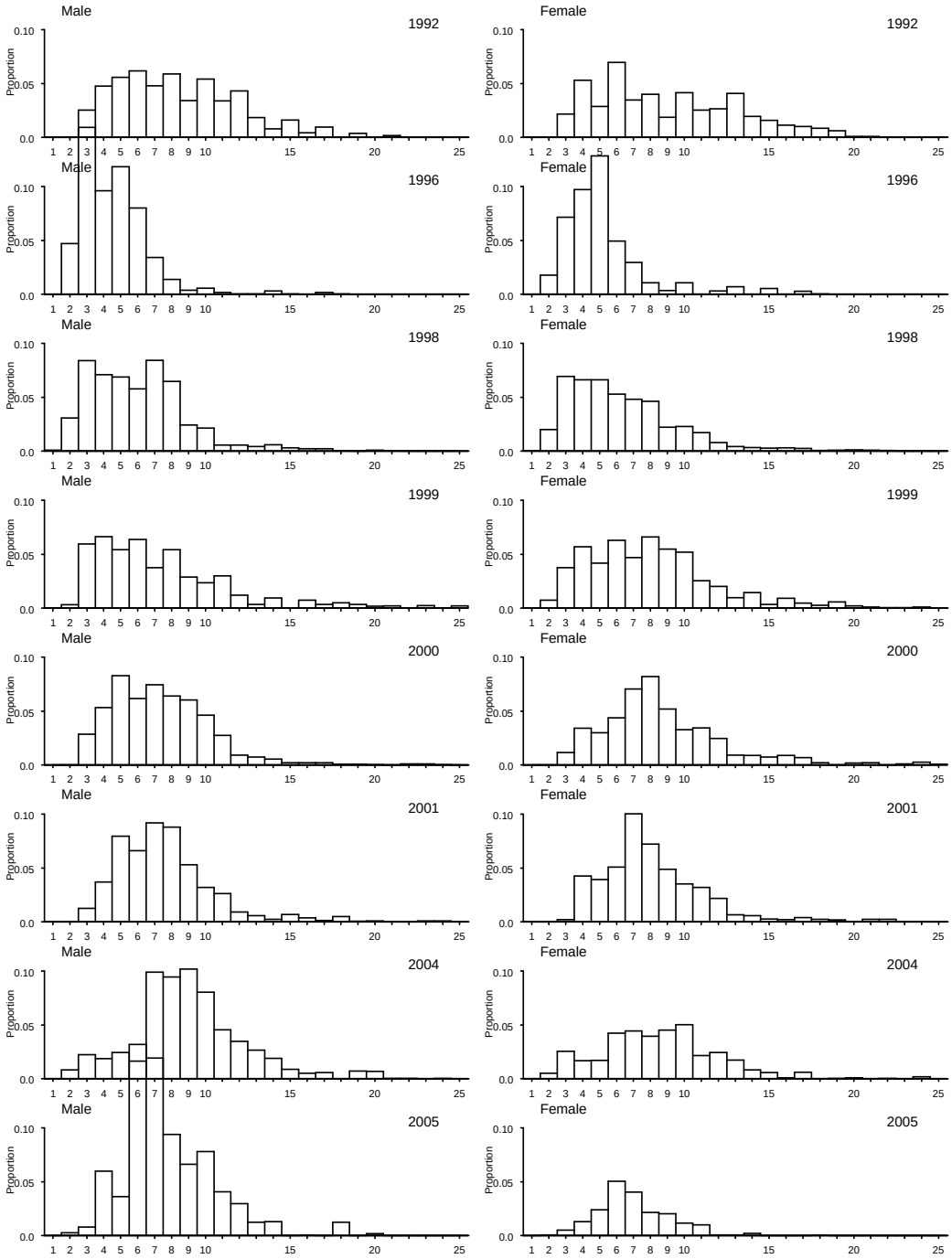

Figure A2: Age frequencies of hake from commercial catch-at-age data in the Chatham Rise (west deep) trawl fishery, 1992 to 2007.

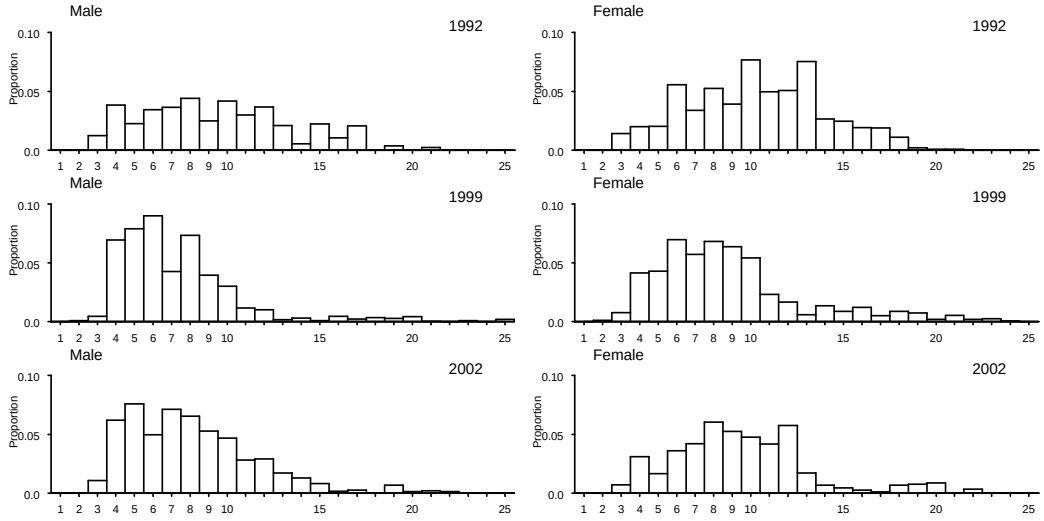

Figure A3: Age frequencies of hake from commercial catch-at-age data in the Chatham Rise (east excl. area 404) trawl fishery, 1992 to 2007.

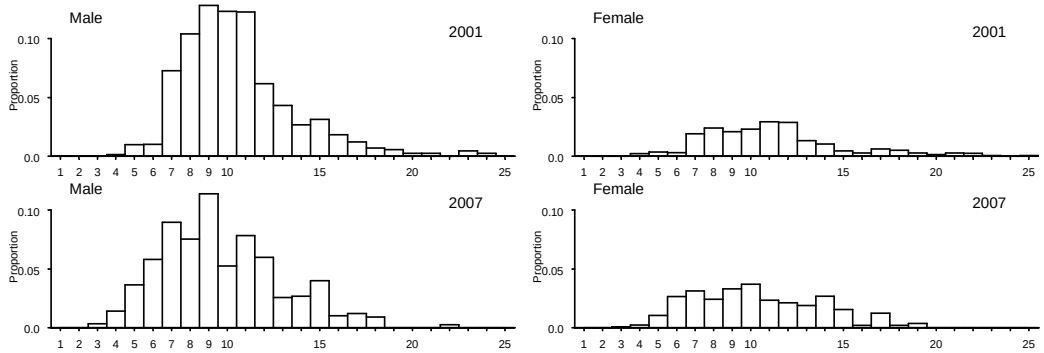

Figure A4: Age frequencies of hake from commercial catch-at-age data in the Chatham Rise (Statistical Area 404) trawl fishery, 1992 to 2007.

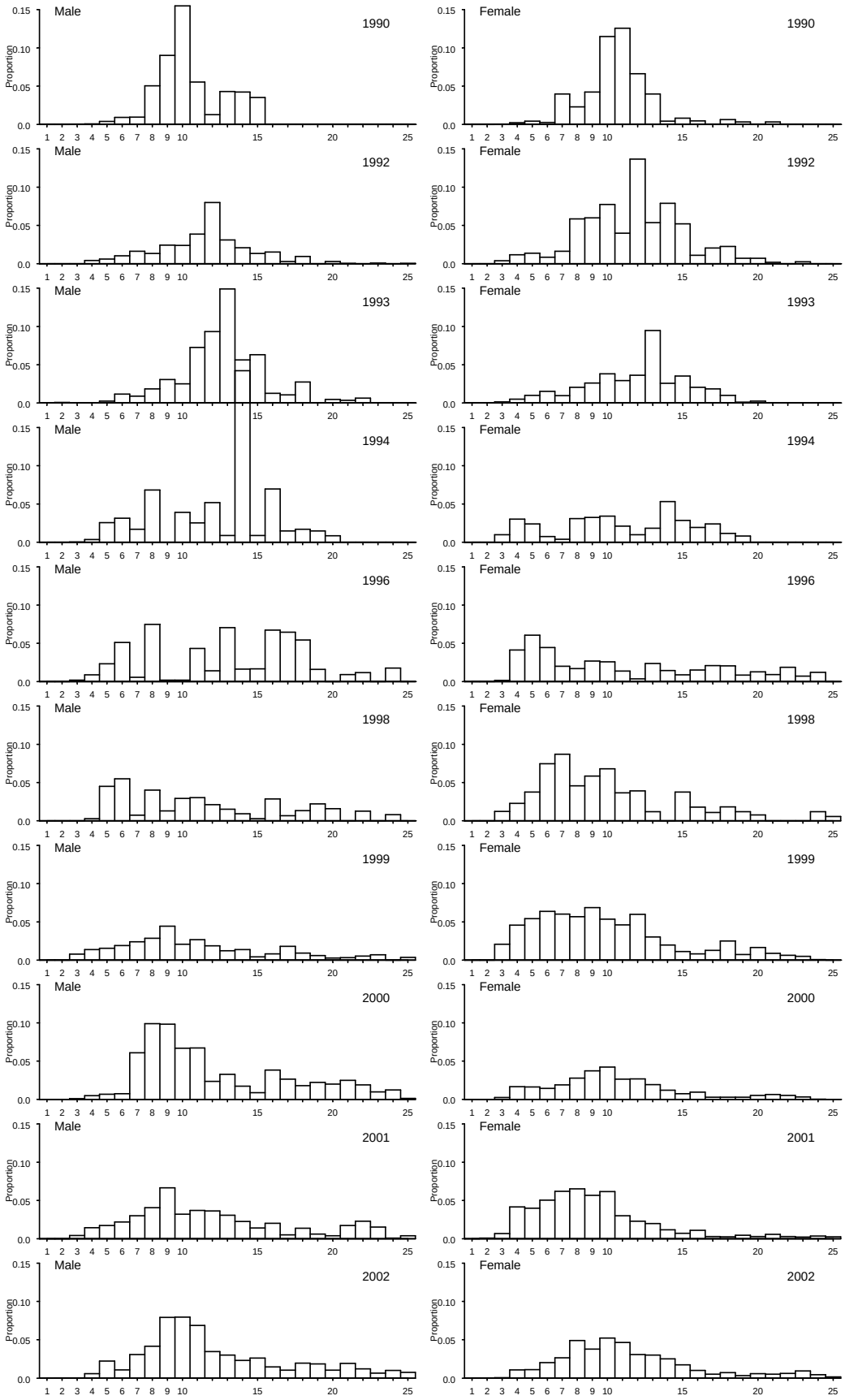

Figure A5: Age frequencies of hake from commercial catch-at-age data in the Sub-Antarctic trawl fishery, 1990 to 2007.

