



Catch-at-age for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) in the 2014–15 fishing year and from a trawl survey in 2016, with a summary of all available data sets from the New Zealand EEZ

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EXECUTIVE SUMMARY

Horn, P.L.; Sutton, C.P. (2017). Catch-at-age for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) in the 2014–15 fishing year and from a trawl survey in 2016, with a summary of all available data sets from the New Zealand EEZ.

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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 2014–15 fishing year (using data and otoliths collected at sea by observers), and from a trawl survey of hoki and middle depth species on the Chatham Rise in January 2016 (TAN1601). The target coefficient of variation (CV) for each estimated catch-at-age distribution from the observer samples and the trawl survey was 30% (mean weighted CV across all age classes).

For hake, the target CV was met for the three commercial fisheries (west Chatham Rise, west coast South Island, and Sub-Antarctic), but was not met for the trawl survey. There were insufficient data to estimate catch-at-age for the east Chatham Rise commercial trawl fishery.

For ling, the target CV was met for the commercial trawl fisheries from west coast South Island and the Sub-Antarctic, and the trawl survey. It was nearly met for the Chatham Rise trawl fishery. There were insufficient data collected to estimate catch-at-age for the 2013 Cook Strait commercial trawl fishery. Catch-at-age was also estimated and the target CV was met for the ling longline fisheries on Chatham Rise in 2013–14 and west coast South Island in 2014–15. No samples from other longline fisheries were available.

Where the target CV was not met, it was not possible to improve the precision for either fishery by reading more otoliths (i.e., increasing the sample size), because all available data and otoliths were used in the analyses. It would be desirable to ensure that, for all fisheries where catch-at-age estimates are produced, sampled (observed) trips occur in the areas and months that were used to produce the time series reported here. Those areas and months are listed in this document. Summaries of all previous catch-at-age distributions made for hake and ling from trawl surveys and commercial fisheries are also provided.

1. INTRODUCTION

This work aimed to determine catch-at-age from the main fisheries for hake and ling in the 2014–15 fishing year, and for hake and ling from a trawl survey conducted in January 2016. 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 reporting requirements for hake and ling in Objective 1 of Project MID201501 “Routine age determination of hoki and middle depth species from commercial fisheries and trawl surveys”, funded by the Ministry for Primary Industries. That objective is:

1. To determine catch-at-age for commercial catches and resource surveys of specified middle depth and deepwater fishstocks.

The report also summarises all historic catch-at-age data sets for hake and ling from trawl surveys and commercial fisheries, and describes the strata used in the analyses of data from the commercial trawl fisheries. The derivation of the strata was presented by Horn & Sutton (2008), although the Chatham Rise hake strata were modified in 2010 (Horn & Francis 2010).

2. METHODS

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

- HAK 1 — commercial trawl fishery, Sep 2014–May 2015 [600].
- HAK 4 — trawl survey, Jan 2016 (project HOK2015-01) [600].
- HAK 4 — commercial trawl fishery, Oct 2014–Apr 2015 [600].
- HAK 7 — commercial trawl fishery, Jun–Sep 2015 [600].

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

- LIN 3&4 — commercial longline fishery, Chatham Rise, Jun–Oct 2015 [580].
- LIN 3&4 — trawl survey, Chatham Rise, Jan 2016 (project HOK2015-01) [600].
- LIN 3&4 — commercial trawl fishery, Chatham Rise, Oct 2014–May 2015 [600].
- LIN 5&6 — commercial longline fishery, spawning, Puysegur, Oct–Dec 2014 [500].
- LIN 5&6 — commercial longline fishery, non-spawning, Campbell, Feb–Jul 2015 [500].
- LIN 6B — commercial longline fishery, Bounty, Nov 2014–Mar 2015 [500].
- LIN 7 — commercial trawl fishery, west coast South Island, Jun–Sep 2015 [600].
- LIN 7&2 — commercial trawl fishery, Cook Strait, Jun–Sep 2015 [500].

Insufficient or no observer otoliths were available from the ling longline fisheries on Chatham Rise (LIN 3&4), Sub-Antarctic (LIN 5&6), and Bounty Plateau (LIN 6B), and also from the winter 2015 Cook Strait trawl fishery (LIN 7&2). Consequently, catch-at-age distributions were not able to be produced for those fisheries. However, a suitable sample was available from the longline fishery off west coast South Island (LIN 7) in winter 2015, enabling a catch-at-age distribution to be produced for this relatively infrequently sampled fishery.

The following additional commercial fishery catch-at-age distribution for ling was estimated using an age-length key derived previously from the December 2014 Sub-Antarctic trawl survey (LIN 5&6).

- LIN 5&6 — commercial trawl fishery, Sub-Antarctic, Sep 2014–Apr 2015.

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 provided a sample with a mean weighted CV similar to that from proportional sampling, but smaller than from 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).

Fishery catch-at-age distributions were scaled to the total estimated catch from each fishery in the time period sampled. For fisheries with multiple strata, length frequency data from each stratum were first scaled to the estimated catch from that stratum, and then the length frequencies from all strata were summed, and the resulting age-length key was applied to the total length frequency. Survey catch-at-age distributions were scaled to total estimated biomass available to the trawl in the survey area.

Observer sampling of the HAK 1 and HAK 4 commercial trawl fisheries have sometimes provided only small numbers of otoliths. Consequently, catch-at-age distributions for these fisheries were estimated using age-length keys combining commercial fishery and trawl survey age data. For example, the age-length key for the 2008–09 HAK 1 fishery included otoliths from observer sampling from September 2008 to May 2009 plus age data from the TAN0813 trawl survey in December 2008.

The target mean weighted CV for hake from trawl surveys has often not been met. To maximise the chances of meeting the target, all hake from the trawl shots used in the survey biomass and scaled length-frequency calculations were measured and their otoliths were collected. Any hake caught in survey tows not used for biomass calculations (i.e., foul shots, midwater tows, or night tows) were also sampled. 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

Data from the Chatham Rise were previously analysed as four separate fisheries (e.g., Horn & Sutton 2009) as shown in Figure 1, and defined as follows:

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

An assessment of the Chatham Rise hake stock (Horn & Francis 2010) concluded that splitting the data into two fisheries (i.e., west and east), rather than four was statistically satisfactory. Consequently, two commercial age frequencies were developed for each year (whenever sufficient data were available) using a single age-length key and two strata separated at longitude 178.1° E. The raw data were still stratified as shown in Figure 1, so each fishery comprised two strata. A single age-length key for each year was used as Horn & Dunn (2007) showed that mean age at length did not differ between fisheries (i.e., in years when there were sufficient data to estimate catch-at-age for both fisheries, the same age-length key was used for both).

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 were measured from it.

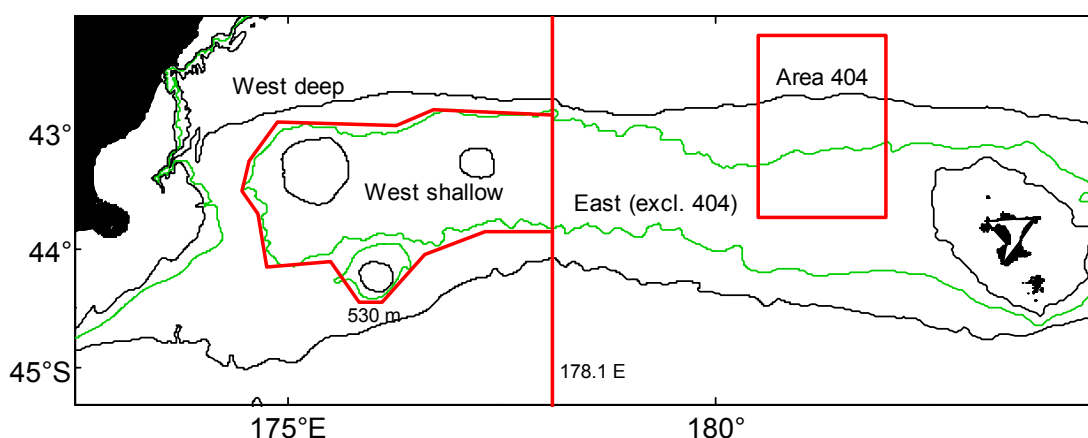


Figure 1: Strata defined for the Chatham Rise hake fishery. The west stratum boundary defined by depth (530 m) is shown only approximately (red). Isobaths at 1000, 500 (green), and 250 m are also shown.

Observer data from each fishery were converted into catch-at-age distributions if there were at least 400 length measurements (west fishery) or 300 length measurements (east fishery). Table 1 summarises the quantities of useful data. In the 2014–15 fishing year, sufficient length data ($n = 522$) were available from the east strata to calculate a catch-at-age distribution, but not for the west strata ($n = 124$). Details of the estimated catch-at-age distribution for east trawl-caught hake in the 2014–15 fishing year are in Table 2. The mean weighted CV of 29% just met the target of 30%.

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

Table 1: Numbers of measured (by fishery) and aged (fisheries combined) male (M) and female (F) hake contributing to samples of proportion-at-age from the two commercial trawl fisheries on the Chatham Rise. The number of tows sampled by observers and the estimated mean weighted CV (%) by age are also listed. Blank cells in the table indicate that insufficient data were available to allow estimation of catch-at-age.

Fishing year	Measured								Aged	
	West				East				M	F
	M	F	Tows	CV	M	F	Tows	CV		
1991–92	2 112	2 636	163	21.9	170	247	25	43.2	233	230
1993–94	355	452	90	36.7					181	217
1994–95	318	603	69	32.8	234	88	14	43.1	170	191
1995–96	802	917	103	28.2					113	165
1996–97	354	233	28	39.6	335	75	28	48.6	145	149
1997–98	3 161	3 046	390	14.9	224	140	44	41.0	393	393
1998–99	712	1 279	171	19.4					290	440
1999–2000	807	901	168	19.0					442	499
2000–01	830	1 135	185	17.6	1 017	283	47	24.7	317	426
2001–02	386	492	89	20.6					455	419
2002–03	176	272	61	25.4					256	345
2003–04	597	438	101	26.8	378	92	38	26.6	364	304
2004–05	896	437	82	24.2					391	343
2005–06	234	330	69	39.1					189	255
2006–07					409	278	47	27.6	368	388
2007–08	286	270	53	20.6					350	335
2008–09	257	162	43	24.3					237	185
2009–10	147	259	38	25.6					228	244
2010–11	202	249	46	34.3					199	251
2011–12									0	0
2012–13									0	0
2013–14	213	221	37	29.5					150	145
2014–15					249	273	33	28.6	91	132

Table 2: Calculated numbers at age, separately by sex, with CVs, for hake sampled by observers during commercial trawl operations in the east Chatham Rise during October 2014–April 2015. Summary statistics for the samples are also presented. Age in years.

Age	Male	CV	Female	CV
2	19	1.716	5	2.869
3	368	0.586	350	0.449
4	1 051	0.294	1 081	0.389
5	1 671	0.227	2 140	0.256
6	721	0.375	748	0.343
7	682	0.328	925	0.307
8	1 037	0.332	449	0.373
9	222	0.768	349	0.385
10	102	0.955	159	0.691
11	0	–	105	0.652
12	102	0.924	73	0.806
13	0	–	155	0.739
14	0	–	74	0.953
15	0	–	14	1.693
16	127	1.207	0	–
17	59	1.169	0	–
Measured males			249	
Measured females			273	
Aged males			91	
Aged females			132	
No. of tows sampled			33	
Mean weighted CV (% , sexes pooled)			28.6	

3.1.2 Sub-Antarctic

There was one major and three very minor hake fisheries in the Sub-Antarctic area, so a single fishery ogive was used for this stock. A commercial age frequency was developed using a single age-length key and the four fishery strata shown in Figure 2 (determined by Horn (2008b)), and defined as follows:

1. Puysegur Bank ($165^{\circ} \text{ E} \leq \text{longitude} \leq 168^{\circ} \text{ E}$, $46^{\circ} \text{ S} \leq \text{latitude} \leq 48^{\circ} \text{ S}$).
2. Snares-Pukaki ($165^{\circ} \text{ E} \leq \text{longitude} \leq 175^{\circ} \text{ E}$, $46^{\circ} \text{ S} \leq \text{latitude} \leq 50.25^{\circ} \text{ S}$, but excluding the Puysegur Bank stratum and the area north of 48° S and east of 171.6°).
3. Auckland Island ($165^{\circ} \text{ E} \leq \text{longitude} \leq 169^{\circ} \text{ E}$, $50.25^{\circ} \text{ S} < \text{latitude} \leq 54^{\circ} \text{ S}$).
4. Campbell Island ($169^{\circ} \text{ E} < \text{longitude} \leq 174^{\circ} \text{ E}$, $50.25^{\circ} \text{ S} < \text{latitude} \leq 54^{\circ} \text{ S}$).

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 were measured from that tow. The time stratum was based on a descriptive analysis indicating a landings peak from September to February (Devine 2008), so it is not logical to use the administrative fishing year (1 October to 30 September) which bisects the fishery timing. Observer data were converted into catch-at-age distributions if there were at least 700 length measurements, and if sufficient otoliths had been collected to produce a comprehensive age-length key.

Table 3 summarises the data used each year to produce the catch-at-age distributions, and the resulting mean weighted CVs. Details of the estimated catch-at-age distribution for trawl-caught hake in the 2014–15 fishing year are in Table 4. The mean weighted CV of 23% was within the target of 30%.

All estimated proportion-at-age distributions from the Sub-Antarctic trawl fishery are presented in Appendix A (Figure A3).

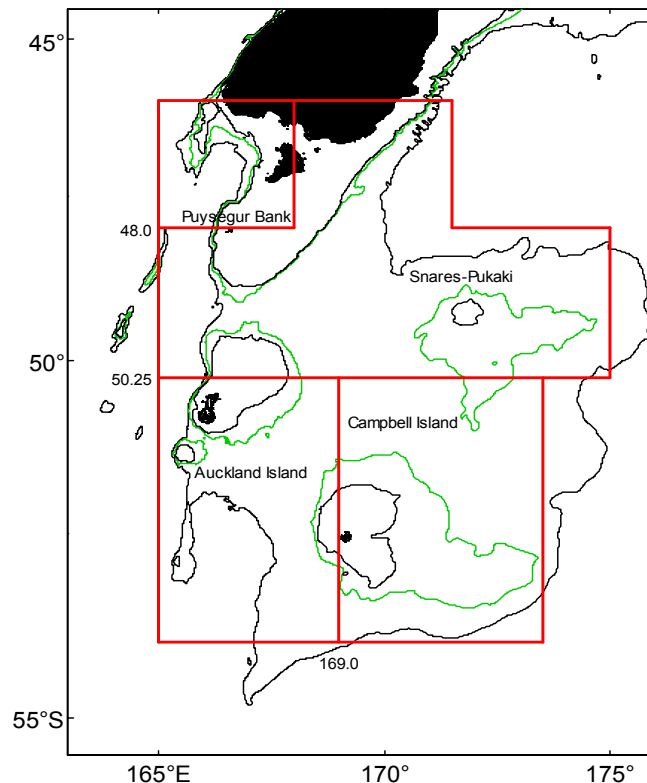


Figure 2: Fishery strata defined for the Sub-Antarctic hake fishery. Numbers show latitudes and longitudes of fishery boundaries. Isobaths at 1000, 500, and 250 m are also shown.

Table 3: Numbers of measured male and female hake, age data used in the age-length key, and tows sampled, and estimated mean weighted CV (%) by age, for the Sub-Antarctic trawl fishery.

Year	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
1989–90	269	47	548	71	74	42.0
1990–91	175	0	588	0	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	0	597	0	92	–
1995–96	289	65	435	110	75	50.0
1996–97	84	0	219	0	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
2007–08	891	325	592	682	89	23.2
2008–09	1 221	311	893	498	109	23.9
2009–10	1 879	418	1 029	611	91	18.2
2010–11	3 738	296	1 212	282	117	20.2
2011–12	4 098	581	1 597	605	109	15.0
2012–13	2 555	412	1 306	666	100	19.5
2013–14	4 027	316	1 443	146	90	19.4
2014–15	2 907	256	800	210	94	22.9

Table 4: Calculated numbers at age, separately by sex, with CVs, for hake sampled by observers during commercial trawl operations in the Sub-Antarctic during September 2014–May 2015. Summary statistics for the samples are also presented. Age in years.