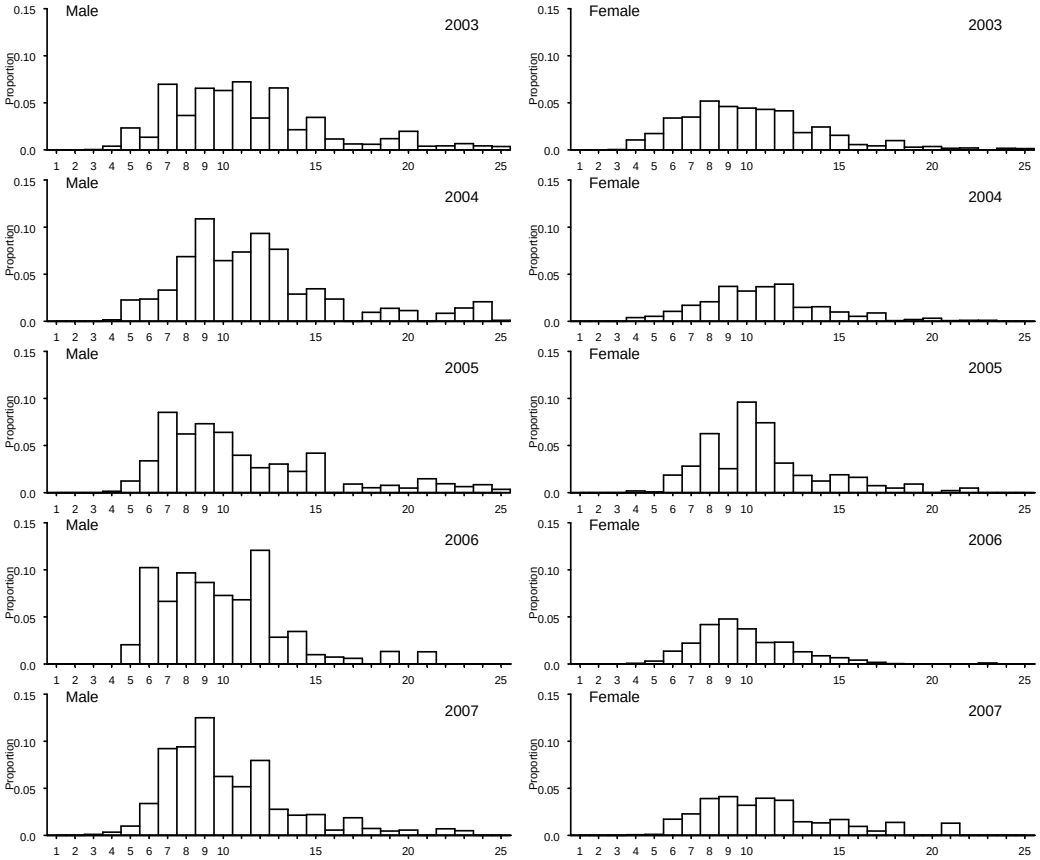

Figure A5 ctd.: Age frequencies of hake from commercial catch-at-age data in the Sub-Antarctic trawl fishery, 1990 to 2007.

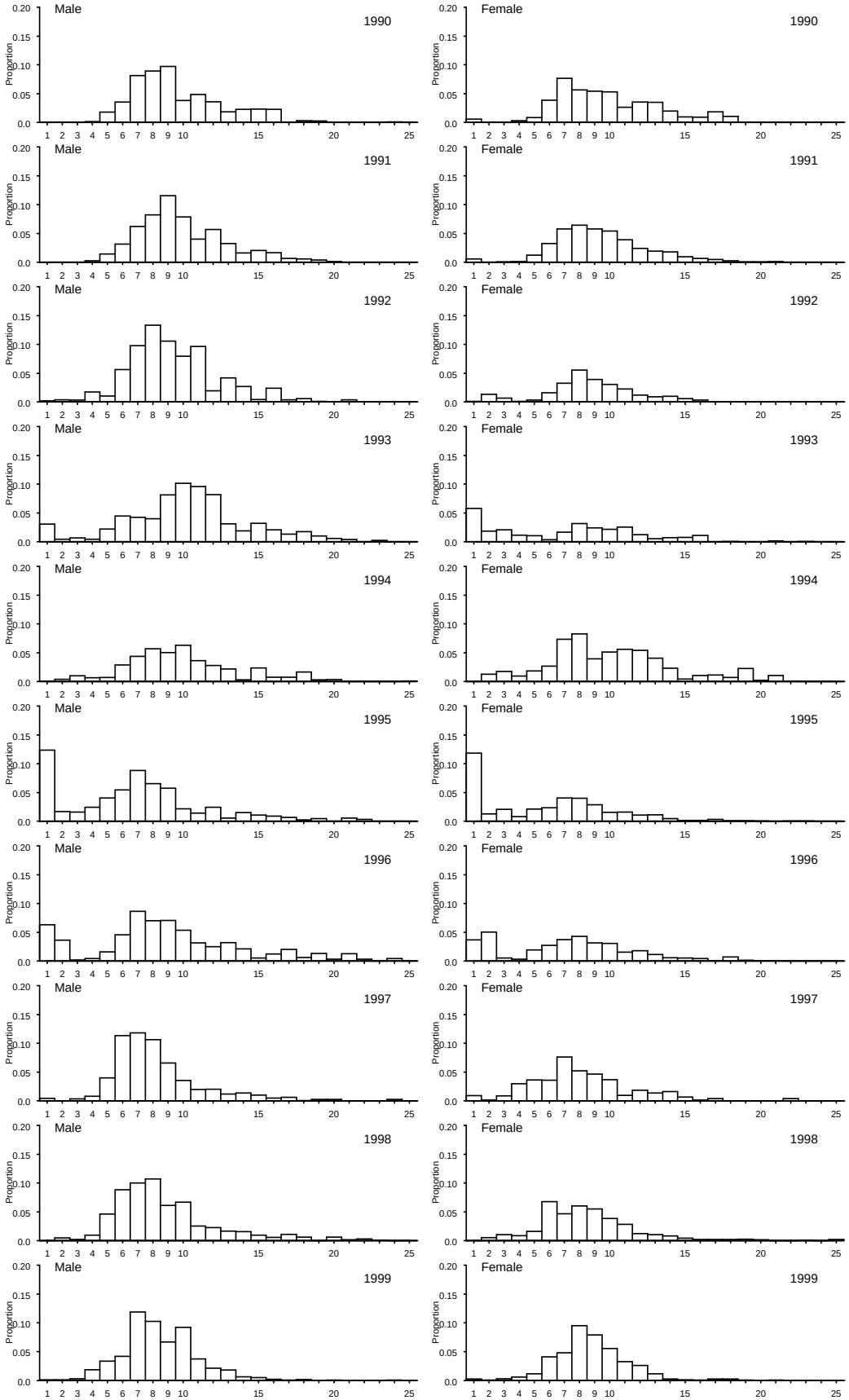

Figure A6: Age frequencies of hake from commercial catch-at-age data in the WCSI trawl fishery, 1990 to 2007.

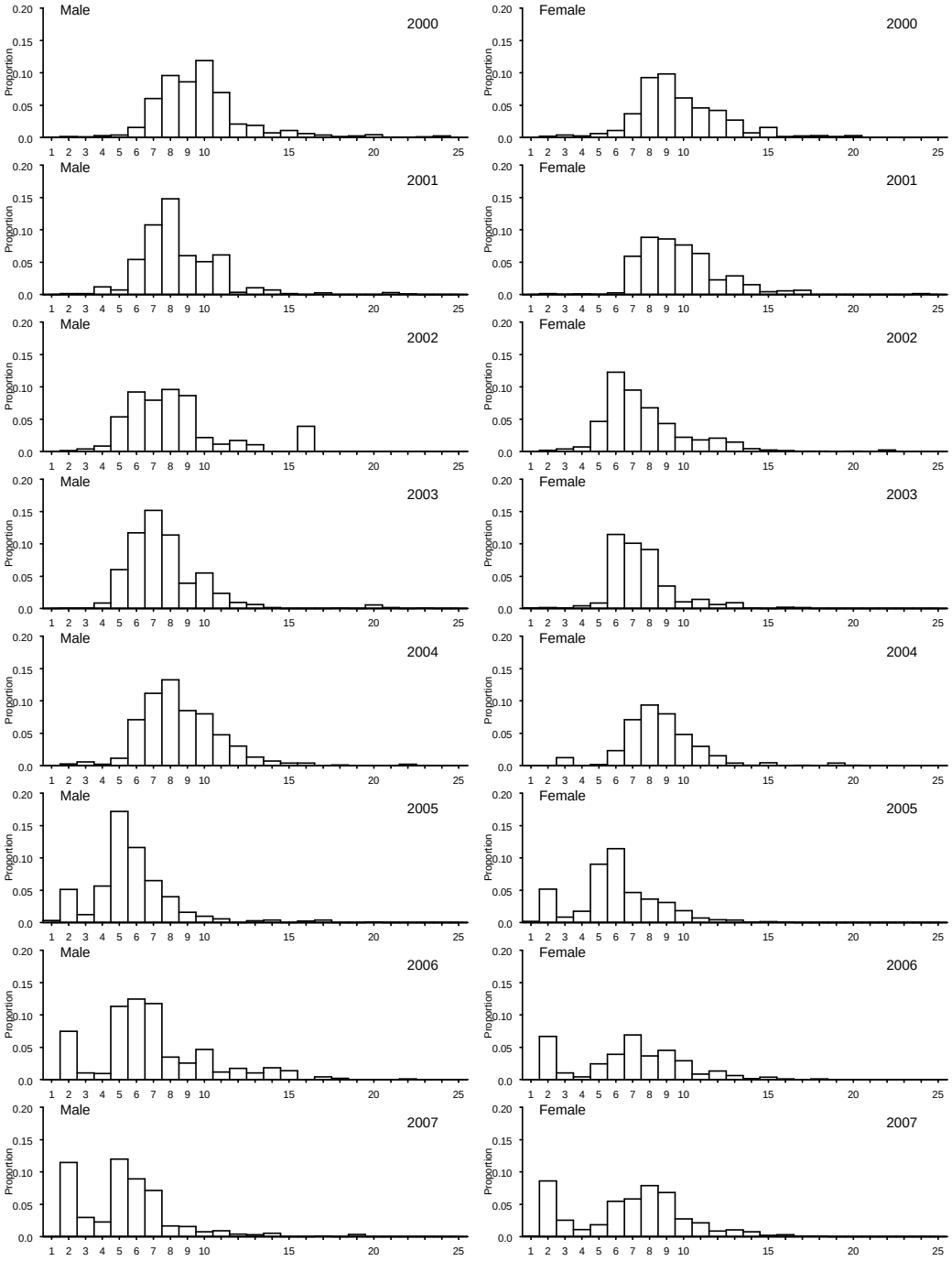

Figure A6 ctd.: Age frequencies of hake from commercial catch-at-age data in the WCSI trawl fishery, 1990 to 2007.

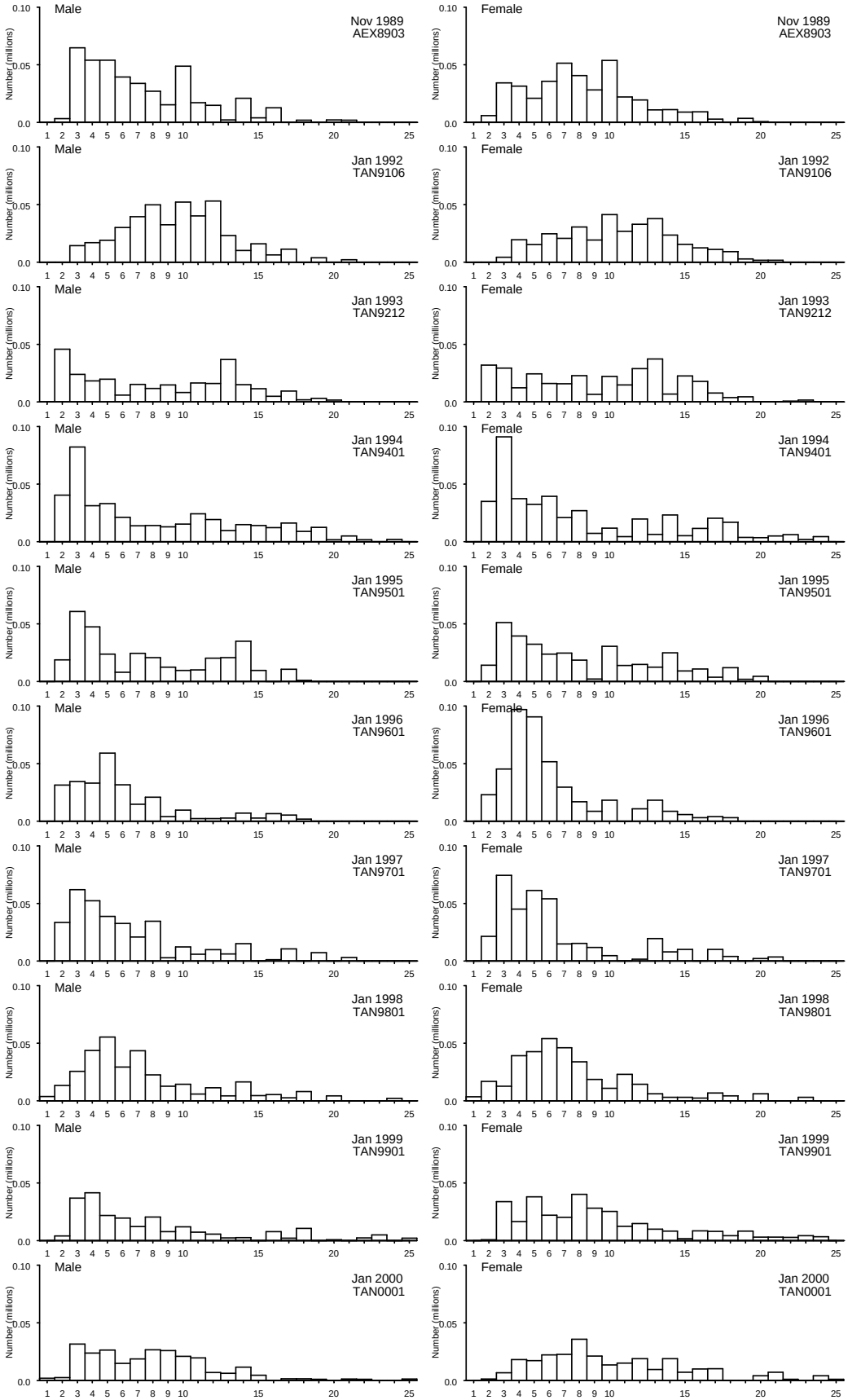

Figure A7: Age frequencies of hake (ages 1 to 25) from resource surveys in the Chatham Rise, 1989–90 to 2007–08.

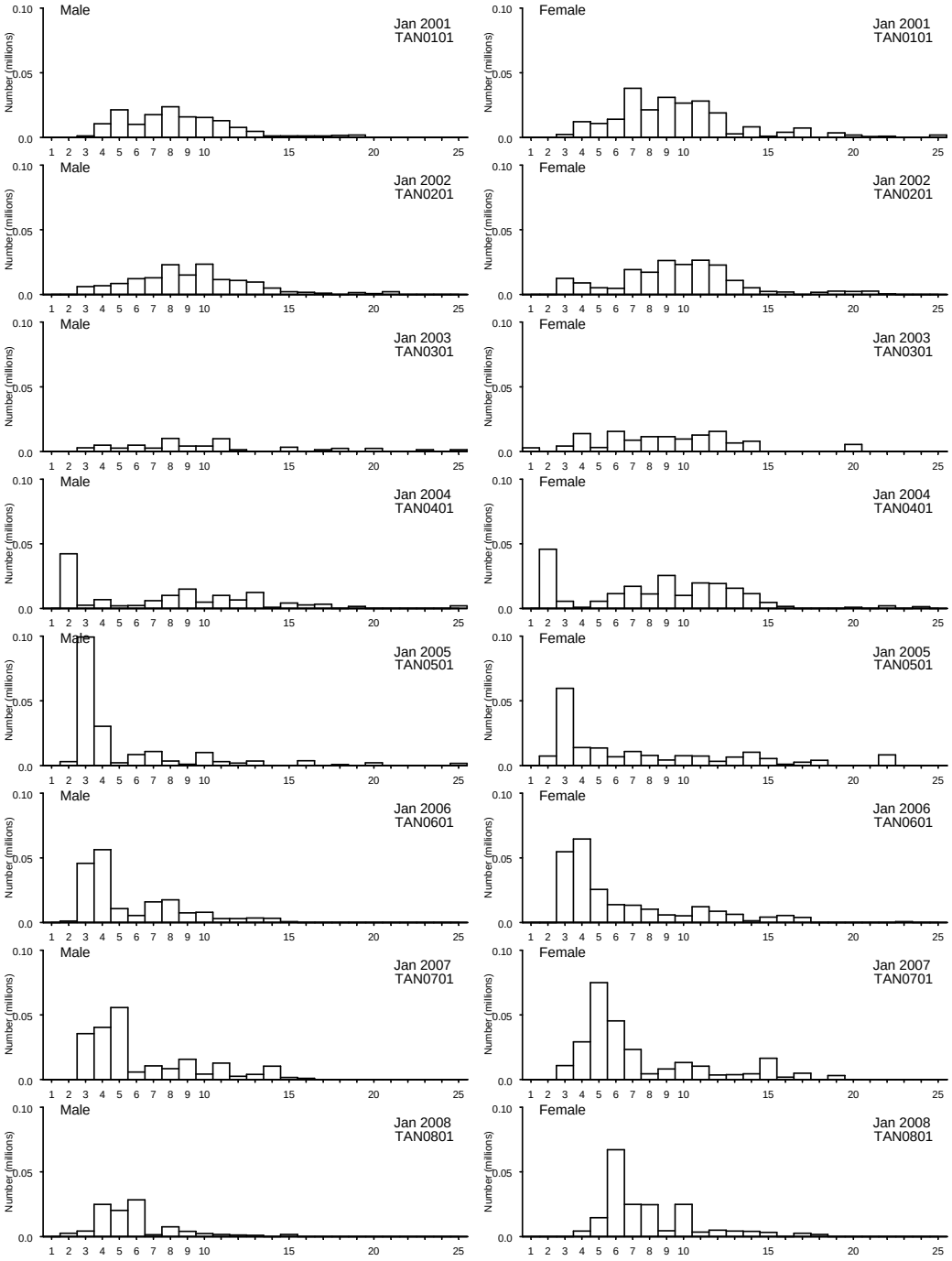

Figure A7 ctd.: Age frequencies of hake (ages 1 to 25) from resource surveys in the Chatham Rise, 1989–90 to 2007–08.

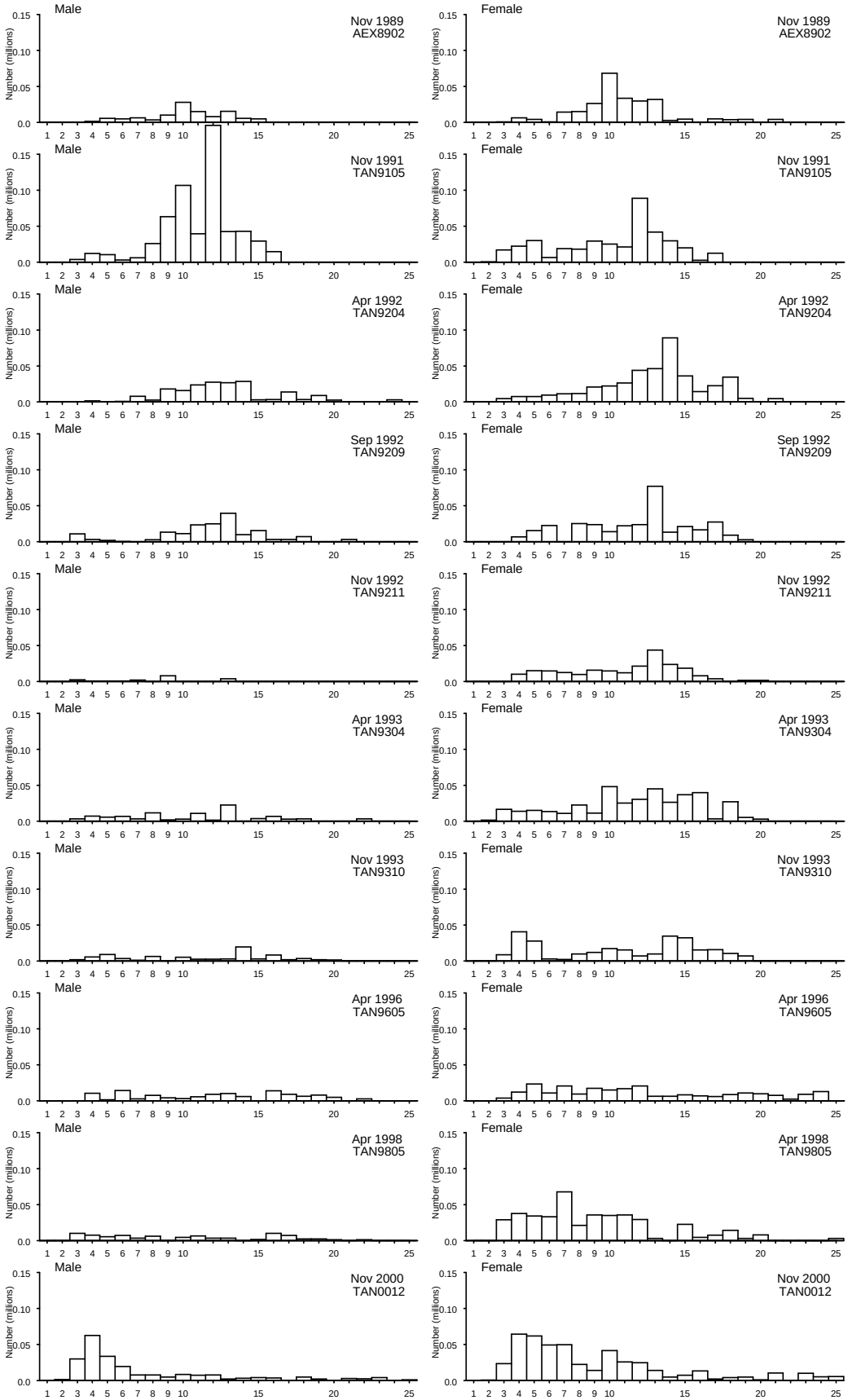

Figure A8: Age frequencies of hake (ages 1 to 25) from resource surveys in the Sub-Antarctic, 1989 to 2007.