Age	Male	CV	Female	CV
4	0	–	4	2.071
5	2 517	0.553	103	0.931
6	8 997	0.305	1 246	0.689
7	20 693	0.198	1 842	0.382
8	23 874	0.174	6 133	0.284
9	29 117	0.164	6 557	0.245
10	17 865	0.213	6 218	0.263
11	11 848	0.261	8 104	0.300
12	13 143	0.246	7 379	0.318
13	7 912	0.327	4 127	0.320
14	3 319	0.460	2 370	0.669
15	4 178	0.446	1 534	0.653
16	2 647	0.473	2 321	0.426
17	7 967	0.274	873	0.637
18	3 820	0.538	612	0.930
19	4 138	0.442	214	1.050
20	3 074	0.483	1 293	0.772
21	3 590	0.463	527	0.874
22	3 402	0.449	841	0.746
23	1 894	0.569	0	–
24	733	1.086	0	–
25	0	–	0	–
26	0	–	0	–
27	281	1.2972	0	–
Measured males			2 907	
Measured females			800	
Aged males			256	
Aged females			210	
No. of tows sampled			94	
Mean weighted CV (% , sexes pooled)			22.9	

3.1.3 West coast South Island (WCSI)

The fishery off WCSI was stratified (by Horn & Sutton (2008)) as follows:

1. Deep (bottom depth ≥ 629 m).
2. North shallow (bottom depth < 629 m, latitude $< 42.55^\circ$ S).
3. South shallow (bottom depth < 629 m, latitude $\geq 42.55^\circ$ S).

A tow was included in the catch-at-age analysis if it occurred between 1 June and 30 September, and if at least five hake were measured from that tow.

Table 5 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. Details of the estimated catch-at-age distribution for trawl-caught hake in the 2014–15 fishing year are in Table 6. The measured sample size was larger than in all previous years, although similar to the 2012–13 sample. The mean weighted CV of 14% was much less than the target of 30%.

All estimated proportion-at-age-distributions from the WCSI trawl fishery are presented in Appendix A (Figure A4).

Table 5: Numbers of measured male and female hake, age data used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age, for the WCSI trawl fishery.

Year	Males		Females		Tows	Mean CV
	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
2007–08	4 682	321	2 416	266	147	17.7
2008–09	5 773	301	3 610	301	178	18.8
2009–10	2 454	130	1 877	134	76	25.4
2010–11	2 489	260	2 489	353	104	16.8
2011–12	2 535	357	2 061	381	140	14.4
2012–13	12 352	325	8 417	443	493	14.3
2013–14	8 128	320	7 242	384	360	13.1
2014–15	12 334	329	10 173	363	498	13.6

Table 6: Calculated numbers at age, separately by sex, with CVs, for hake sampled by observers during commercial trawl operations off the WCSI during June–September 2015. Summary statistics for the samples are also presented. Age in years.

Age	Male	CV	Female	CV
0	7	2.536	0	–
1	896	0.698	662	0.742
2	11 718	0.175	10 610	0.168
3	2 636	0.279	1 530	0.285
4	20 622	0.250	4 257	0.298
5	221 493	0.085	25 144	0.215
6	202 034	0.109	68 133	0.141
7	149 914	0.128	111 032	0.126
8	78 152	0.175	140 737	0.104
9	33 565	0.274	68 933	0.155
10	9 764	0.503	28 653	0.222
11	28 652	0.306	18 882	0.279
12	3 997	0.761	12 541	0.348
13	6 699	0.654	6 388	0.523
14	7 652	0.620	1 961	0.811
15	4 722	0.808	20	1.618
16	11 974	0.458	2 088	0.817
17	6 383	0.510	3 405	0.711
18	4 291	0.742	3 089	0.647
19	2 762	1.044	1 934	1.042
20	11 601	0.446	1 170	1.024
21	3 672	0.948	1 170	1.047
22	1 121	1.133	0	–
23	2 762	1.034	0	–
24	2 775	1.056	0	–
Measured males			12 334	
Measured females			10 174	
Aged males			329	
Aged females			363	
No. of tows sampled			498	
Mean weighted CV (% , sexes pooled)			13.6	

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 Chatham Rise was surveyed. However, to ensure comparability, the distributions presented here are for the core strata only, i.e., 200–800 m.

Table 7 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. The 30% target was met in only one of the 20 surveys (TAN9106, see Table 7). The details of the estimated catch-at-age distribution for hake caught in the January 2016 trawl survey are given in Table 8. The mean weighted CV of 41% was greater than the target of 30%.

All estimated proportion-at-age distributions from the Chatham Rise trawl surveys are presented in Appendix A (Figure A5). It is likely that a strong year class was produced in 2002 (i.e., spawned at the start of the 2001–02 fishing year, and aged 2 years in January 2004), and that it was followed by two further relatively strong year classes in 2003 and 2004. The progression of these year classes, but particularly that from 2002, is apparent in the survey size distributions since TAN0401. A relatively

strong year class spawned at the start of the 1990–91 fishing year (age 3 in January 1994) is also apparent.

Table 7: Numbers of measured male and female hake, age data used in the age-length key, and tows sampled, and estimated mean weighted CV (%) by age, for the Chatham Rise trawl surveys.

Source	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
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
TAN0901	259	238	201	191	70	32.5
TAN1001	122	142	97	107	56	39.7
TAN1101	49	74	63	65	45	44.5
TAN1201	48	78	83	98	54	49.5
TAN1301	51	73	109	112	47	48.4
TAN1401	38	88	65	91	46	55.4
TAN1601	67	115	91	106	46	40.8

Table 8: Calculated numbers at age in the survey area, separately by sex, with CVs, for hake caught during a trawl survey of the Chatham Rise in January 2016 (survey TAN1601). Summary statistics for the samples are also presented. Age in years.

Age	Male	CV	Female	CV
2	6 848	1.017	9 035	0.656
3	9 877	0.948	16 569	0.548
4	21 820	0.526	21 988	0.486
5	47 542	0.348	50 970	0.308
6	14 575	0.460	23 580	0.510
7	15 469	0.539	30 273	0.453
8	14 656	0.543	21 906	0.469
9	17 892	0.614	34 406	0.430
10	10 261	0.783	19 404	0.537
11	1 492	1.412	9 140	0.701
12	3 685	0.889	7 569	0.638
13	3 934	0.884	11 311	0.868
14	4 585	1.315	12 030	0.645
15	4 679	1.619	2 492	1.344
16	0	–	665	1.777
17	3 785	1.337	0	–
18	0	–	665	1.699
19	0	–	0	–
20	0	–	0	–
21	0	–	0	–
22	0	–	1 962	1.324
Measured males				67
Measured females				91
Aged males				115
Aged females				106
No. of tows sampled				46
Mean weighted CV (% , sexes pooled)				40.8

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 was conducted in summer. Those surveys 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. For 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 9 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. No survey in this series was conducted in December 2015.

All estimated proportion-at-age distributions from the Sub-Antarctic trawl surveys are presented in Appendix A; Figure A6 shows the summer survey distributions and Figure A7 shows the spring and autumn survey distributions.

Table 9: Numbers of measured male and female hake, age data used in the age-length key, and tows sampled, and estimated mean weighted CV (%) by age for the Sub-Antarctic resource surveys.

Survey	Males		Females		Tows	Mean CV
	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
TAN0813	289	188	808	412	39	30.9
TAN0911	152	164	382	436	37	36.3
TAN1117	405	238	423	357	37	37.3
TAN1215	155	222	359	537	36	39.1
TAN1412	41	41	169	176	29	47.7
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

3.2.3 West coast South Island

Trawl survey catch-at-age distributions are estimates of the numbers of hake, by sex and age, available to the trawl in the survey. A combined trawl and acoustic survey by *Tangaroa* in 2000 (O'Driscoll et al. 2004) was replicated (with some modifications) in winter 2012 (O'Driscoll et al. 2014) and winter 2013 (O'Driscoll et al. 2015), so a three survey comparable time series is available. The biomass estimates from the three surveys were standardised using random day-time bottom trawl stations in strata 1&2A, B, and C, and 4A, B, and C (depth 300–650 m), with stratum areas from the 2012 survey (O'Driscoll et al. 2014).

Table 10 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. Because no otoliths from the 2000 survey were aged, the scaled length-frequency distribution from that survey was applied to the WCSI commercial fishery age-length key for 2000. The age-length keys for the 2012 and 2013 surveys were derived using otoliths collected during the surveys. There was no survey in this series conducted in winter 2015.

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

Table 10: Numbers of measured male and female hake, age data used in the age-length key, and tows sampled, and estimated mean weighted CV (%) by age for the west coast South Island trawl surveys.

Survey	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
TAN0007	331	230	407	255	36	26.4
TAN1210	211	330	228	332	36	26.6
TAN1308	94	255	213	371	34	33.7

3.3 Observer catch-at-age data from ling longline fisheries

3.3.1 Chatham Rise

The longline fishery data from the Chatham Rise were 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 11 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. There were no or insufficient data collected from the Chatham Rise ling longline fishery in 2010–12 and 2015.

Table 11: Numbers of measured male and female ling, age data used in the age-length key, trips and sets sampled, and estimated mean weighted CV (%) by age, for the Chatham Rise longline fishery.

Year	Males		Females		Trips	Sets	Mean CV
	Measured	Aged	Measured	Aged			
2002	4 966	284	2 998	309	5	538	20.4
2003	3 038	337	2 071	289	5	429	19.1
2004	1 066	302	747	293	2	139	21.8
2005	889	356	479	234	1	137	21.6
2006	266	95	294	141	1	48	36.6
2007	351	174	268	139	4	62	31.1
2008	574	216	570	262	4	84	25.9
2009	619	283	798	413	3	147	21.5
2013	314	112	655	252	1	50	25.9
2014	789	288	801	284	3	156	21.9

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 longline fishery data from the Sub-Antarctic stock were 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 030), with a time stratum of 1 October to 31 December. The non-spawning fishery was defined as a single stratum comprising all of FMAs 5 and 6, excluding Statistical Area 030 and the Bounty Plateau, with a time stratum of 1 February to 31 July. Ling on the Bounty Plateau were analysed separately from Sub-Antarctic ling because they are believed to comprise a distinct biological stock (Horn 2005).

Table 12 summarises the 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 CVs. No observer sampling of either the spawning or non-spawning fisheries occurred in the 2014–15 fishing year.

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).

Table 12: Numbers of measured male and female ling, age data used in the age-length key, trips and sets sampled, and estimated mean weighted CV (%) by age, for the Sub-Antarctic spawning and non-spawning longline fisheries.

Fishery and year	Males		Females		Trips	Sets	Mean CV
	Measured	Aged	Measured	Aged			
Spawning line fishery							
2000	4 044	242	4 231	278	1	83	20.6
2001	2 084	131	1 962	143	2	55	28.7
2002	670	197	898	284	1	157	22.6
2003	1 250	211	1 687	307	2	214	20.0
2004	887	208	1 129	289	2	168	22.5
2005	193	88	362	179	1	54	28.6
2006	233	108	707	345	1	94	23.3
2007	412	191	418	217	1	82	25.1
2008	227	68	198	62	1	24	44.3
2010	89	51	361	177	1	45	34.0
Non-spawning line fishery							
1998	608	73	2 763	395	1	34	23.1
1999	3 316	214	7 535	428	2	136	18.3
2001	674	103	2 040	235	2	58	25.3
2003	304	128	611	273	2	43	29.3
2005	413	114	716	307	2	113	25.9
2009	165	61	454	196	1	49	28.0
2010	151	78	424	214	1	49	29.0
2011	180	60	823	267	1	64	27.3
2012	316	109	979	320	2	91	23.7
2014	156	57	782	258	2	59	29.8

3.3.3 West coast South Island

The line fishery data from west coast South Island were analysed using a single area stratum and a time stratum of 1 May to 31 August.

Table 13 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. The 2003, 2006 and 2007 age-length keys were developed using age data from the trawl fisheries in the same years, as no otoliths were sampled from longline trips. The 2006 and 2007 data were collected under the SeaFIC ling longline logbook programme (Langley 2001). The 2012 age-length key was developed using 129 otoliths sampled from a longline trip, plus additional age data from the July 2012 research trawl survey off WCSI. Two longline trips targeting ling off WCSI were sampled in the 2014–15 fishing year; the resulting estimated catch-at-age distribution is given in Table 14. The mean weighted CV of 29.5% just met the target value of 30%. All estimated proportion-at-age distributions from the WCSI longline fishery are presented in Appendix B (Figure B4).

Table 13: Numbers of measured male and female ling, age data used in the age-length key, trips and sets sampled, and estimated mean weighted CV (%) by age, for the west coast South Island longline fishery.

Year	Males		Females		Trips	Sets	Mean CV
	Measured	Aged	Measured	Aged			
2003	123	215	148	246	3	24	37.9
2006	104	191	301	329	7	24	35.0
2007	109	119	192	169	7	28	42.2
2012	190	246	379	311	1	31	29.3
2015	296	144	188	97	2	49	29.5

Table 14: Calculated numbers at age, separately by sex, with CVs, for ling sampled by observers during commercial longline operations off WCSI (LIN 7) in May–August 2015. Summary statistics for the samples are also presented. Age in years.

Age	Male	CV	Female	CV
7	685	0.991	0	–
8	2 740	0.453	467	1.572
9	6 720	0.284	1 580	0.538
10	5 406	0.323	4 125	0.386
11	8 124	0.252	4 811	0.404
12	8 193	0.265	6 781	0.303
13	5 615	0.297	5 101	0.312
14	3 683	0.410	3 398	0.413
15	1 568	0.572	1 974	0.514
16	1 245	0.606	1 164	0.642
17	2 032	0.591	321	1.230
18	1 451	0.705	200	1.455
19	773	0.896	0	–
20	462	1.036	367	1.067
21	567	1.047	96	1.547
22	0	–	13	2.521
23	317	1.311	0	–
Measured males				296
Measured females				188
Aged males				144
Aged females				97
No. of sets sampled				49
Mean weighted CV (% , sexes pooled)				29.5

3.3.4 Cook Strait

The line fishery data from Cook Strait were 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 016 and 017), and a time stratum of 1 June to 30 September.

Table 15 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. The 2001 age-length key used 57 otoliths collected from the longline fishery (i.e., all that were collected), plus 316 otoliths collected from the trawl fishery in the same area and year. There was no observer sampling of Cook Strait longline-caught ling in the 2014–15 fishing year. All estimated proportion-at-age distributions from the Cook Strait longline fishery are presented in Appendix B (Figure B5).

Table 15: Numbers of measured male and female ling, age data used in the age-length key, trips and sets sampled, and estimated mean weighted CV (%) by age, for the Cook Strait longline fishery.

Year	Males		Females		Trips	Sets	Mean CV
	Measured	Aged	Measured	Aged			
2001	315	179	356	194	1	17	29.8
2003	165	164	145	142	1	31	33.1
2006	607	319	538	275	1	116	19.3
2007	238	125	180	92	1	43	33.8

3.3.5 Bounty Plateau

The longline fishery data from the Bounty Plateau were 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 31 March.

Table 16 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. There were no data collected from the Bounty Plateau ling longline fishery in the 2014–15 fishing year. All estimated proportion-at-age distributions from the Bounty Plateau longline fishery are presented in Appendix B (Figure B6).

Table 16: Numbers of measured male and female ling, age data used in the age-length key, trips and sets sampled, and estimated mean weighted CV (%) by age, for the Bounty Plateau longline fishery.