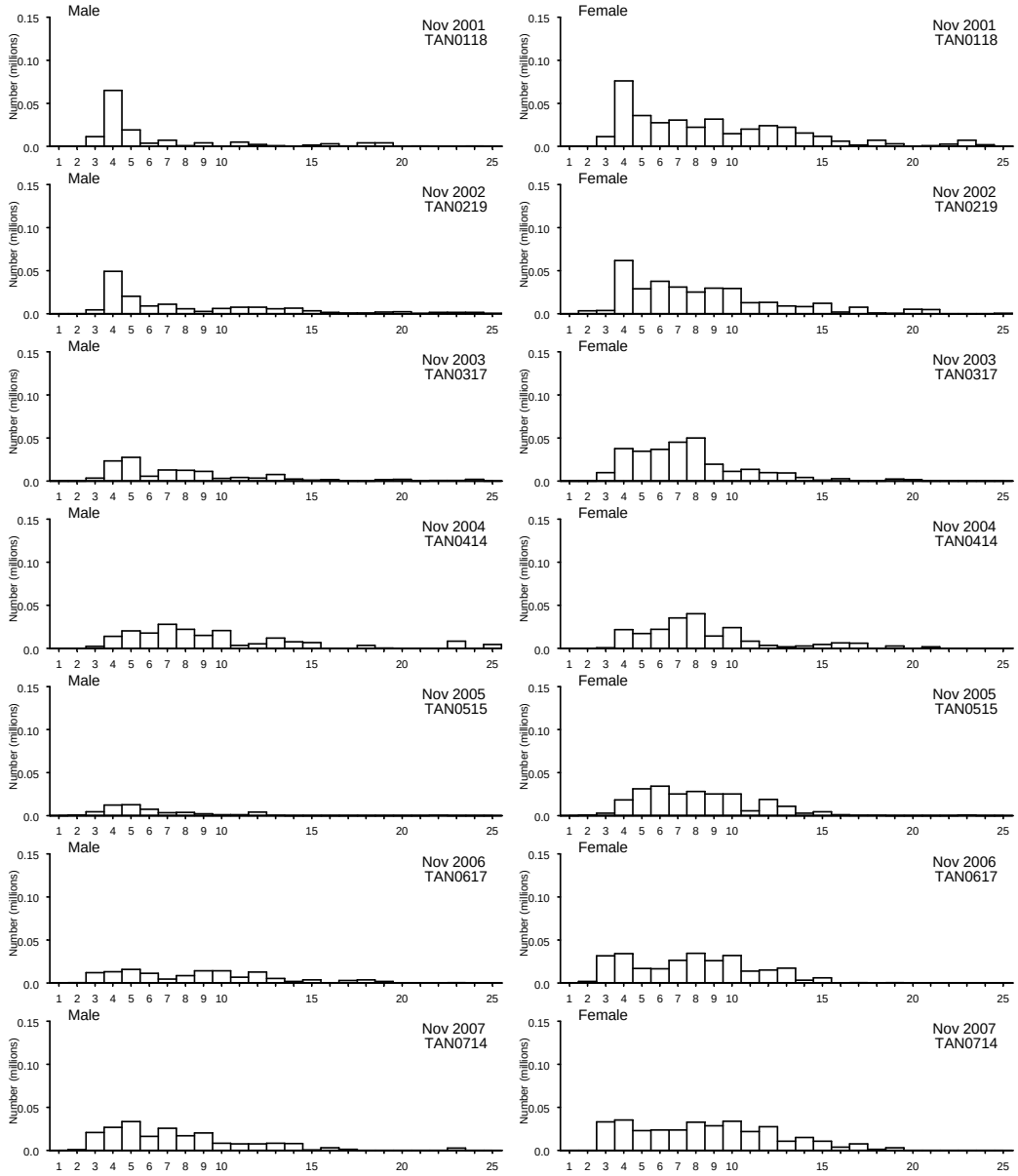

Figure A8 ctd.: Age frequencies of hake (ages 1 to 25) from resource surveys in the Sub-Antarctic, 1989 to 2007.

Appendix B: Summaries of the proportions-at-age data for ling from resource surveys and observer sampling of line and trawl fisheries

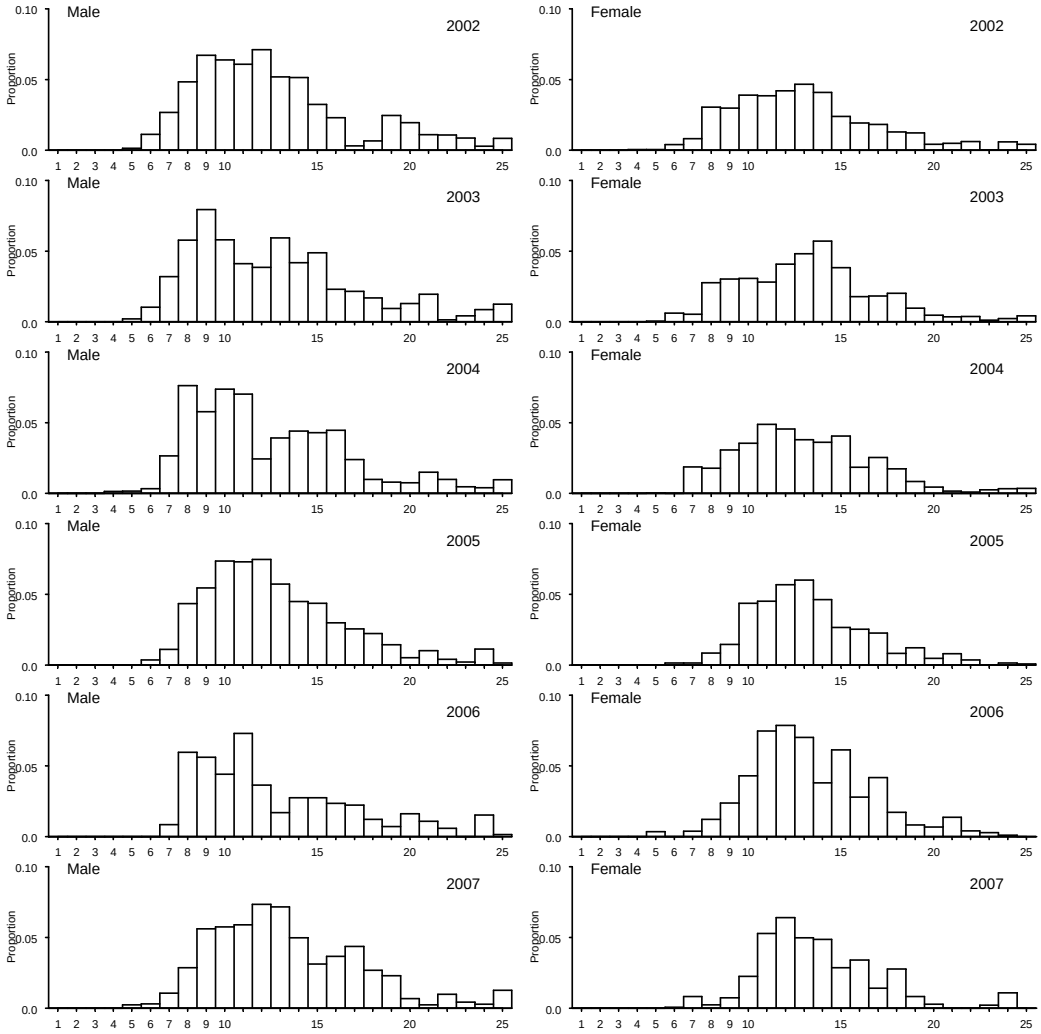

Figure B1: Age frequencies of ling from commercial catch-at-age data in the Chatham Rise longline fishery, 2002 to 2007.

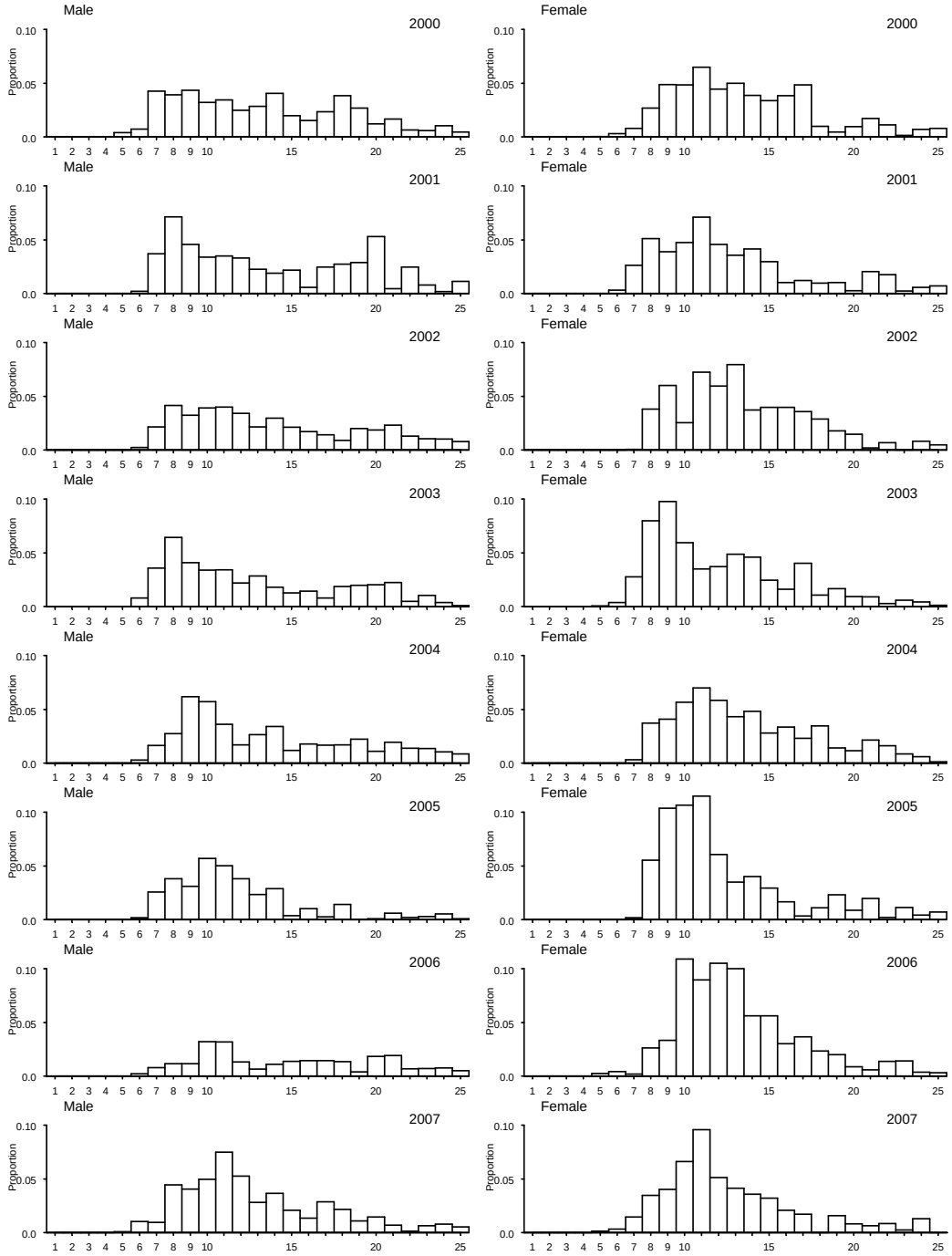

Figure B2: Age frequencies of ling from commercial catch-at-age data in the Sub-Antarctic (spawning season) longline fishery, 2000 to 2007.

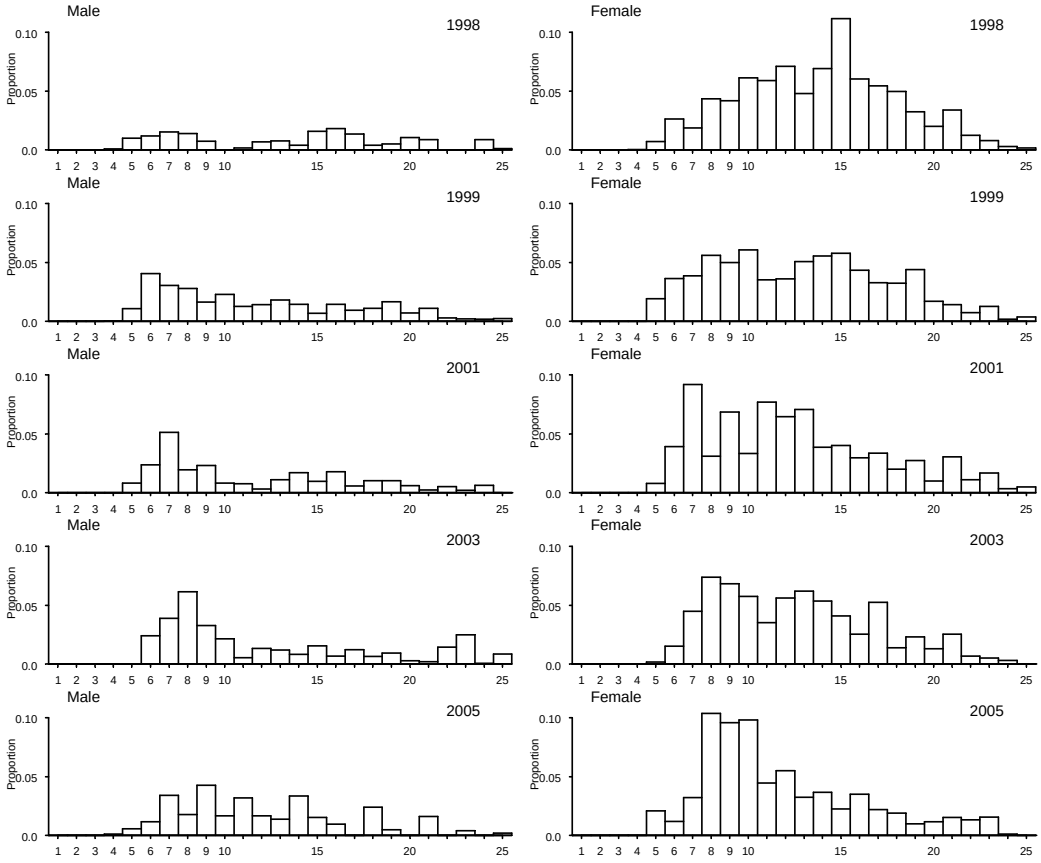

Figure B3: Age frequencies of ling from commercial catch-at-age data in the Sub-Antarctic (non-spawning season) longline fishery, 1998 to 2005.

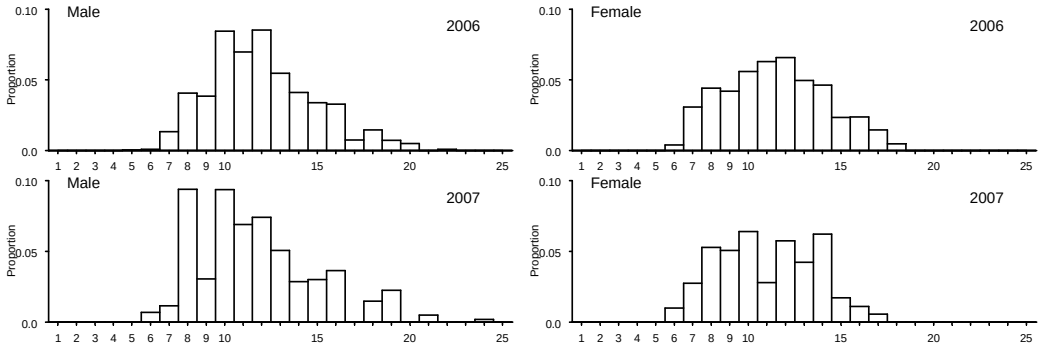

Figure B4: Age frequencies of ling from commercial catch-at-age data in the Cook Strait longline fishery, 2006 to 2007.

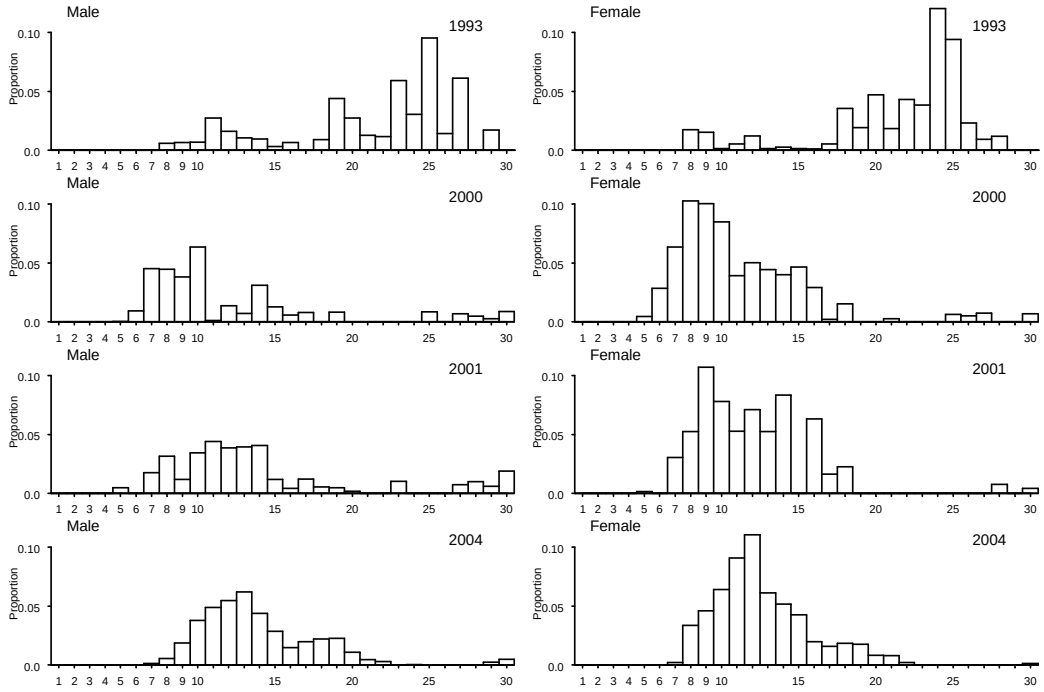

Figure B5: Age frequencies of ling from commercial catch-at-age data in the Bounty Plateau longline fishery, 1993 to 2004.

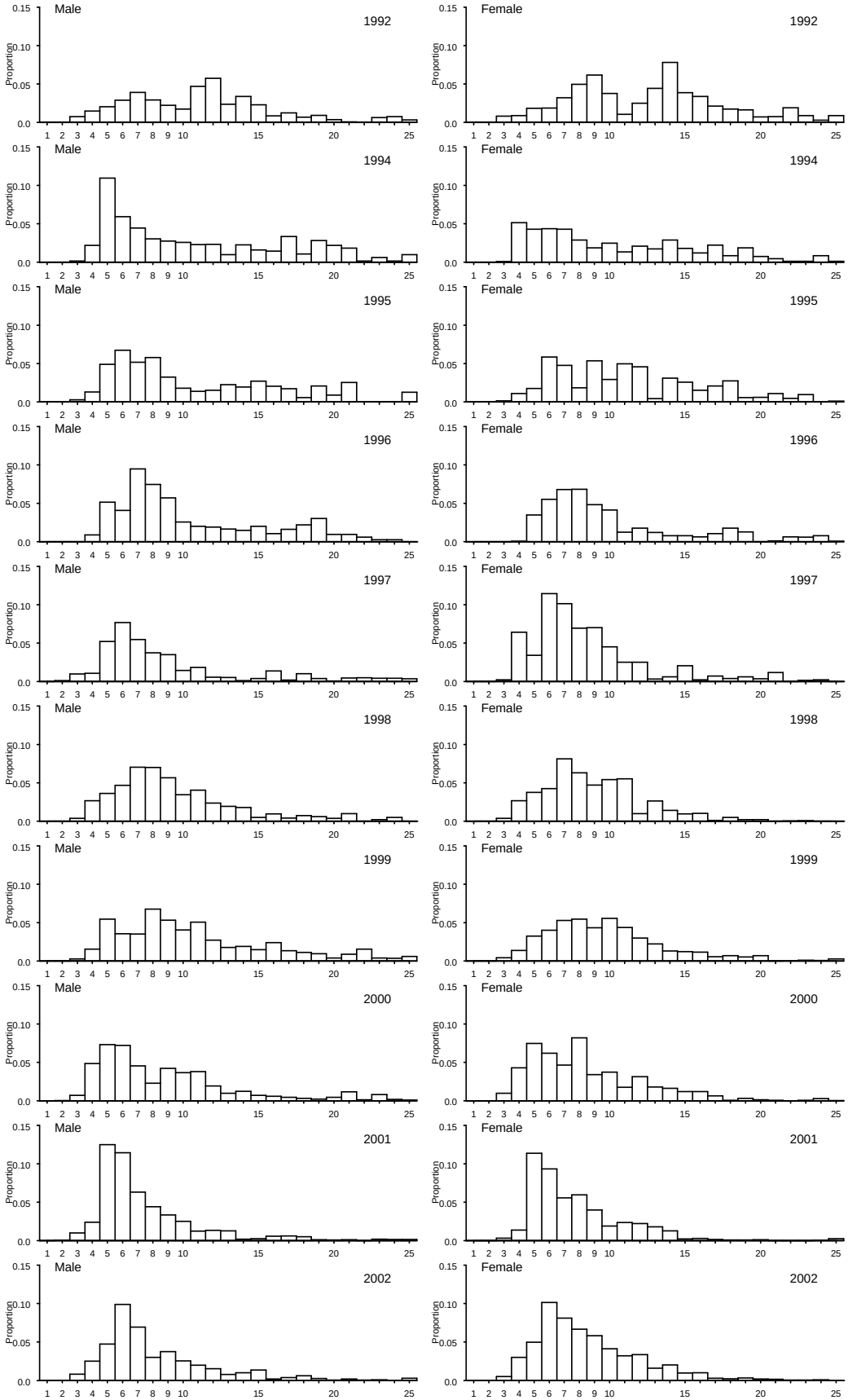

Figure B6: Age frequencies of ling from commercial catch-at-age data in the Chatham Rise trawl fishery, 1992 to 2007.