Year	Males		Females		Trips	Sets	Mean CV
	Measured	Aged	Measured	Aged			
1992–93	201	52	237	69	1	24	50.4
1999–2000	1 102	106	2 184	185	1	41	26.9
2000–01	405	50	713	66	1	20	43.6
2003–04	1 155	200	1 628	300	3	272	20.0
2007–08	308	156	562	271	1	86	25.3
2008–09	262	116	213	88	1	42	37.3

3.4 Observer catch-at-age data from ling trawl fisheries

3.4.1 Chatham Rise

Trawl fishery data from the Chatham Rise were used if they were collected between 1 October and 31 May in each fishing year, and were stratified using the following four strata:

1. Coast (longitude $\leq 174^\circ$ E, target not scampi).
2. Scampi (all tows targeting scampi).
3. North Rise (latitude $< 43.55^\circ$ S, longitude $> 174^\circ$ E, target not scampi).
4. South Rise (latitude $\geq 43.55^\circ$ S, longitude $> 174^\circ$ E, target not scampi).

Scampi target tows comprise a separate stratum because the gear used in this fishery usually retains ling of a smaller average size than the trawls used to target fishes.

Table 17 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. The estimated catch-at-age distribution for trawl-caught ling in the 2014–15 fishing year is given in Table 18. The observer sampling in 2014–15 was at a lower level than in all but one year since 1997–98; all available otoliths were aged. The mean weighted CV of 33% almost met the target value of 30%.

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

Table 17: Numbers of measured male and female ling, age data used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age, for the Chatham Rise trawl fishery.

Source	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
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
2007–08	2 755	317	2 070	325	276	20.9
2008–09	1 034	323	1 120	298	141	32.4
2009–10	526	318	571	309	87	28.9
2010–11	492	308	521	293	74	27.3
2011–12	739	257	767	297	82	26.4
2012–13	981	278	1 083	315	130	24.1
2013–14	1 385	314	1 674	258	164	29.7
2014–15	330	102	499	176	47	33.4

Table 18: Calculated numbers at age, separately by sex, with CVs, for ling sampled by observers during commercial trawl operations on the Chatham Rise during October 2014–May 2015. Summary statistics for the samples are also presented. Age in years.

Age	Male	CV	Female	CV
3	270	2.095	0	–
4	2 140	0.756	1 970	0.813
5	17 256	0.455	21 983	0.497
6	19 294	0.466	31 617	0.335
7	26 228	0.362	23 274	0.367
8	13 273	0.434	30 421	0.387
9	10 894	0.628	18 994	0.325
10	5 691	0.617	20 537	0.254
11	2 078	0.791	9 078	0.458
12	553	1.166	1 516	0.687
13	7 986	1.037	2 998	0.577
14	76	1.958	6 286	0.462
15	886	0.894	1 845	0.590
16	0	–	206	1.414
17	1 173	1.026	247	1.343
18	393	1.216	0	–
19	1 734	0.625	255	1.393
20	0	–	808	1.076
21	0	–	421	1.228
22	0	–	0	–
23	0	–	0	–
24	0	–	0	–
25	1 609	1.540	0	–
26	0	–	421	1.209
Measured males				330
Measured females				499
Aged males				102
Aged females				176
No. of tows sampled				47
Mean weighted CV (% , sexes pooled)				33.4

3.4.2 Sub-Antarctic

Trawl fishery data from the Sub-Antarctic were used if they were collected between 1 September and 30 April in each fishing year, and were stratified using the following three strata:

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

Table 19 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. The estimated catch-at-age distribution for trawl-caught ling in the 2014–15 fishing year are given in Table 20. The mean weighted CV of 19% was less than the target value of 30%.

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

Table 19: Numbers of measured male and female ling, age data used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age, for the Sub-Antarctic trawl fishery.

Source	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
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
2007–08	4 104	229	3 258	353	183	23.3
2008–09	2 877	245	3 803	324	184	19.4
2009–10	2 899	226	3 266	336	121	21.7
2010–11	2 212	236	2 630	279	215	21.4
2011–12	2 826	260	2 398	316	131	21.9
2012–13	4 565	286	5 542	317	275	21.6
2013–14	2 236	232	2 716	311	147	20.3
2014–15	3 920	264	3 274	363	229	19.2

Table 20: Calculated numbers at age, separately by sex, with CVs, for ling sampled by observers during commercial trawl operations in the Sub-Antarctic during September 2014–April 2015. Summary statistics for the samples are also presented. Age in years.

Age	Male	CV	Female	CV
3	509	1.268	528	0.853
4	4 705	0.526	10 157	0.381
5	53 056	0.225	46 692	0.301
6	124 716	0.186	95 923	0.225
7	247 240	0.159	147 380	0.167
8	202 318	0.193	140 214	0.165
9	105 226	0.277	98 899	0.199
10	117 553	0.250	67 462	0.220
11	67 600	0.323	33 255	0.313
12	45 106	0.404	46 342	0.250
13	36 604	0.366	25 786	0.336
14	29 739	0.486	22 188	0.314
15	20 559	0.705	15 363	0.361
16	14 147	0.797	8 891	0.467
17	34 124	0.487	21 810	0.279
18	61 999	0.326	9 865	0.366
19	18 589	0.745	10 346	0.536
20	2 671	0.712	3 242	0.646
21	6 753	0.628	2 859	0.574
22	10 247	0.636	2 299	0.732
23	2 030	1.149	1 828	0.827
24	840	1.132	0	–
25	2 482	1.054	0	–
26	0	–	1 103	1.278
27	0	–	0	–
28	0	–	0	–
29	1 805	1.092	0	–
Measured males			3 920	
Measured females			3 274	
Aged males			264	
Aged females			363	
No. of tows sampled			229	
Mean weighted CV (% , sexes pooled)			19.2	

3.4.3 West coast South Island

Trawl fishery data off WCSI were used if they were collected between 1 June and 30 September each year, and were stratified using the following three strata:

1. Deep (bottom depth \geq 498 m).
2. North shallow (bottom depth < 498 m, latitude < 42.42° S).
3. South shallow (bottom depth < 498 m, latitude \geq 42.42° S).

Table 21 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. There were insufficient data (particularly otoliths) collected to estimate the catch-at-age distribution for trawl-caught ling from 2008–09 to 2010–11. The details of the estimated catch-at-age distribution for trawl-caught ling in the 2014–15 fishing year are given in Table 22, where the amount of length data and otoliths was higher than in all other sampled years. The mean weighted CV of 21% was less than the target value of 30%.

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

Table 21: Numbers of measured male and female ling, age data used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age, for the WCSI trawl fishery.

Year	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
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
2008	805	209	824	251	98	24.1
2012	686	321	576	345	83	31.8
2013	1 270	283	1 302	376	153	23.9
2014	619	183	692	202	95	31.6
2015	3 684	292	3 822	363	417	21.2

Table 22: Calculated numbers at age, separately by sex, with CVs, for ling sampled by observers during commercial trawl operations off WCSI during June–September 2015. Summary statistics for the samples are also presented. Age in years.

Age	Male	CV	Female	CV
2	73	1.231	144	0.948
3	1 576	0.894	3 117	0.333
4	10 071	0.257	12 068	0.237
5	17 038	0.209	15 503	0.233
6	9 394	0.297	4 027	0.461
7	7 054	0.404	6 817	0.323
8	14 287	0.293	4 539	0.397
9	20 061	0.195	10 251	0.247
10	20 632	0.226	10 116	0.254
11	11 661	0.264	12 632	0.233
12	19 530	0.216	12 162	0.217
13	12 676	0.255	11 133	0.227
14	5 552	0.511	11 370	0.238
15	5 969	0.415	14 263	0.209
16	4 004	0.476	5 546	0.342
17	929	0.670	3 720	0.408
18	1 732	0.722	3 040	0.503
19	334	0.931	1 219	0.430
20	112	1.133	3 109	0.429
21	610	0.978	506	0.534
22	672	0.989	1 205	0.818
23	235	0.938	764	0.847
24	206	1.210	483	0.673
25	75	0.923	398	0.804
26	241	0.774	0	–
27	31	1.478	83	0.984
28	0	–	31	1.153
29	0	–	32	1.419
30	0	–	0	–
31	39	1.327	0	–
Measured males			3 684	
Measured females			3 822	
Aged males			292	
Aged females			363	
No. of tows sampled			417	
Mean weighted CV (% , sexes pooled)			21.2	

3.4.4 Cook Strait

The trawl fishery in Cook Strait was 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 016 and 017), and a time stratum of 1 June to 30 September.

Table 23 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. There were insufficient data collected to estimate the catch-at-age distribution for trawl-caught ling in 2015 (164 length measurements).

All estimated proportion-at-age distributions from the Cook Strait trawl fishery are presented in Appendix B (Figure B10).

Table 23: Numbers of measured male and female ling, age data used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age, for the Cook Strait trawl fishery.

Year	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
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
2008	569	280	470	226	44	27.0
2009	241	180	219	164	62	33.4
2010	274	195	250	196	41	36.2

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 was surveyed. However, to ensure comparability, the distributions presented here are for the core strata only, i.e., 200–800 m.

Table 24 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. The details of the estimated catch-at-age distribution for ling caught in the January 2016 trawl survey are given in Table 25. The mean weighted CV of 22% was less than the target of 30%.

All estimated proportion-at-age distributions from the Chatham Rise trawl surveys are presented in Appendix B (Figure B11).

Table 24: Numbers of measured male and female ling, age data used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age, for the Chatham Rise trawl surveys.

Survey	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
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
TAN0901	946	338	880	312	103	24.3
TAN1001	608	322	882	339	70	25.0
TAN1101	523	334	508	313	80	30.6
TAN1201	656	273	697	313	93	23.0
TAN1301	646	287	652	324	83	24.9
TAN1401	515	322	482	275	82	26.4
TAN1601	860	317	863	325	86	21.8

Table 25: Calculated numbers at age in the survey area, separately by sex, with CVs, for ling caught during a trawl survey of the Chatham Rise in January 2016 (survey TAN1601). Summary statistics for the samples are also presented. Age in years.

Age	Male	CV	Female	CV
2	7 361	1.284	5 684	1.042
3	138 963	0.296	135 325	0.245
4	312 820	0.201	375 478	0.186
5	205 769	0.233	180 597	0.228
6	178 643	0.242	195 548	0.194
7	212 930	0.228	189 385	0.211
8	218 213	0.208	128 910	0.255
9	114 046	0.292	81 270	0.319
10	84 310	0.344	118 809	0.262
11	91 147	0.314	112 983	0.253
12	68 525	0.354	72 521	0.299
13	32 918	0.534	20 654	0.557
14	67 721	0.362	25 729	0.518
15	54 234	0.394	35 015	0.424
16	79 636	0.343	33 950	0.422
17	27 491	0.496	39 493	0.365
18	52 299	0.374	42 460	0.357
19	44 734	0.408	13 694	0.669
20	42 893	0.447	11 693	0.767
21	20 863	0.500	6 818	0.751
22	1 679	1.645	15 125	0.655
23	2 015	1.324	13 692	0.582
24	12 183	0.609	4 609	0.992
25	11 730	0.968	9 152	0.938
26	1 389	1.540	3 972	1.517
27	3 467	1.494	7 430	1.016
28	2 910	1.484	0	–
29	3 428	1.605	0	–
30	3 428	1.329	0	–
31	0	–	0	–
32	2 667	1.404	0	–
Measured males				860
Measured females				863
Aged males				317
Aged females				325
No. of tows sampled				86
Mean weighted CV (% , sexes pooled)				21.8

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 was conducted in summer. Those surveys 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. 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 autumn surveys are derived from the core 300–800 m strata only.

Table 26 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. There was no survey in this series conducted in December 2015.

All estimated proportion-at-age distributions from the Sub-Antarctic trawl surveys are presented in Appendix B; Figure B12 shows the summer survey distributions and Figure B13 shows the autumn survey distributions.

Table 26: Numbers of measured male and female ling, age data used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age, for the Sub-Antarctic trawl surveys.

Survey	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
Summer surveys						
AEX8902	760	160	1 067	234	133	28.8
TAN9105	1 563	213	2 079	348	151	19.8
TAN9211	1 249	227	1 668	354	146	20.7
TAN9310	1 520	254	1 894	351	127	22.2
TAN0012	1 761	244	1 696	351	85	19.2
TAN0118	1 316	268	1 290	326	95	19.8
TAN0219	1 661	224	1 606	350	88	20.8
TAN0317	1 270	243	1 156	333	70	22.1
TAN0414	1 433	256	1 146	339	79	26.7
TAN0515	1 095	279	988	300	82	22.4
TAN0617	969	250	1 011	355	80	22.6
TAN0714	1 014	229	1 288	353	79	21.4
TAN0813	1 162	250	994	327	80	26.6
TAN0911	830	232	882	339	70	22.8
TAN1117	1 264	266	1 321	322	80	23.6
TAN1215	1 391	289	1 555	316	80	25.5
TAN1412	1 175	262	1 261	365	76	21.1
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

3.5.3 West coast South Island

Trawl survey catch-at-age distributions are estimates of the numbers of ling, by sex and age, available to the trawl in the survey. A combined trawl and acoustic survey by *Tangaroa* in 2000 (O'Driscoll et al. 2004) was replicated (with some modifications) in winter 2012 (O'Driscoll et al. 2014) and winter 2013 (O'Driscoll et al. 2015), so a three year comparable time series is available. The biomass estimates from the three surveys were standardised using random daytime bottom trawl stations in strata 1&2A, B, and C, and 4A, B, and C (depth 300–650 m), with stratum areas from the 2012 survey (O'Driscoll et al. 2014).

Table 27 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. Because no otoliths from the 2000 survey were aged, the scaled length-frequency distribution from that survey was applied to the WCSI commercial fishery age-length key for 2000. The age-length keys for the 2012 and 2013 surveys were derived using otoliths collected during the surveys. No survey in this series was conducted in 2015.

All estimated proportion-at-age distributions from the west coast South Island trawl surveys are presented in Appendix B (Figure B14).

Table 27: Numbers of measured male and female ling, age data used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age for the west coast South Island resource surveys.

Survey	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
TAN0007	784	284	637	276	45	29.5
TAN1210	962	305	722	308	48	26.7
TAN1308	1 026	224	768	298	53	30.1

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 CV were available from the HAK 7 fishery off WCSI, the HAK 1 fishery in the Sub-Antarctic, and the HAK 4 fishery on the east Chatham Rise. The target was almost always met for samples from the WCSI fishery (see Table 5). The sampling intensity in the HAK 7 (WCSI) commercial trawl fishery was higher in 2014–15 than in any previous year. Sampling intensity in the Sub-Antarctic varied considerably between years, with consequent wide variation in the mean weighted CVs (see Table 3) and the sampling intensity of this fishery in 2014–15 was moderate. Hake on Chatham Rise were analysed as two separate fisheries (see Table 1), and although sampling intensity was low in 2014–15 there were sufficient data to produce a reasonable catch-at-age distribution for the east fishery; a distribution for this fishery was last produced in 2006–07. Sampling of the west Chatham Rise fishery resulted in catch-at-age distributions in all but one year from 1991–92 to 2010–11, but sampling intensity was low since then and only one distribution was produced.

The January 2016 Chatham Rise survey produced low numbers of hake (158 measured fish in the analysed strata), and consequently the catch-at-age distribution for the trawl survey had a mean weighted CV much higher than the target of 30% (41%). No improvements in the precision can be achieved, however, as all available data were included in the analysis. The target of 30% was met only once in this survey series, although the values were often between 30 and 40% (see Table 7). There was no survey of the Sub-Antarctic in December 2015.

On the Chatham Rise, younger hake tend to be concentrated in the west, with the population dominated by fish aged 2–10 years (see Appendix A, Figure A1). Middle-aged and older hake (i.e., 5–15 years old) tend to dominate catches in the east (see Figure A2). Previous analyses showed that males and females appeared to be about evenly abundant in all areas except Statistical Area 404, where males dominated the catch (Horn & Sutton 2009). Some year class progressions were apparent. The year class that spawned at the start of the 1990–91 fishing year (age 3 years in January 1994) appears relatively strong, and can be tracked in some subsequent distributions through to about 2003. There was a clear year class progression apparent in the Chatham Rise survey distributions from 2004 to 2011 (Figure A5). The year class that spawned in late 2001 (aged 2+ years in January 2004) clearly progressed through to age 9+ years in 2011, for both males and females. It also appears likely that the two following year classes (2002 and 2003) were moderately strong.