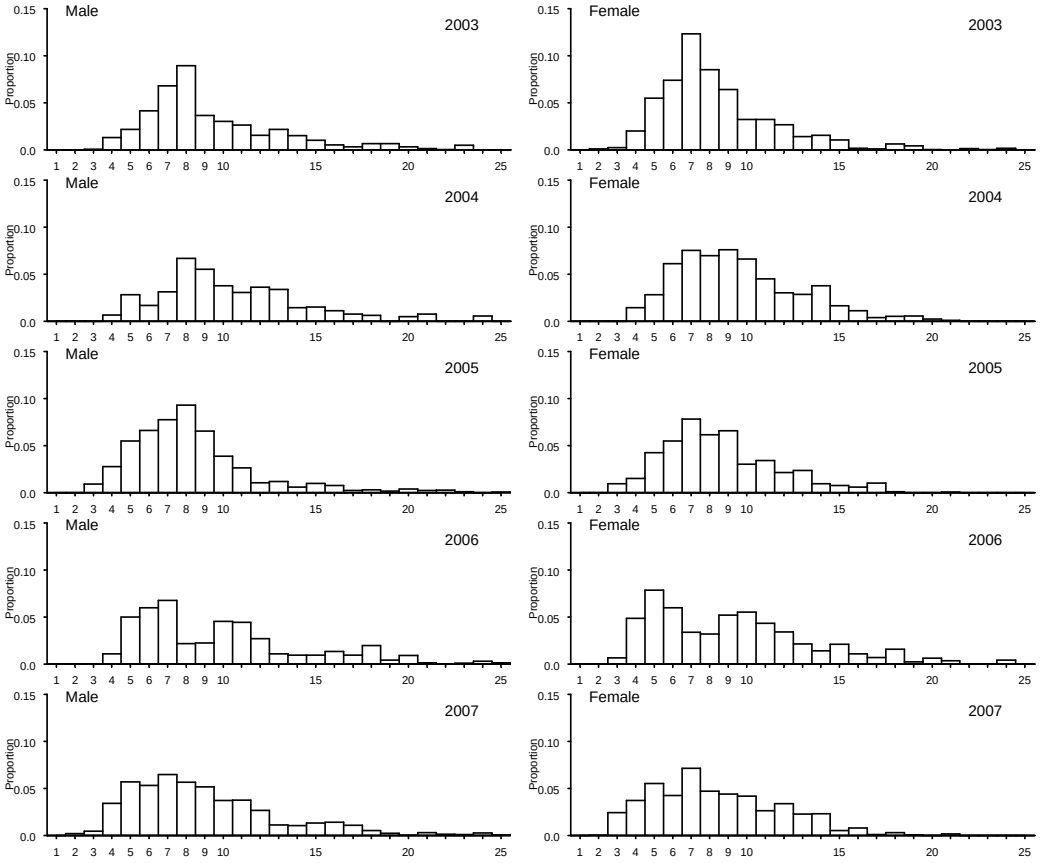

Figure B6 ctd.: Age frequencies of ling from commercial catch-at-age data in the Chatham Rise trawl fishery, 1992 to 2007.

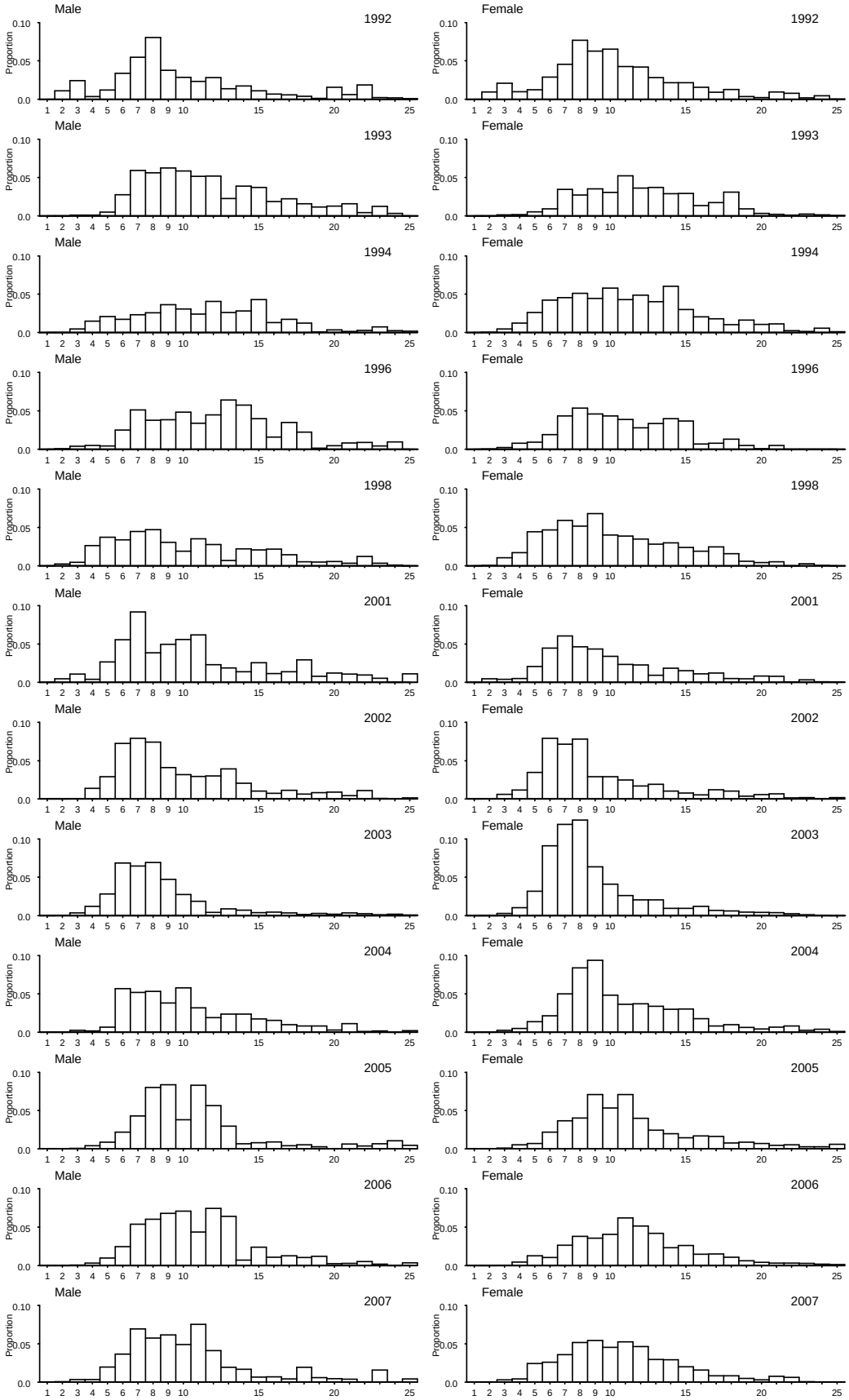

Figure B7: Age frequencies of ling from commercial catch-at-age data in the Sub-Antarctic trawl fishery, 1992 to 2007.

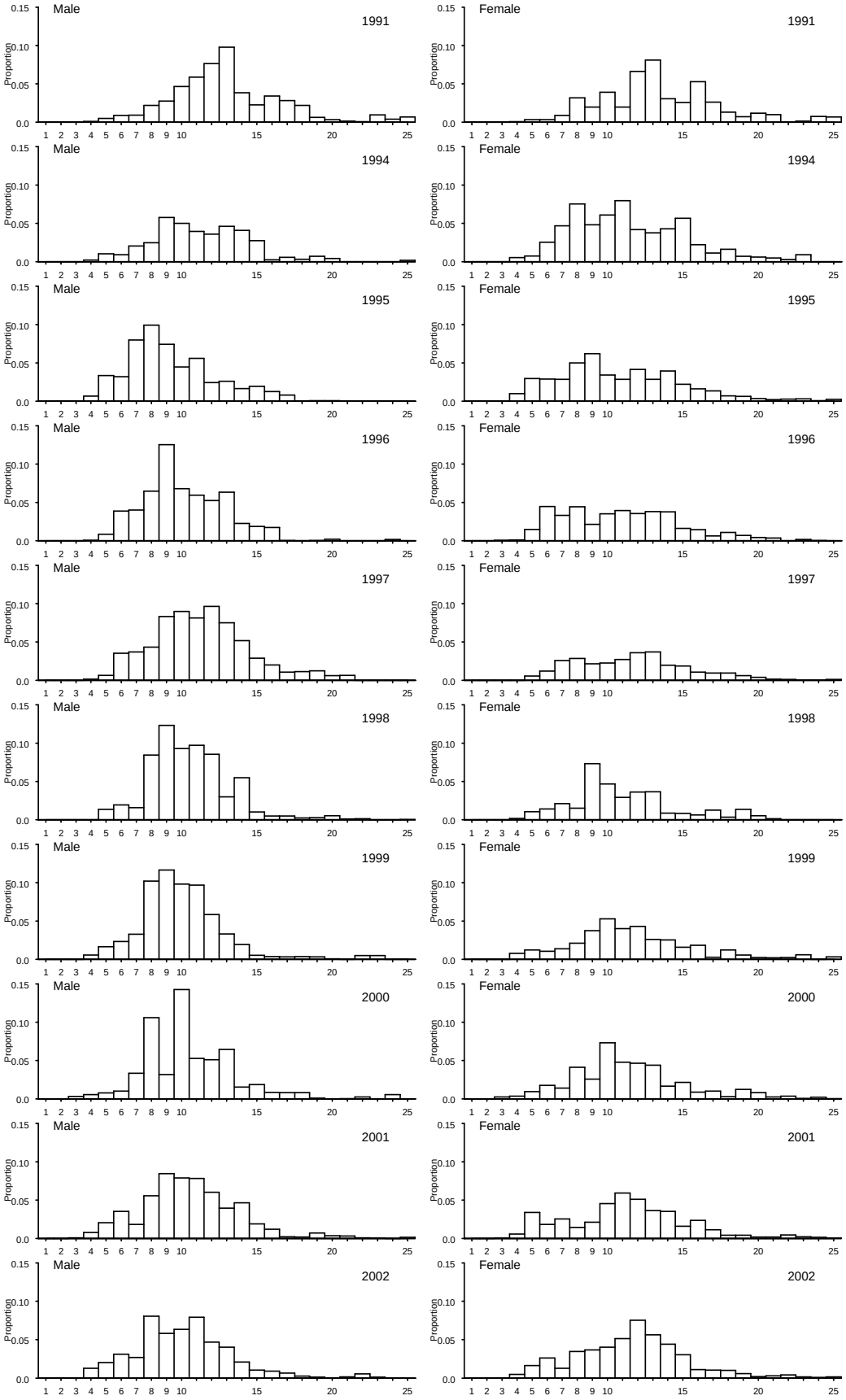

Figure B8: Age frequencies of ling from commercial catch-at-age data in the WCSI trawl fishery, 1991 to 2007.