In the Sub-Antarctic, there were some clear year class progressions, particularly in the male distributions. Figure A3 shows the progressions of hake aged 10 in 1990 through to age 16 in 1996, aged 6 in 1998 through to age 12 years in 2004, and age 5 in 2009 through to age 11 years in 2015.

The WCSI trawl catch was dominated by hake aged 5–12 years, with no clearly apparent year class progressions (see Figure A4). In some years, large numbers of 1- or 2-year-old fish were taken by the fishery, but these did not always manifest as strong cohorts in later years. The relatively abundant 2-year-old fish in catches from 2005, 2006, and 2007 progressed to comprise a high proportion of the catch from 2010 to 2012. Since 2011, fish older than 10 years appear to have been less abundant in the catch than

in most previous years. A characteristic of most of the WCSI distributions was that numbers of fish aged 3 and 4 years were generally very low. Fish of this age may be much less vulnerable or available to the trawl during the winter months of the fishery than younger or older hake.

4.2 Ling

Catch-at-age distributions were produced for one commercial longline fishery in 2014–15 (west coast South Island), and the target CV was met. Catch-at-age distributions were scheduled to be produced for the Chatham Rise, Sub-Antarctic and Bounty Plateau fisheries, but they were either not sampled by observers in 2014–15, or the sample size was insufficient to analyse (i.e., Chatham Rise). The west coast South Island longline fishery is not scheduled for regular analysis because it is predominantly conducted from small vessels and is rarely sampled by observers. However, a reasonable sample from two trips in 2014–15 was used to produce the fifth catch-at-age distribution for this fishery. Observer sampling on ling longline vessels declined in recent years in tandem with a reduction in effort by this fleet. It would be desirable to ensure that trips that are observed in the various areas occur during the months chosen for analysis of the particular fisheries (see Section 2).

Catch-at-age distributions were produced for trawl fisheries catching ling in three areas. The Sub-Antarctic distribution used observer length data applied to age-length keys obtained from a trawl survey, i.e., Sub-Antarctic length data collected from September 2014 to April 2015 were applied to the age-length key from the December 2014 (TAN1412) trawl survey of the Sub-Antarctic. The estimated CV was below the target value, as it was for all distributions in this series. The Chatham Rise and WCSI distributions relied entirely on observer length data and otoliths. The Chatham Rise catch-at-age distribution had a mean weighted CV just above the target of 30%. Most samples in this series were close to the target, but the level of observer sampling was relatively low in this fishery in 2014–15 (see Table 17). The WCSI commercial fishery was more extensively sampled in 2014–15 than in any previous year (see Table 21). Consequently, the estimated catch-at-age distribution had one of the lowest mean weighted CVs of the series. An estimate of catch-at-age for the ling bycatch from the Cook Strait hoki spawning fisheries was not able to be produced for 2014 as insufficient fish were sampled. No age structure for the Cook Strait fishery has been produced since 2010.

Sufficient ling otoliths and length-frequency data were available from a trawl survey of the Chatham Rise (January 2016) to meet the mean weighted CV target. The target was met in all but one of the previous surveys of this area (see Table 24).

The ling longline fisheries caught few fish younger than 7 years, and much of the catch was older than 12 years. Sex ratios of the longline catch were about 1:1 on the Chatham Rise and in Cook Strait, but were biased towards females in the other fisheries, particularly the Sub-Antarctic non-spawning fishery (see Figure B3). Year class progressions were not apparent in the longline series, although in the Chatham Rise fishery, females at age 13 in 2002 can be observed progressing to age 18 in 2007.

Recruitment to the trawl fisheries was generally about two years earlier than to the longline fisheries (i.e., at about 5 years), and most of the catch was 13 years or younger. Some year class progressions were apparent in some of the trawl series, particularly for female fish. On the Chatham Rise, a relatively strong year class of fish aged 5 in 2001 can be followed through to 2008 when they are 12 years old. Ling in the Sub-Antarctic aged 6 and 8 in 2002 are still relatively strong in 2006 at ages 10 and 12 years. Some similar patterns in Chatham Rise and Sub-Antarctic trawl survey catch-at-age are also apparent, as would be expected given that the same age-length key is applied to trawl fisheries and trawl surveys from a particular area. In the Cook Strait trawl fishery, female ling exhibit a relatively strong year class aged 7 in 2001 through to age 11 in 2005.

The ling trawl catch-at-age distributions from the WCSI fishery often exhibited 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). Fish of this size may be less vulnerable or available to the trawl during the winter months of the fishery.

4.3 Observer sampling

All the commercial fishery catch-at-age distributions reported here were reliant on the collection by observers of length data and otoliths. It was noted above that some planned catch-at-age distributions could not be estimated owing to insufficient data being collected. In some situations this has resulted from a marked reduction in effort in a fishery, e.g., the hake trawl fishery on the eastern Chatham Rise has produced relatively small catches since 2009–10 (Horn 2013). But for some fisheries, there was either insufficient or no observer sampling, or the observed trips occurred at times outside the ‘main’ fishery period used to estimate commercial catch-at-age, e.g., the Chatham Rise longline fishery. Sampling levels of trawl-caught ling off WCSI were low or inadequate in most years from 2006 to 2014, despite the presence of observers who comprehensively sampled hoki and hake from the same fishery that produces most of the ling catch. It appears likely that most observers were not aware of the need to comprehensively sample ling from the WCSI hoki target fishery (although this may have been rectified in 2015). If possible, it would be desirable to ensure that, for all fisheries where catch-at-age estimates are produced, sampled (observed) trips occur in the areas and months used to produce the time series reported here, and observers are adequately briefed on the sampling requirements. The areas and months for each fishery are listed in this document in the sections above, e.g., for the Chatham Rise ling longline fishery the chosen season is from June to October.

5. ACKNOWLEDGMENTS

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Appendix A: Summaries of the proportions-at-age data for hake

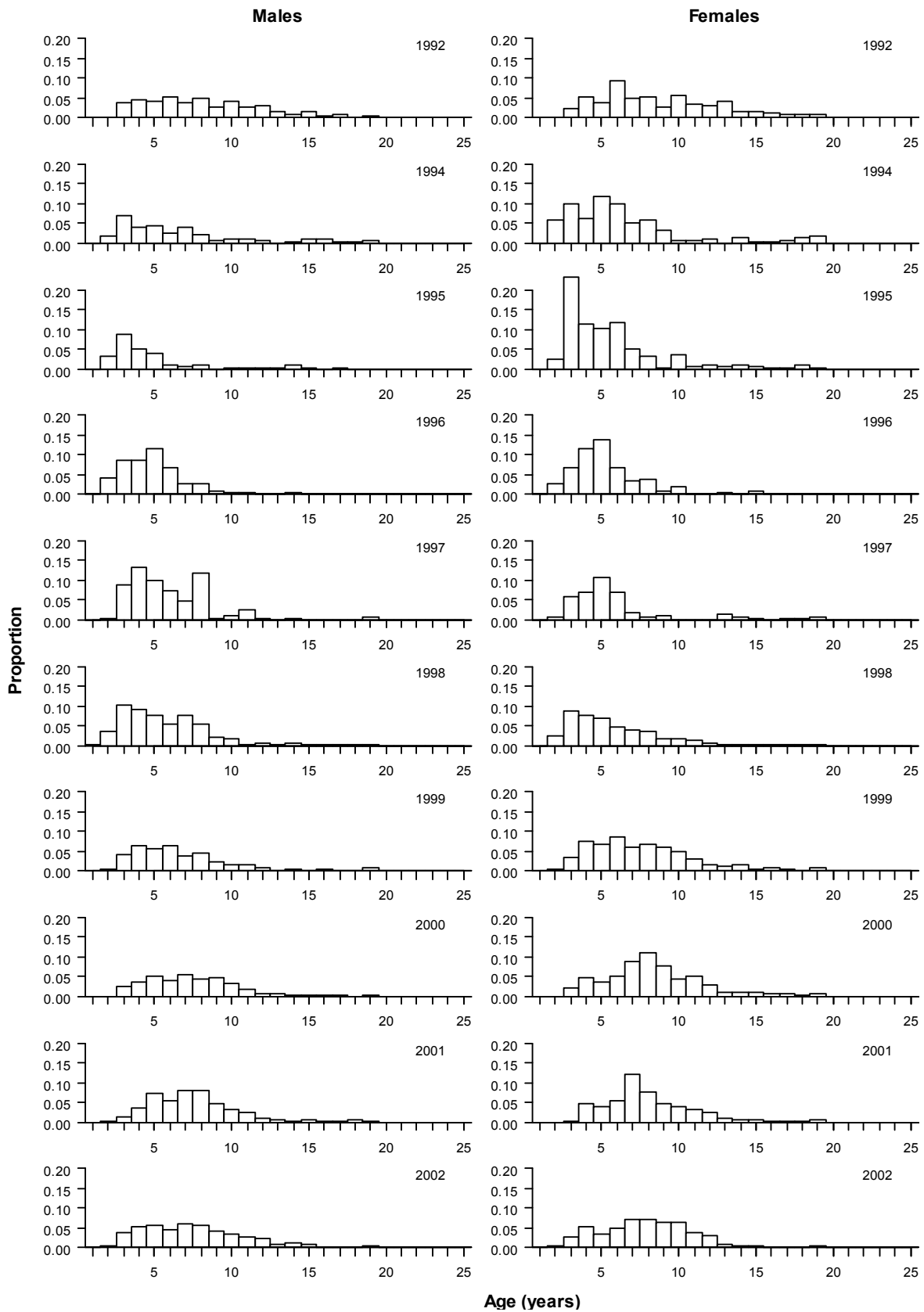


Figure A1: Age frequency distributions of hake from commercial catch-at-age data in the Chatham Rise (west) trawl fishery, 1992 to 2015. Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “2002” denotes the October 2001–April 2002 sample.

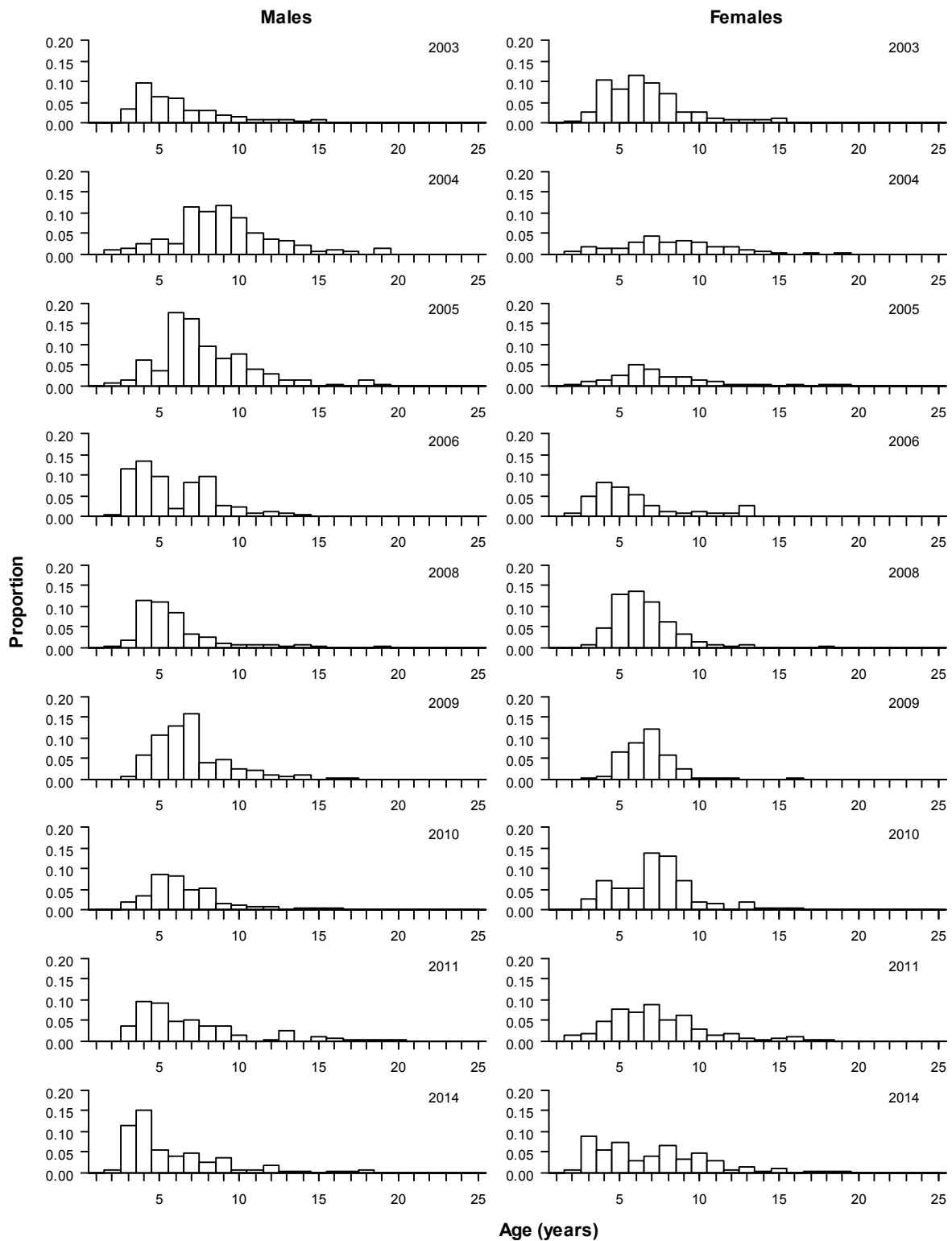


Figure A1 ctd.

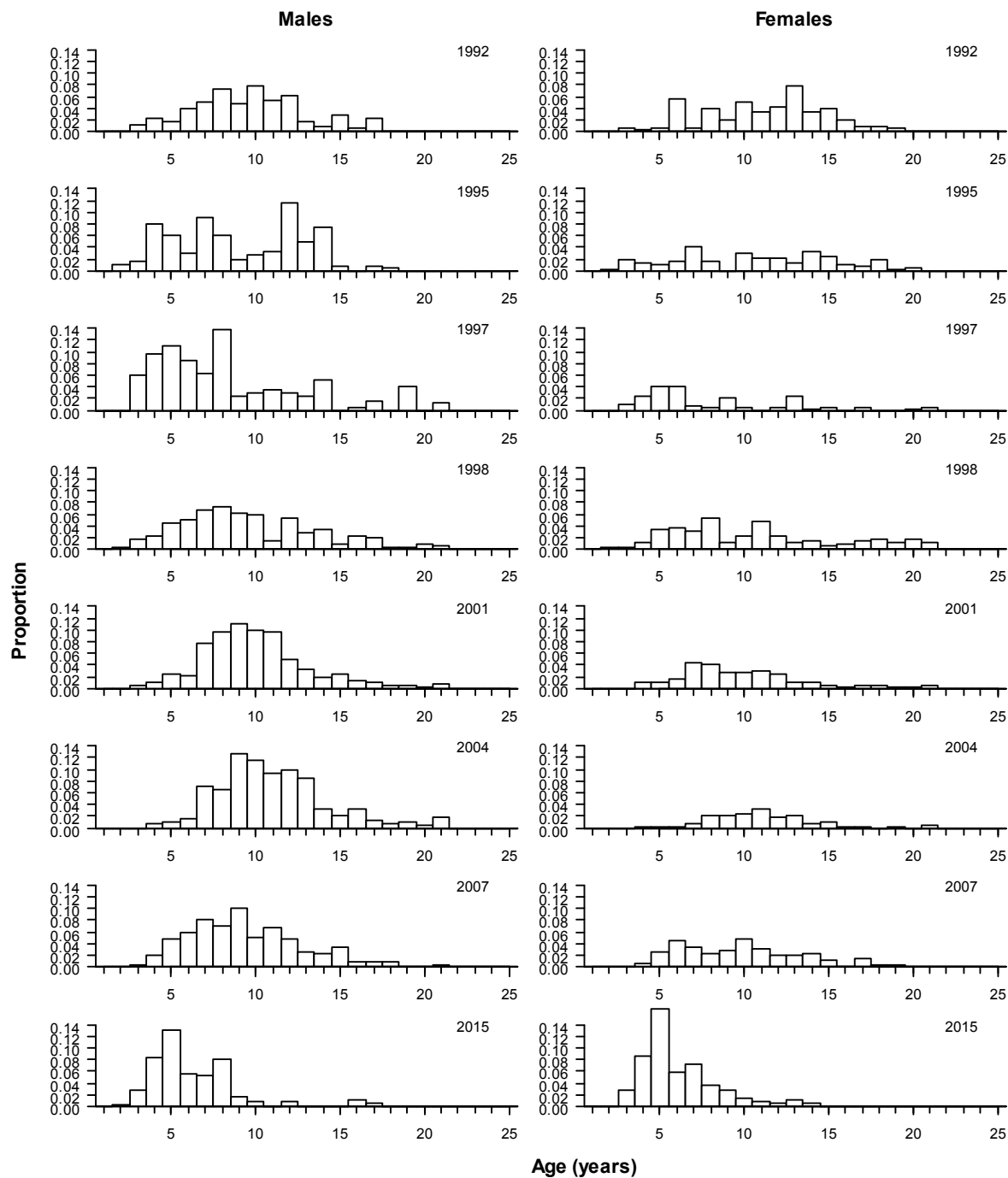


Figure A2: Age frequency distributions of hake from commercial catch-at-age data in the Chatham Rise (east) trawl fishery, 1992 to 2015. Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “1992” denotes the October 1991–April 1992 sample.

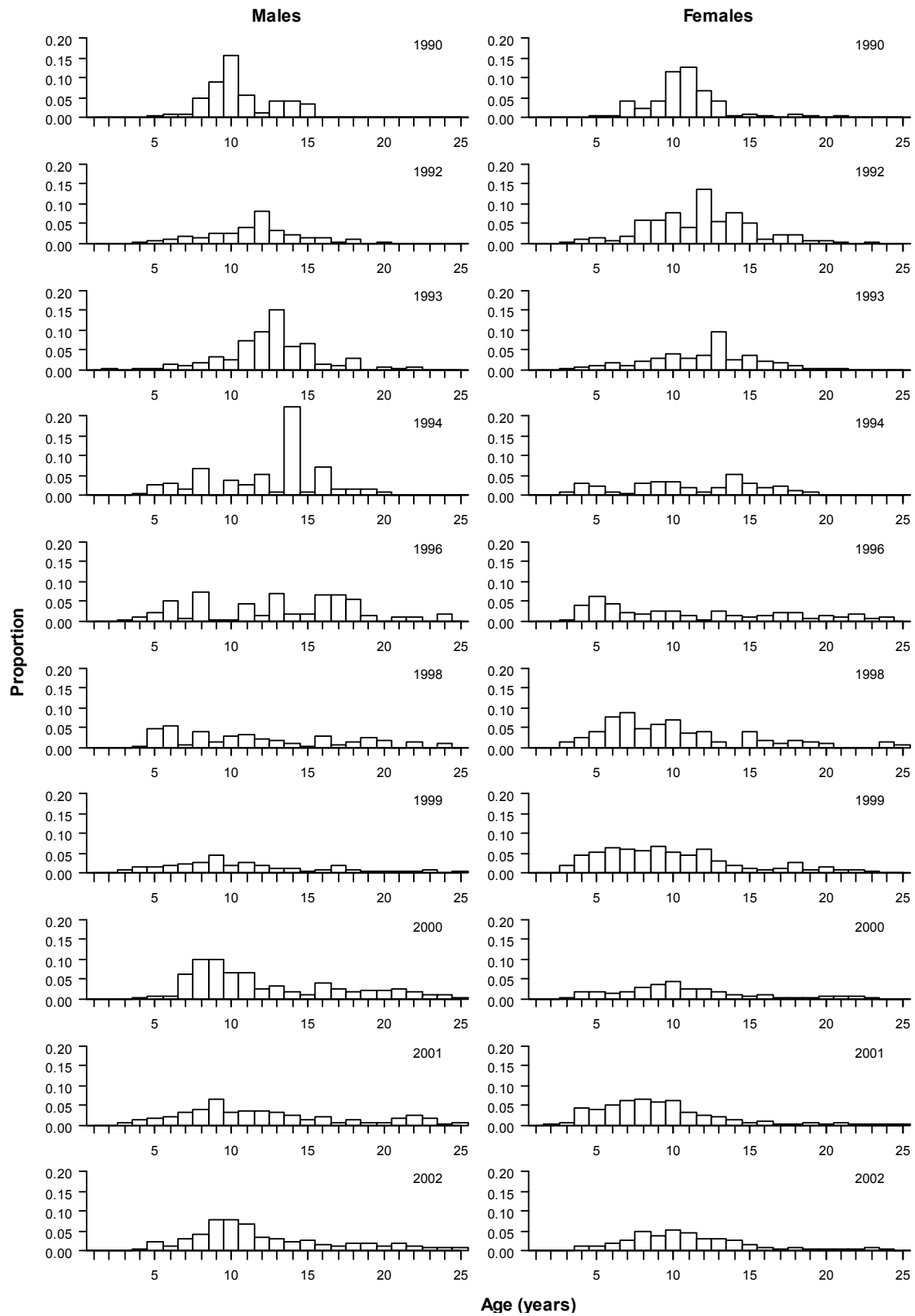


Figure A3: Age frequency distributions of hake from commercial catch-at-age data in the Sub-Antarctic trawl fishery, 1990 to 2015. Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “2002” denotes the September 2001–May 2002 sample.

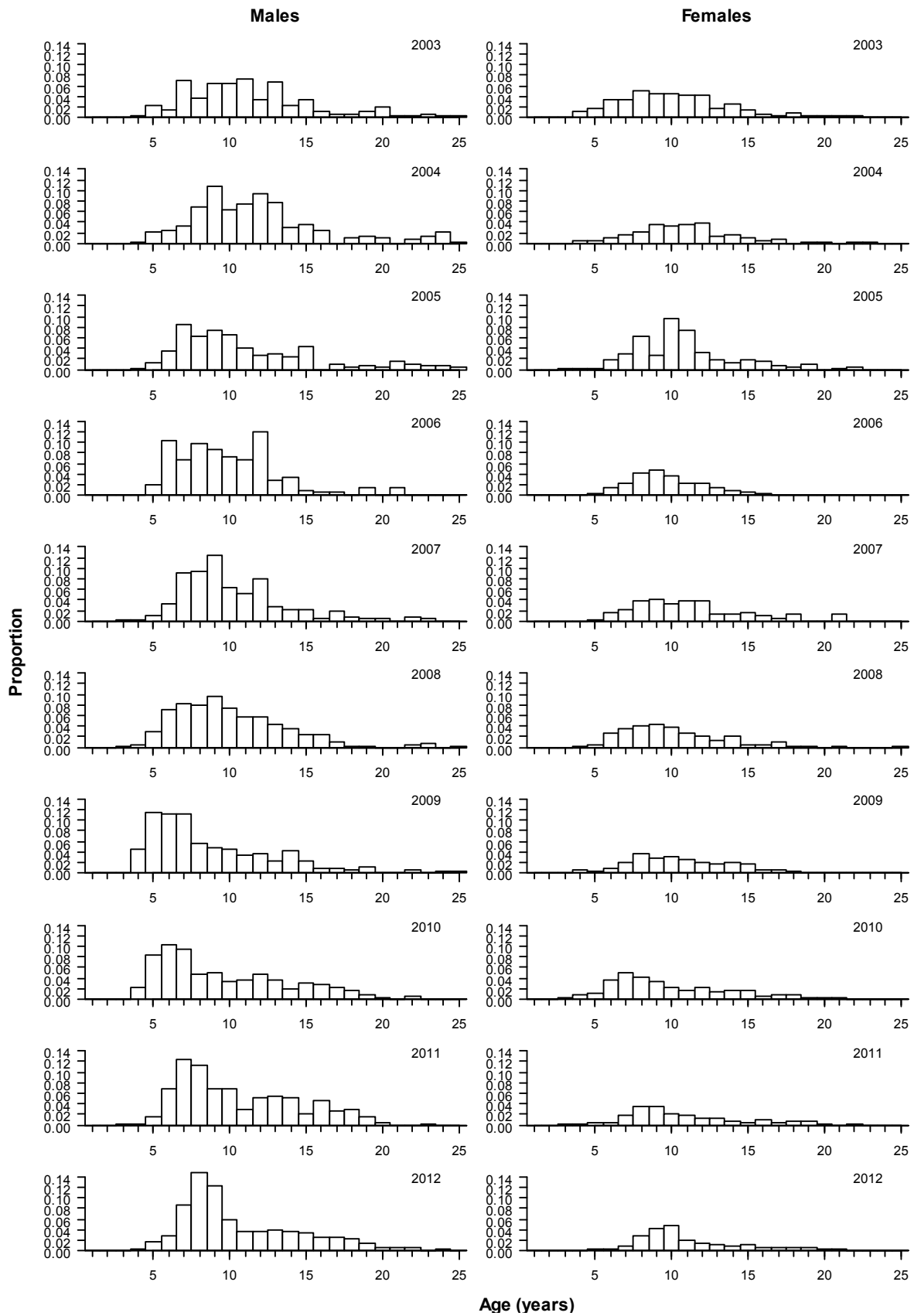


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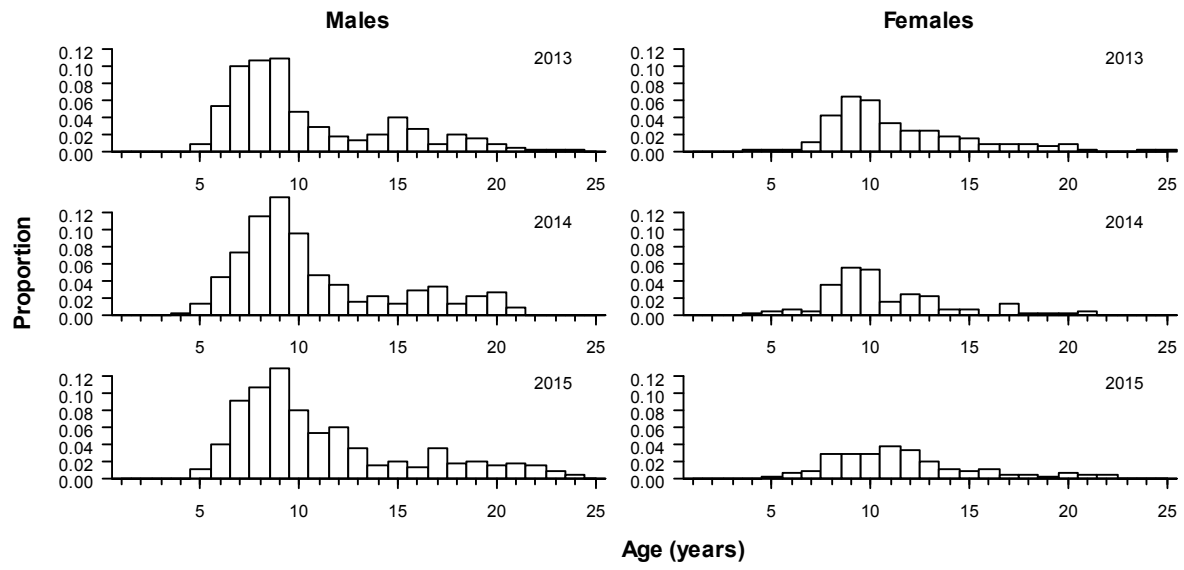


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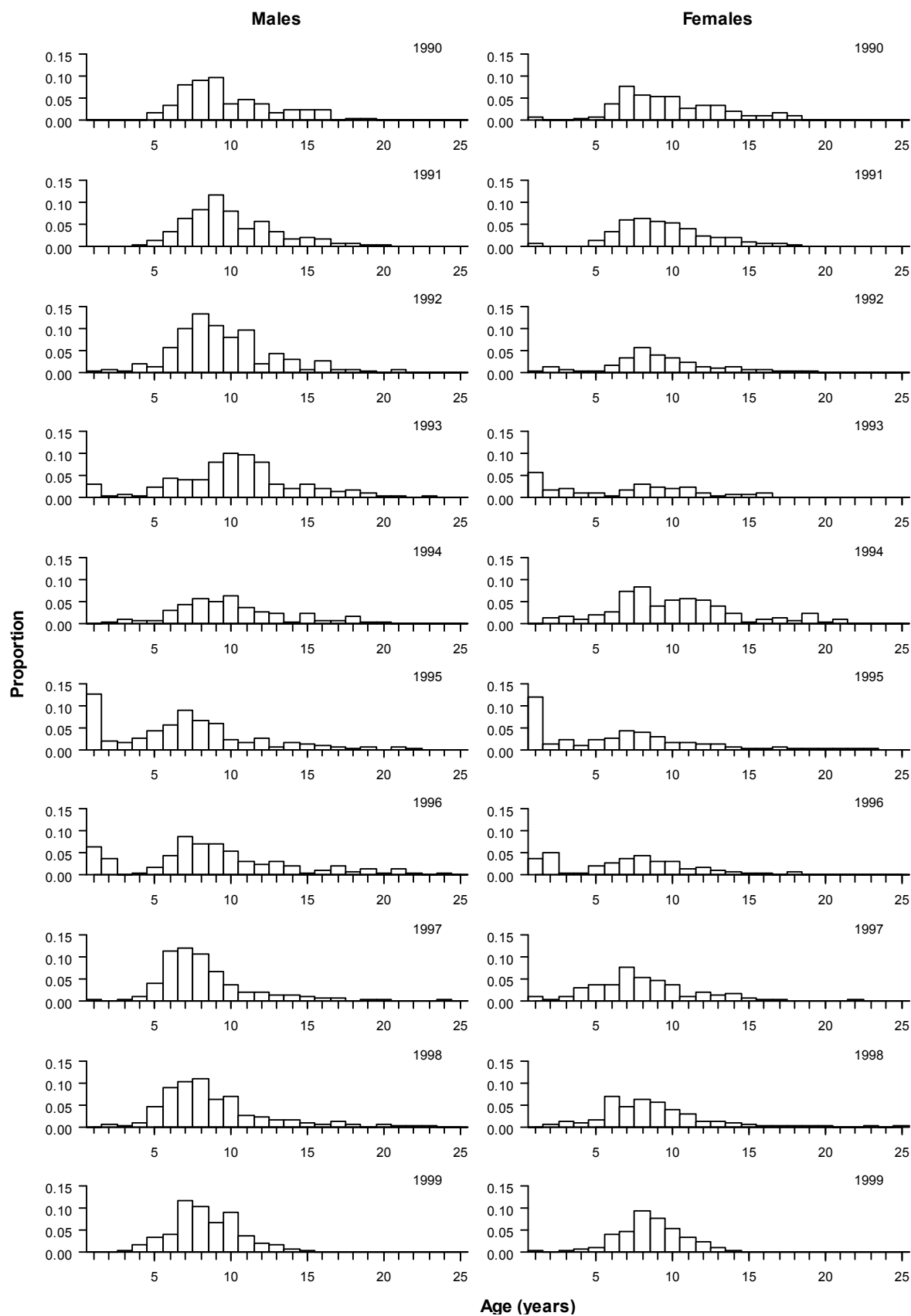


Figure A4: Age frequency distributions of hake from commercial catch-at-age data in the WCSI trawl fishery, 1990 to 2015.