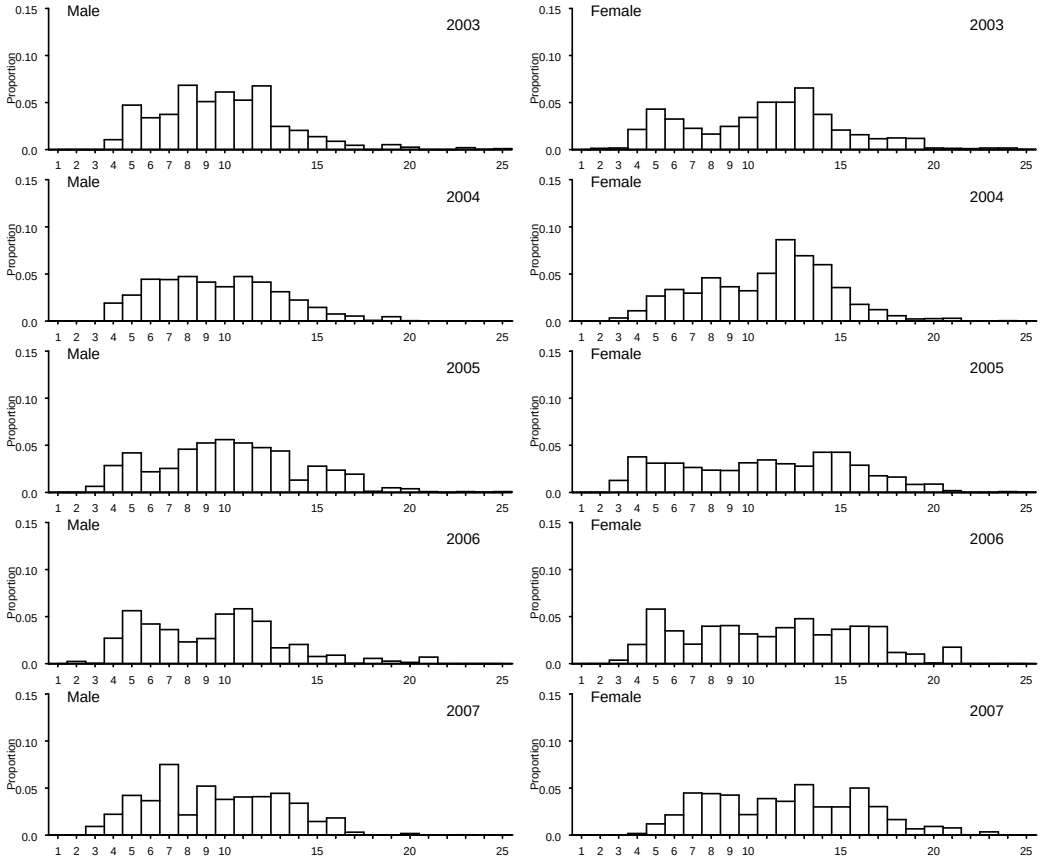

Figure B8 ctd.: Age frequencies of ling from commercial catch-at-age data in the WCSI trawl fishery, 1991 to 2007.

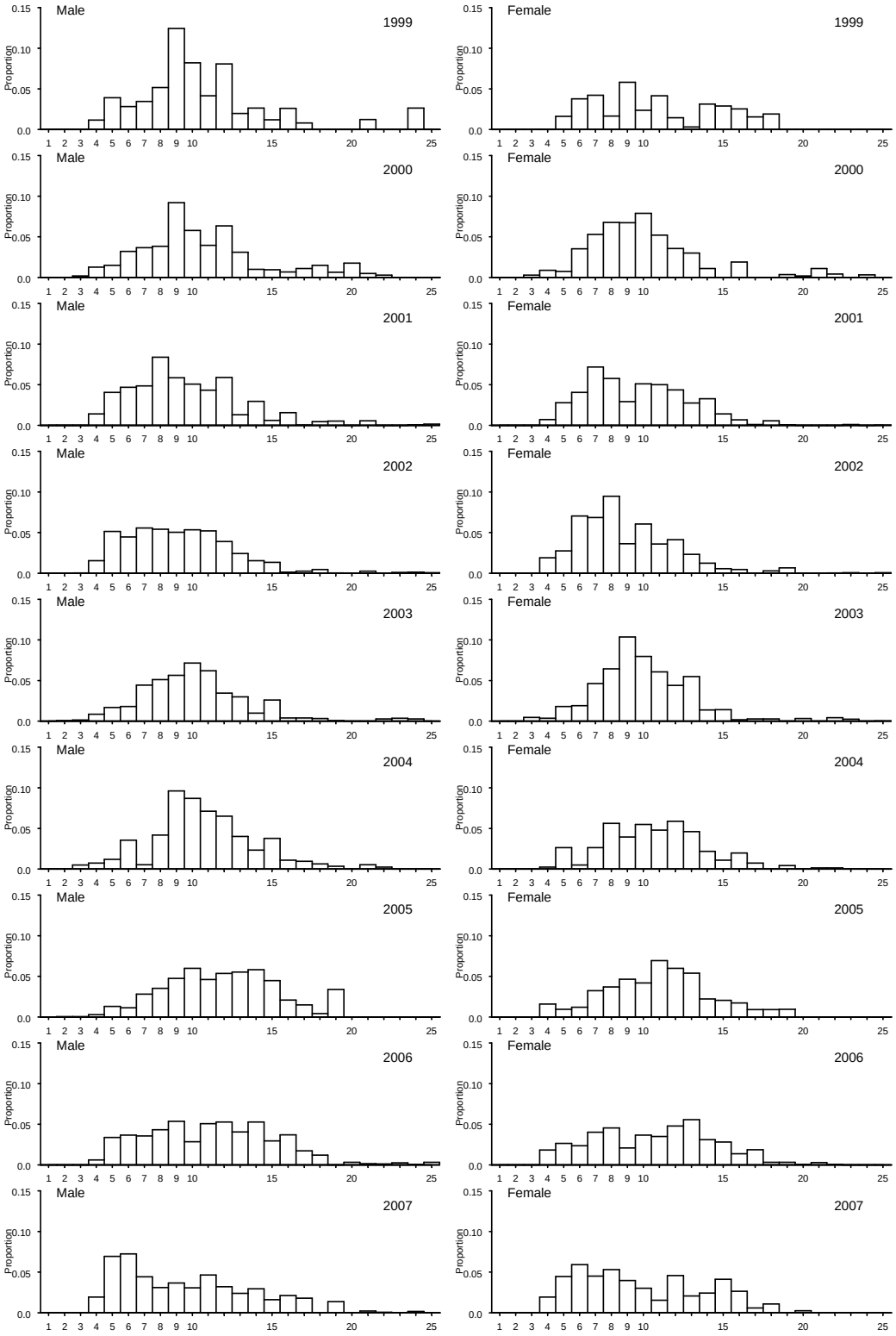

Figure B9: Age frequencies of ling from commercial catch-at-age data in the Cook Strait trawl fishery, 1999 to 2007.

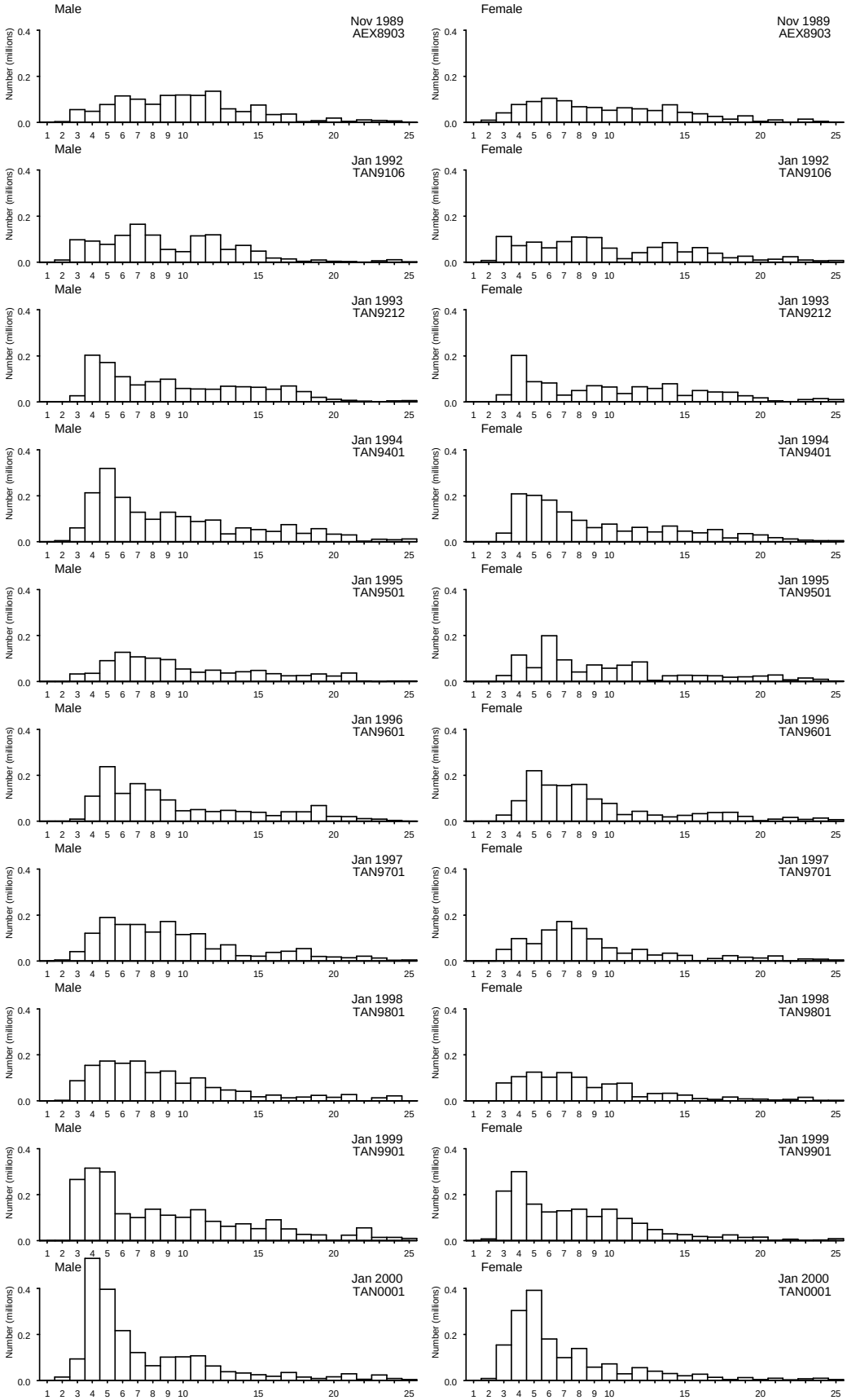

Figure B10: Age frequencies of ling (ages 1 to 25) from resource surveys in the Chatham Rise, 1989–90 to 2007–08.