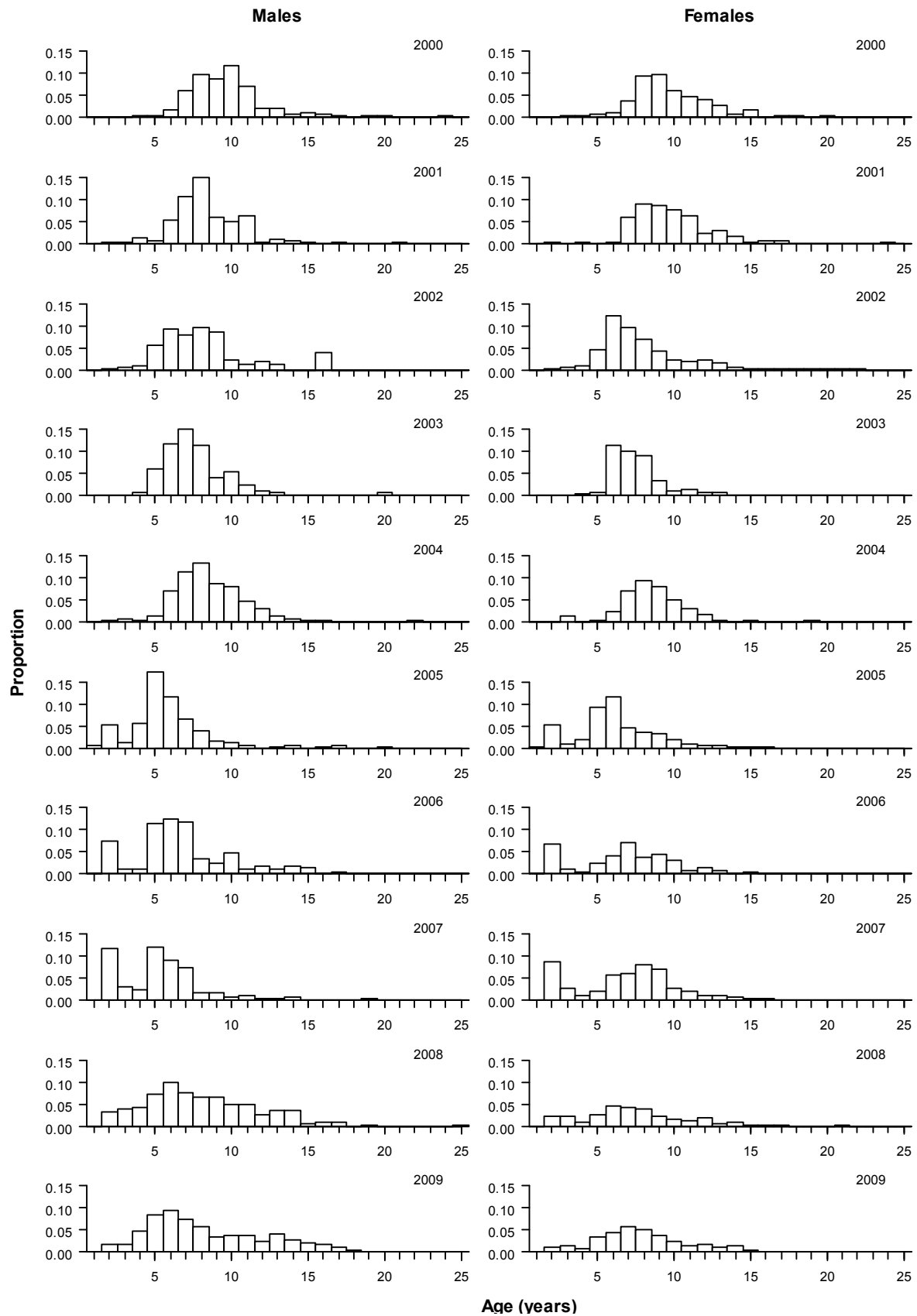


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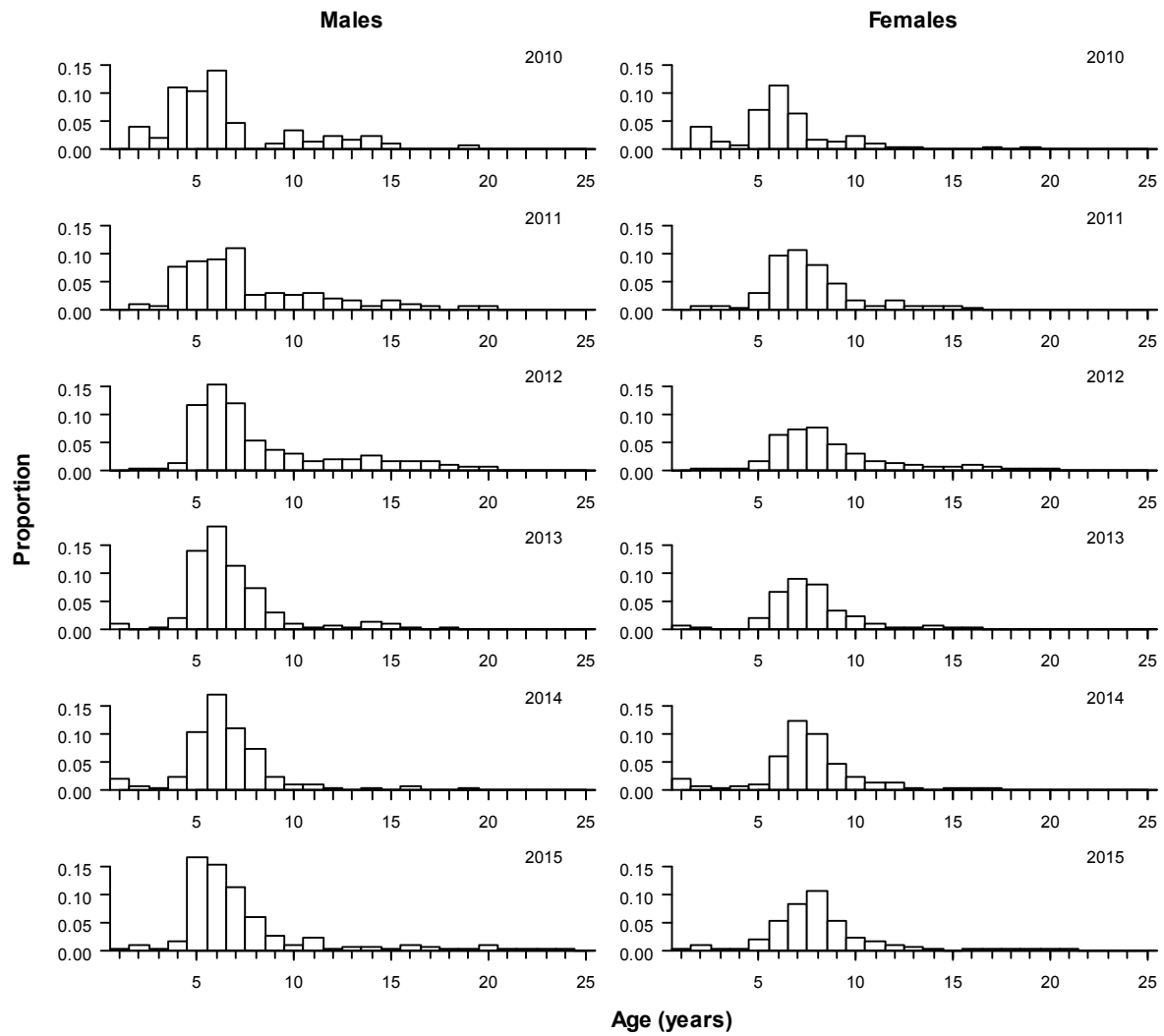


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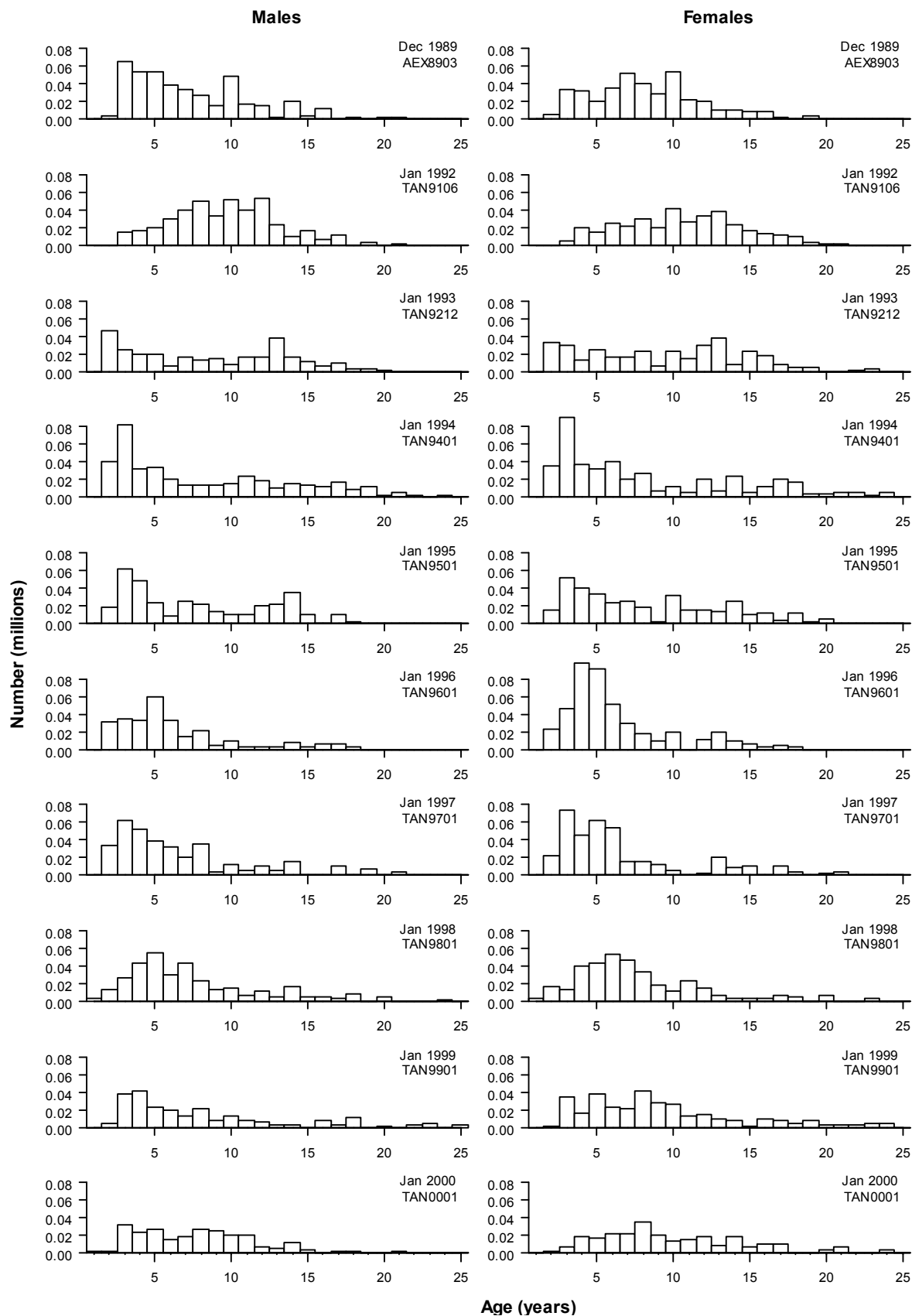


Figure A5: Age frequency distributions of hake (ages 1 to 25) from resource surveys in the Chatham Rise, 1989–90 to 2015–16.

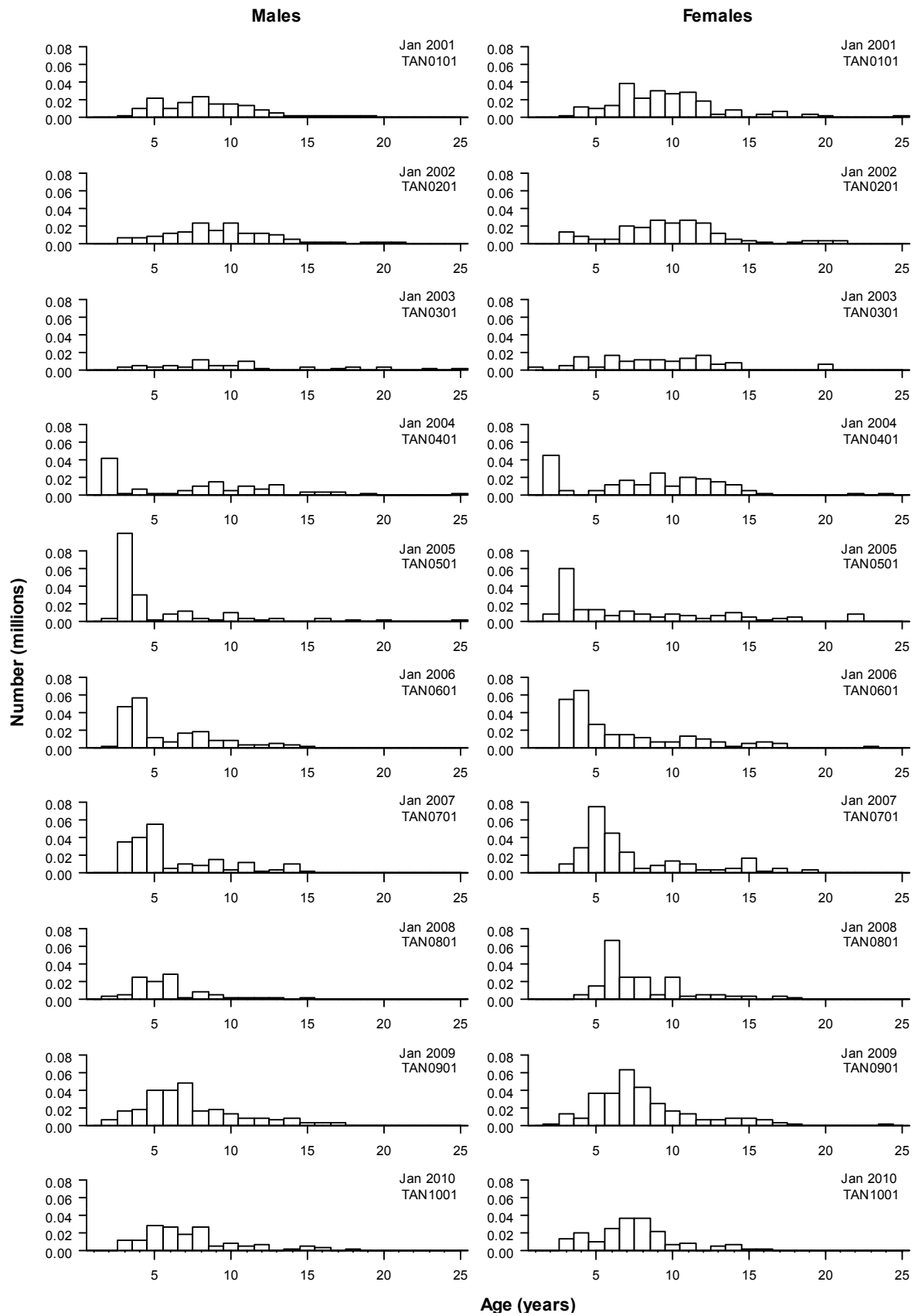


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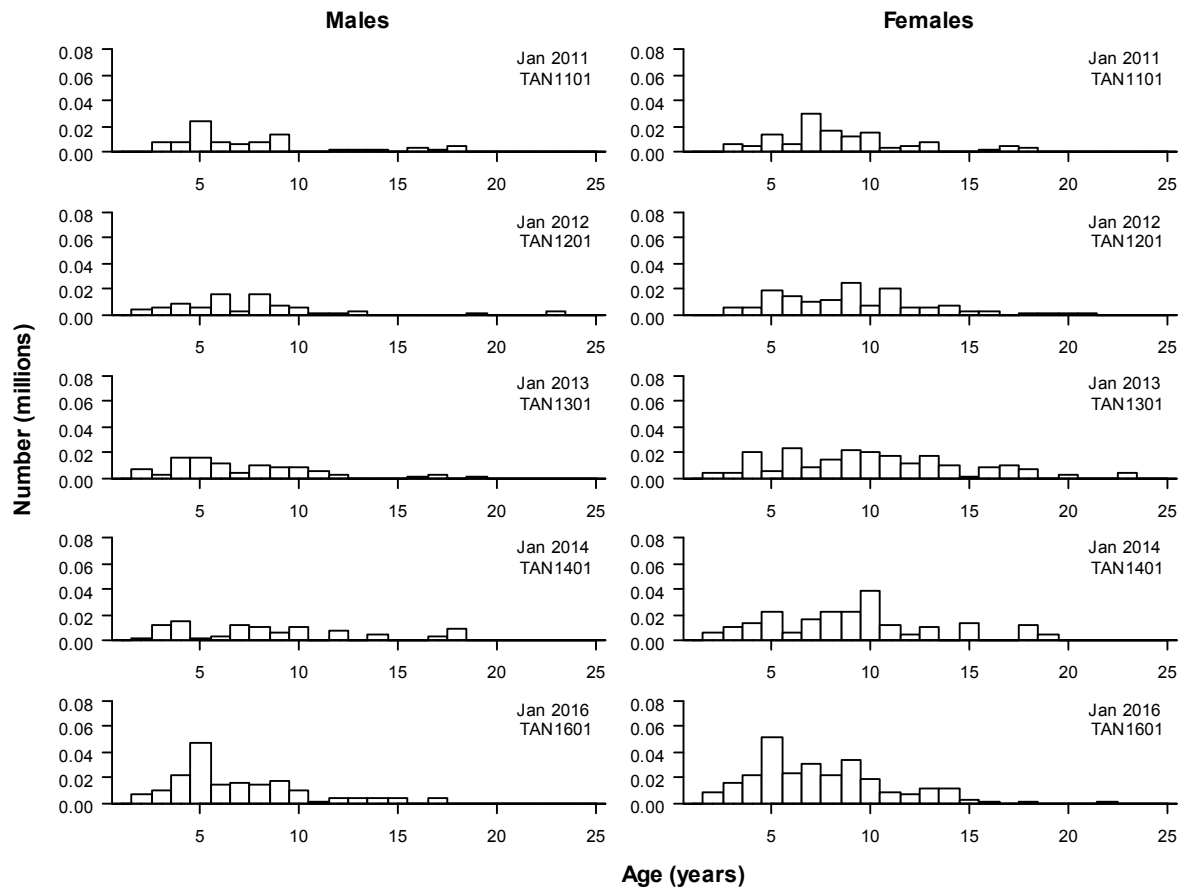


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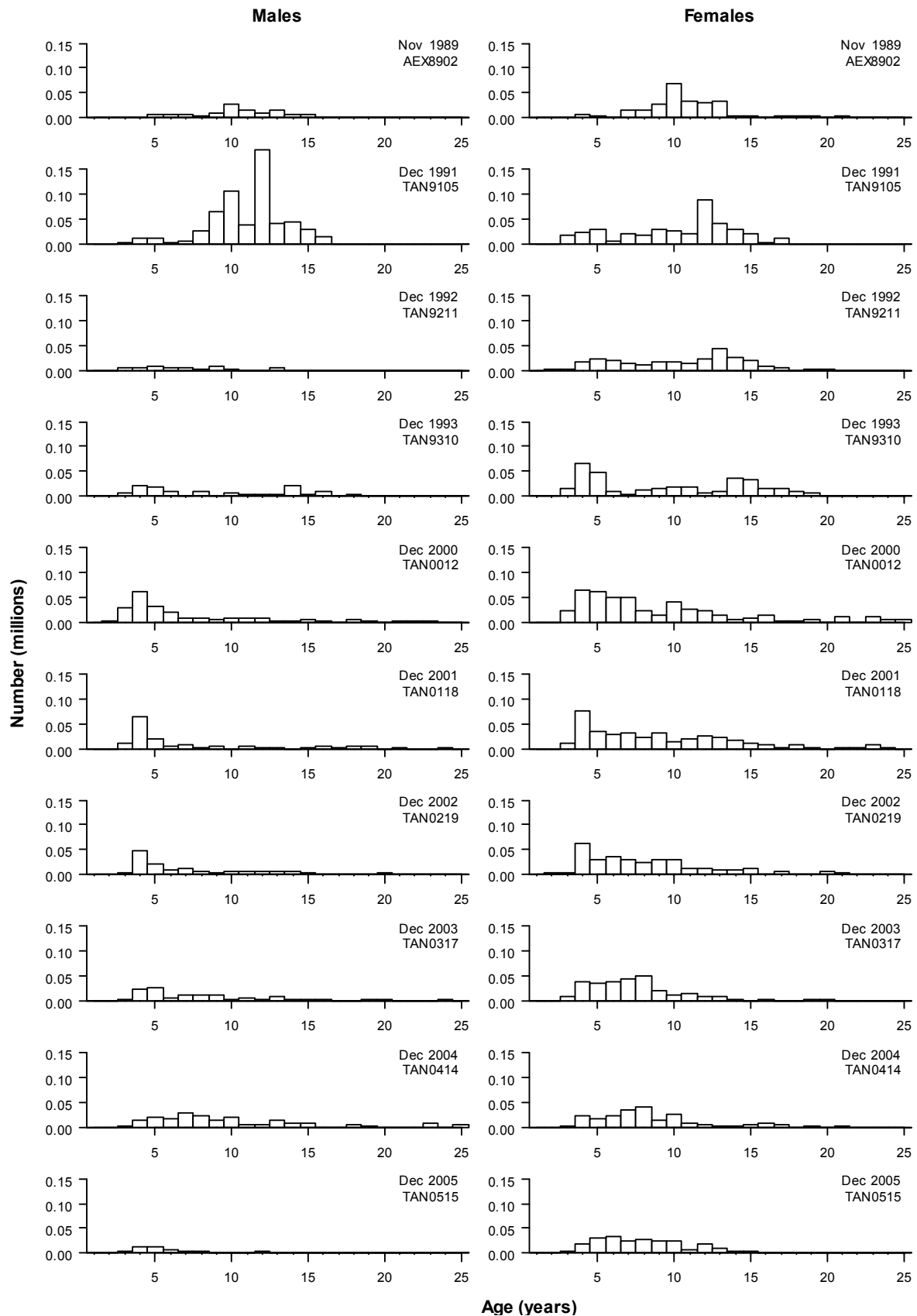


Figure A6: Age frequency distributions of hake (ages 1 to 25) from summer resource surveys in the Sub-Antarctic, 1989 to 2015.

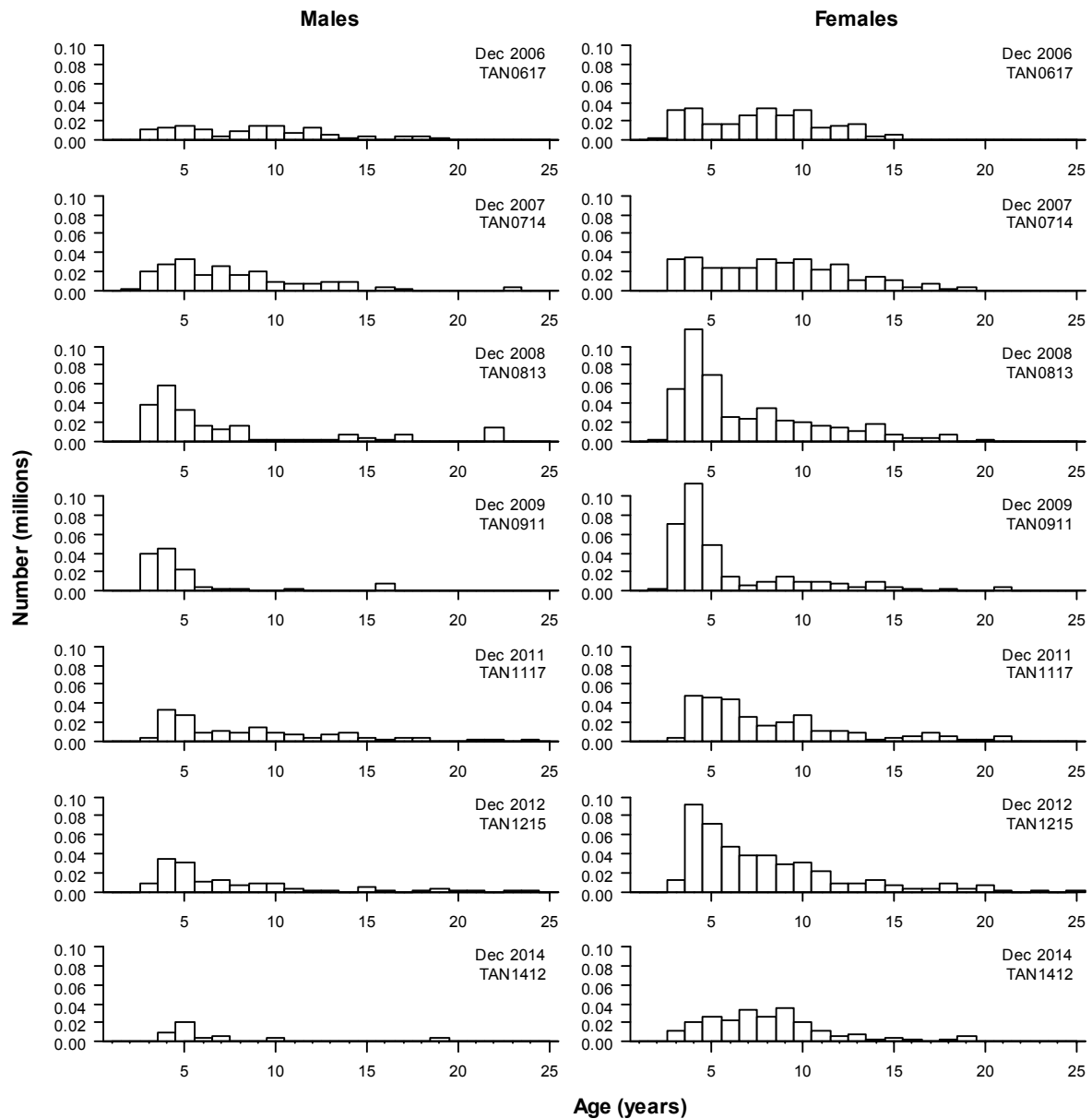


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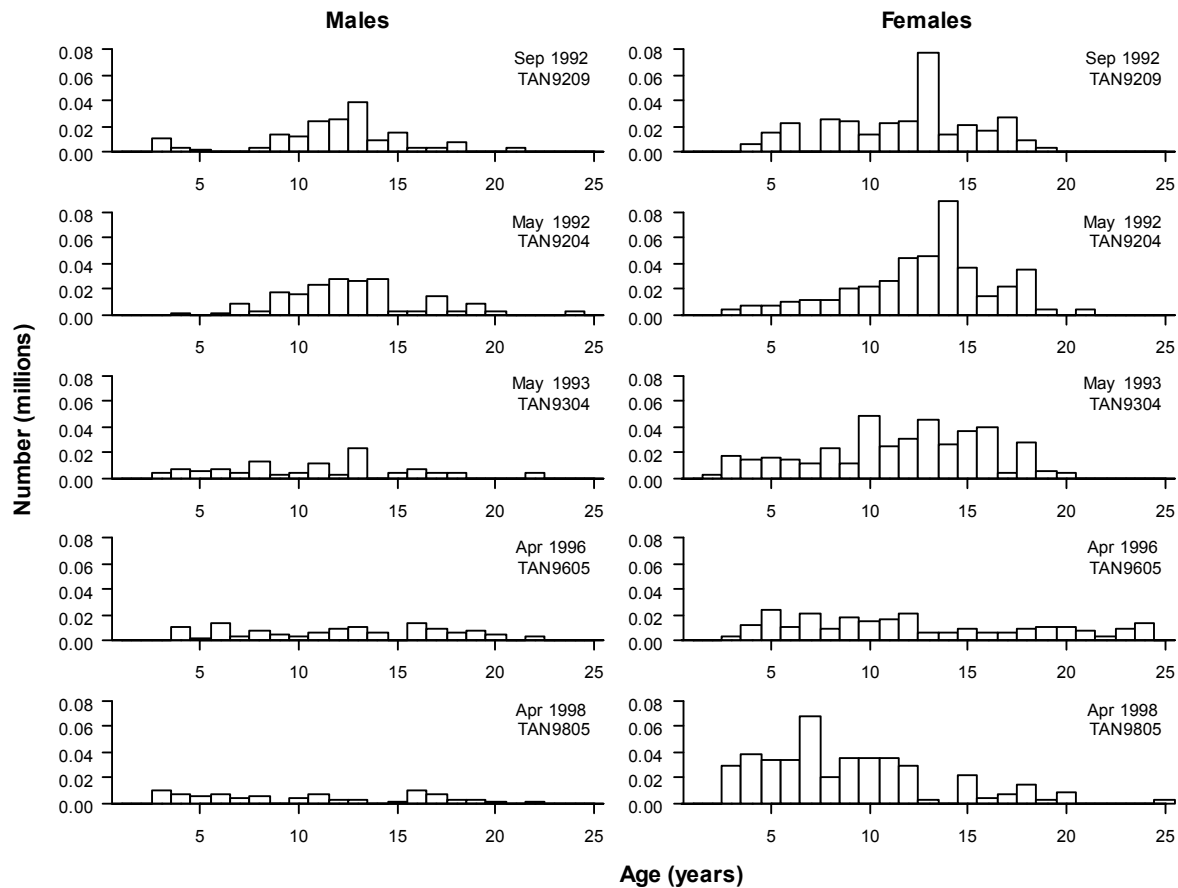


Figure A7: Age frequency distributions of hake (ages 1 to 25) from spring (September) and autumn (April–May) resource surveys in the Sub-Antarctic, 1992 to 1998.

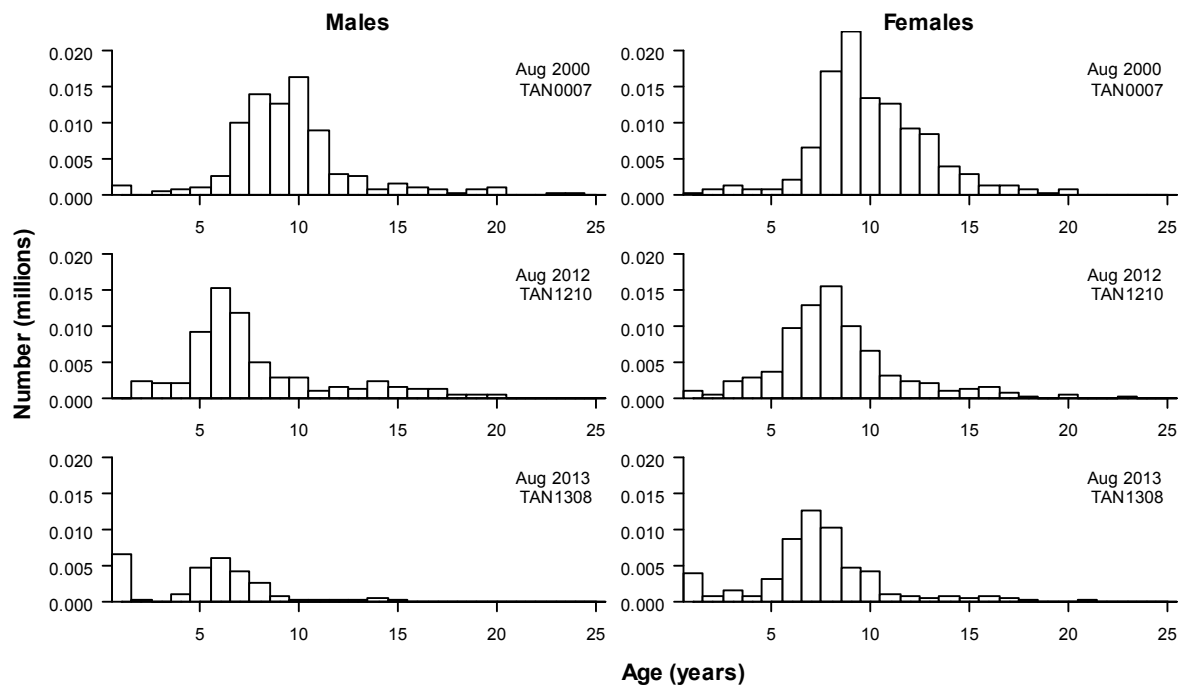


Figure A8: Age frequency distributions of hake (ages 1 to 25) from resource surveys off WCSI, from 2000 to 2014.