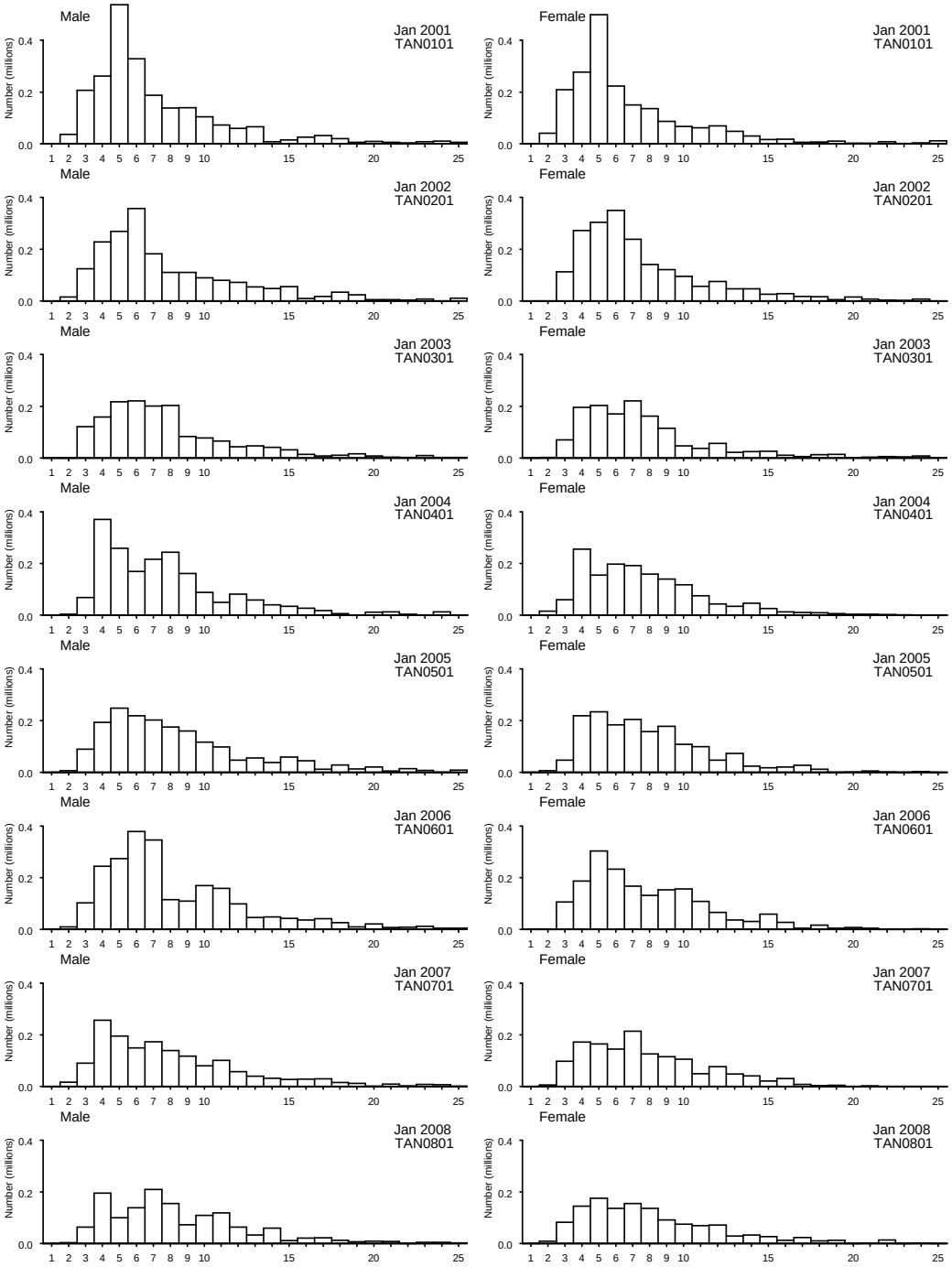

Figure B10 ctd.: Age frequencies of ling (ages 1 to 25) from resource surveys in the Chatham Rise, 1989–90 to 2007–08.

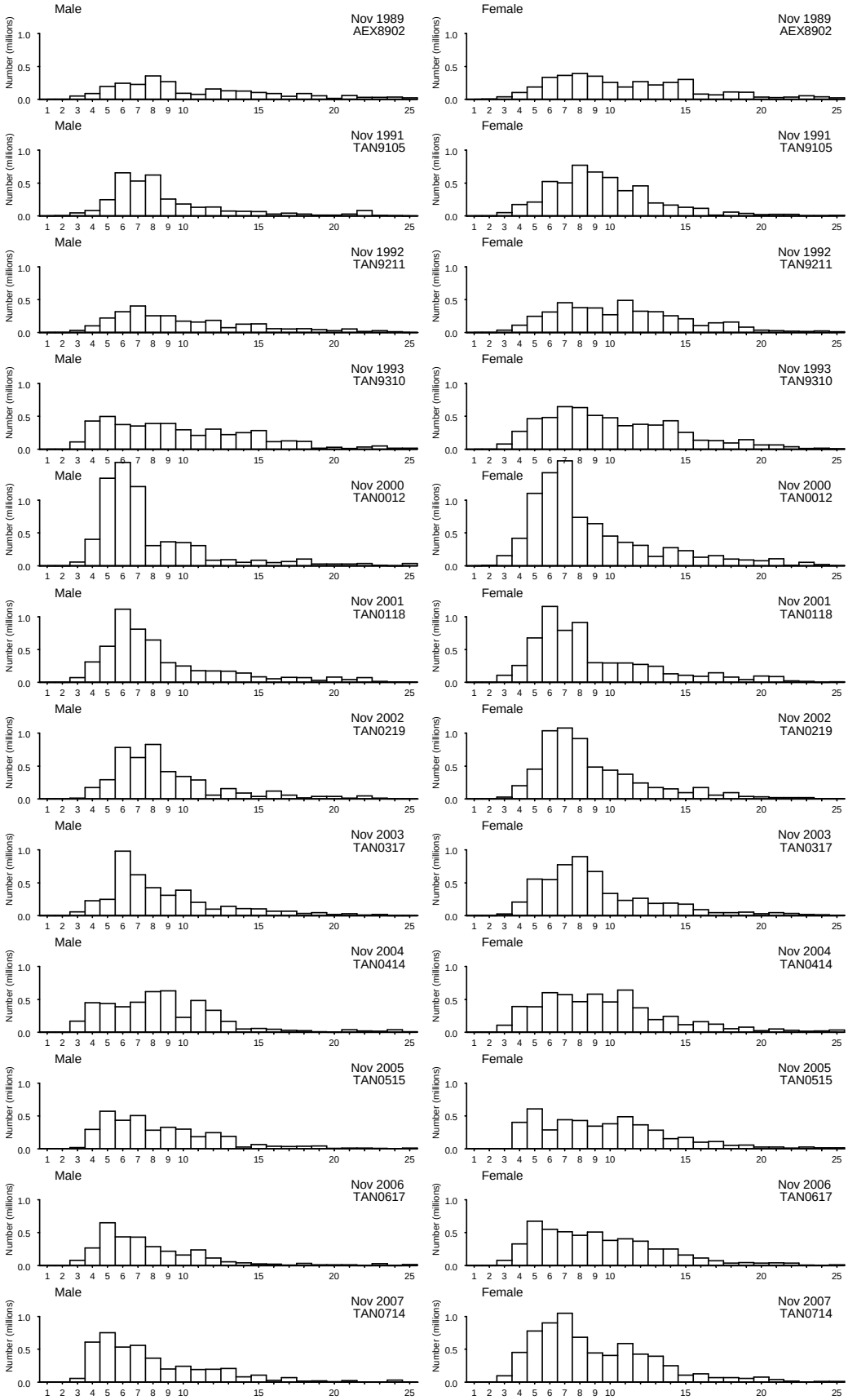

Figure B11: Age frequencies of ling (ages 1 to 25) from summer resource surveys in the Sub-Antarctic, 1989 to 2007.

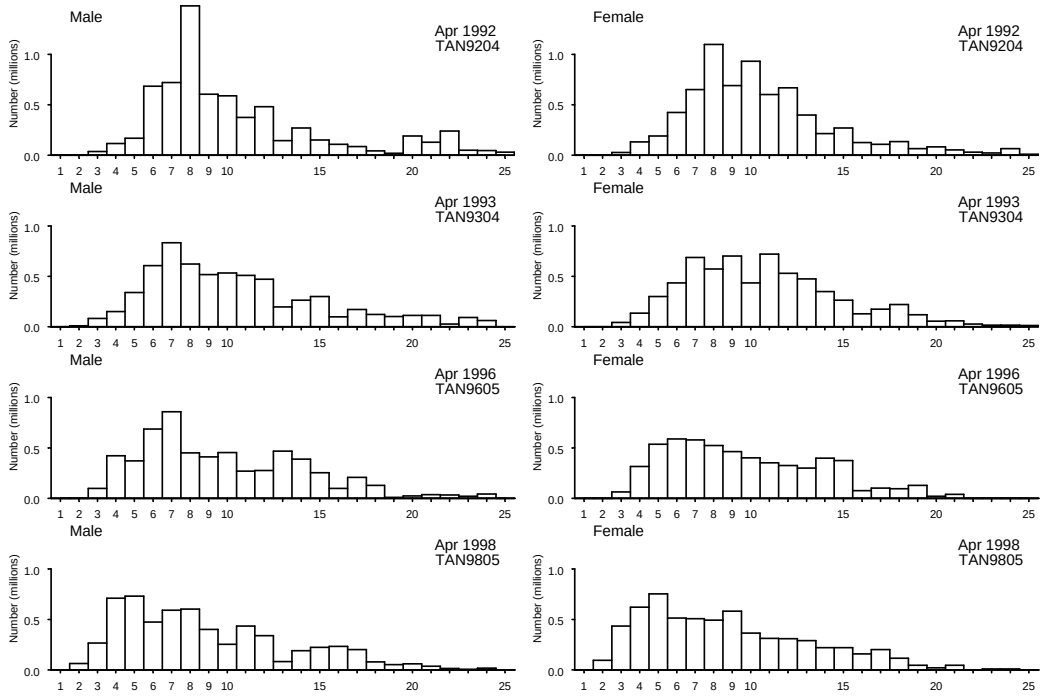

Figure B12: Age frequencies of ling (ages 1 to 25) from autumn resource surveys in the Sub-Antarctic, 1992 to 1998.