Appendix B: Summaries of the proportions-at-age data for ling

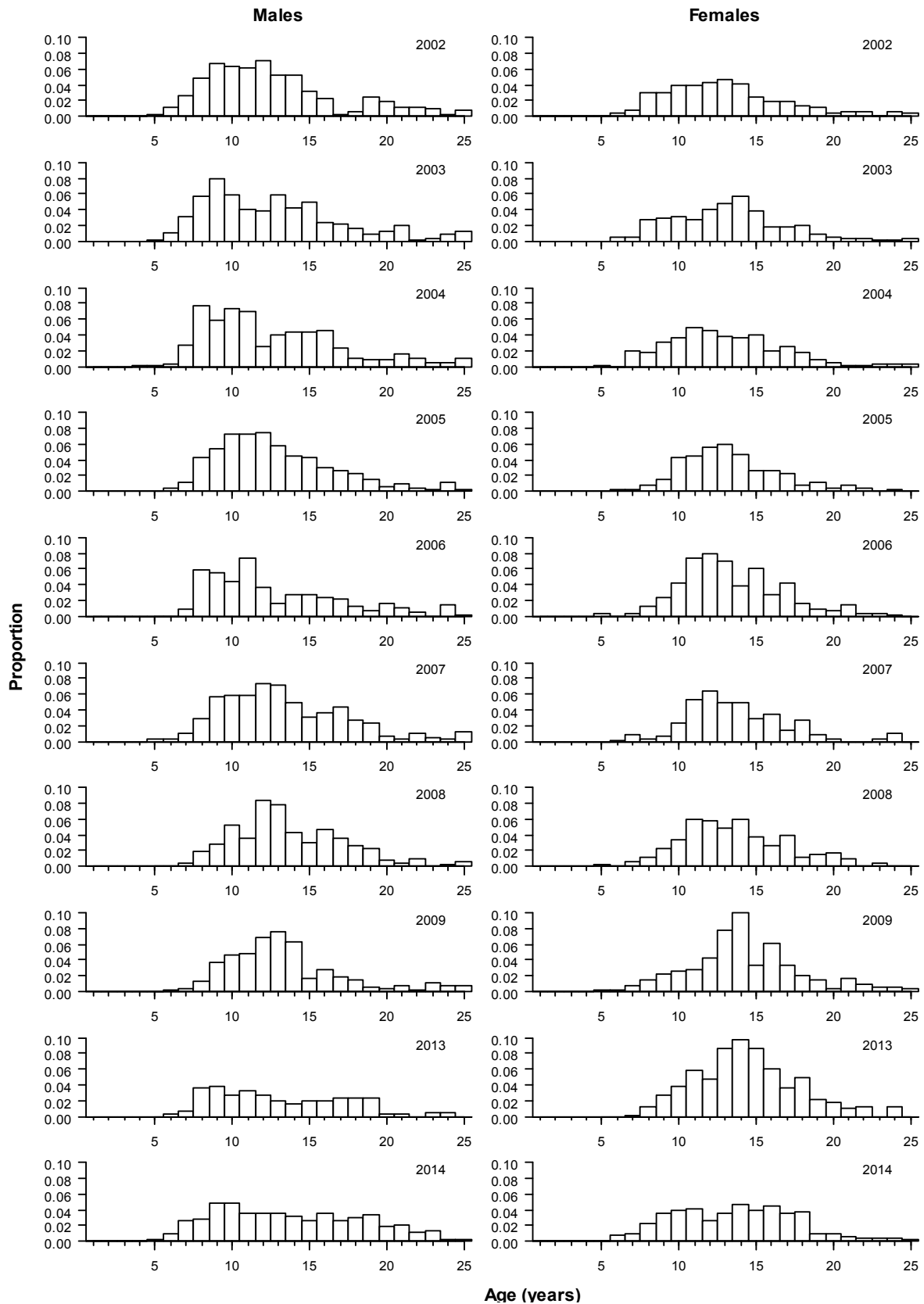


Figure B1: Age frequency distributions of ling from commercial catch-at-age data in the Chatham Rise longline fishery, 2002 to 2015.

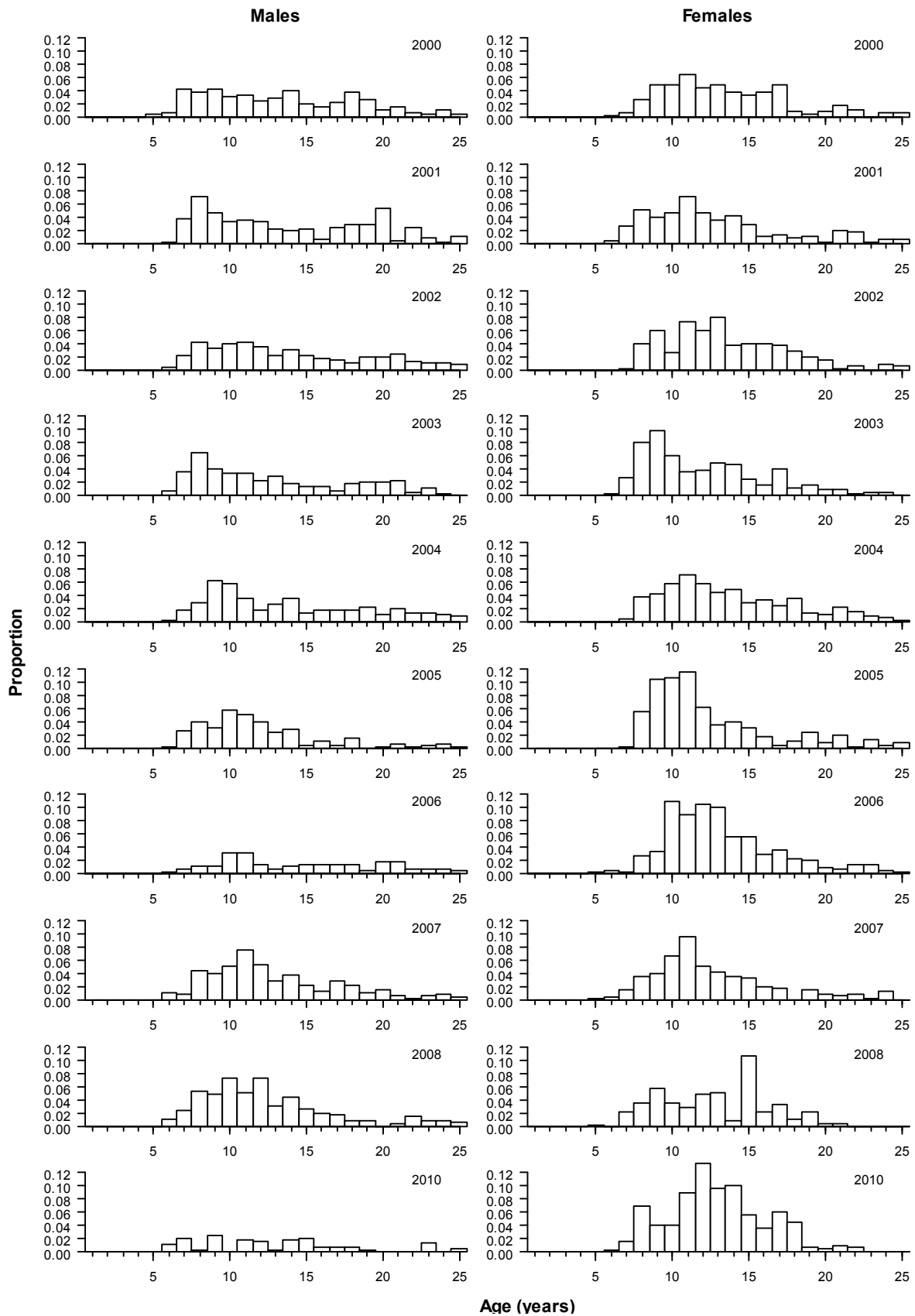


Figure B2: Age frequency distributions of ling from commercial catch-at-age data in the Sub-Antarctic (spawning season) longline fishery, 2000 to 2015.

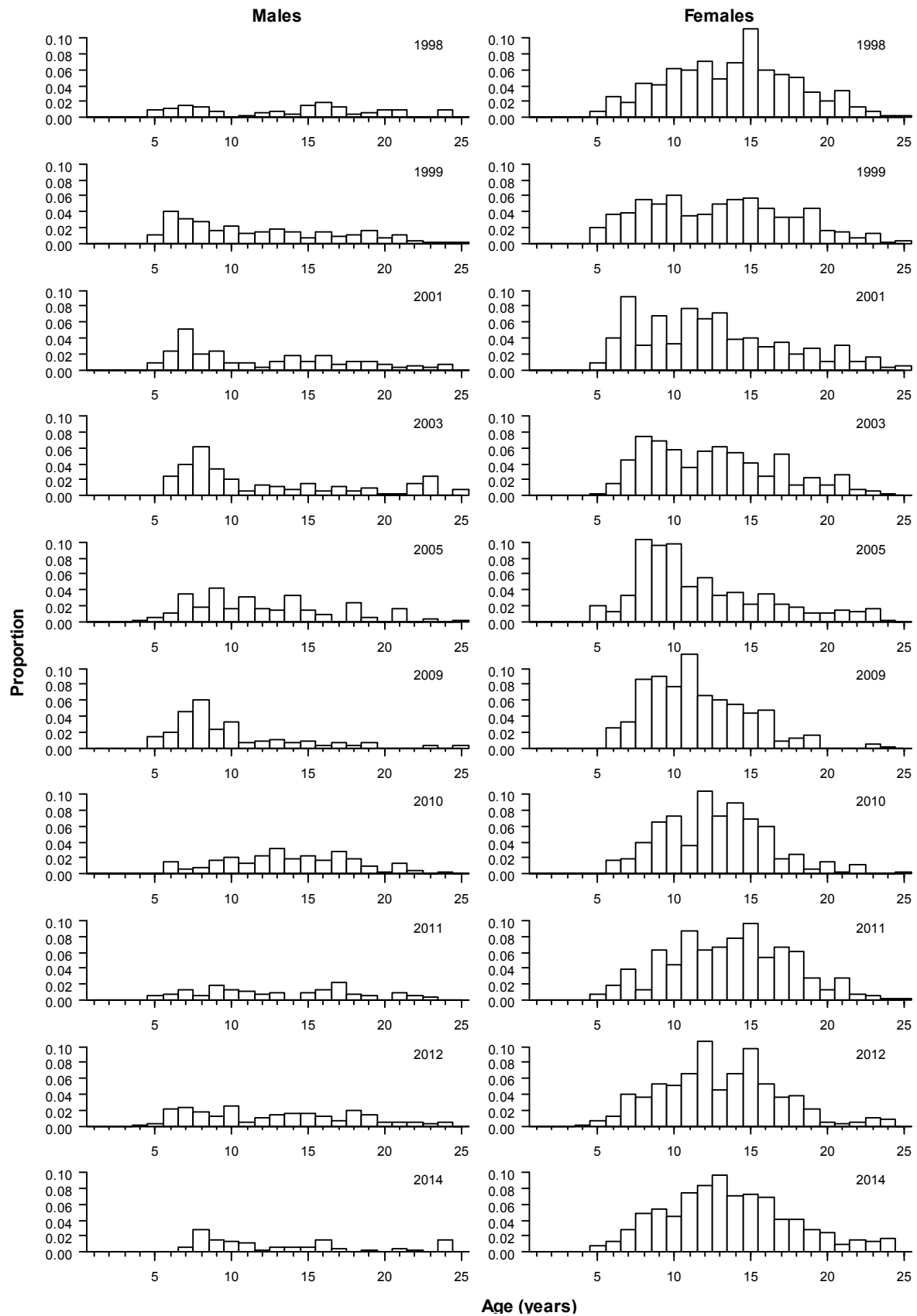


Figure B3: Age frequency distributions of ling from commercial catch-at-age data in the Sub-Antarctic (non-spawning season) longline fishery, 1998 to 2015.

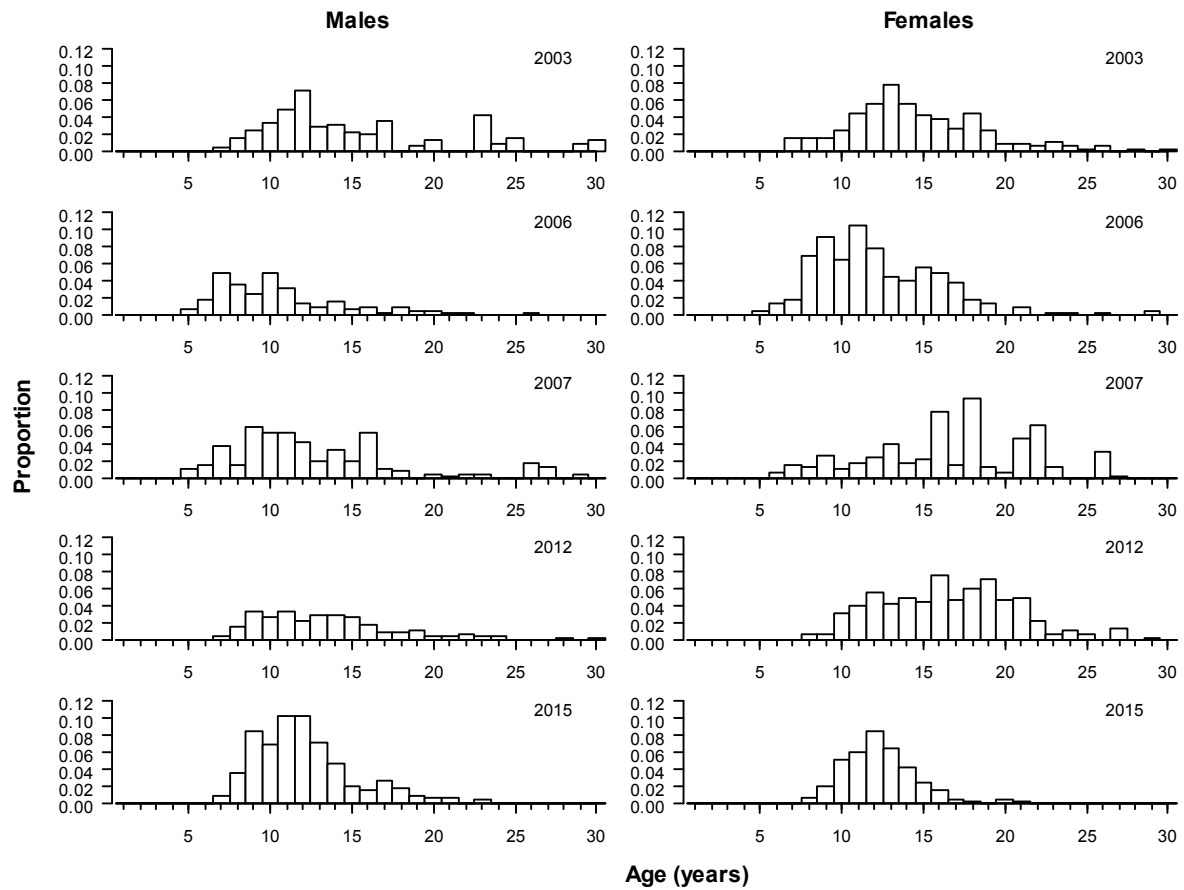


Figure B4: Age frequency distributions of ling from commercial catch-at-age data in the west coast South Island line fishery, 2003 to 2015.

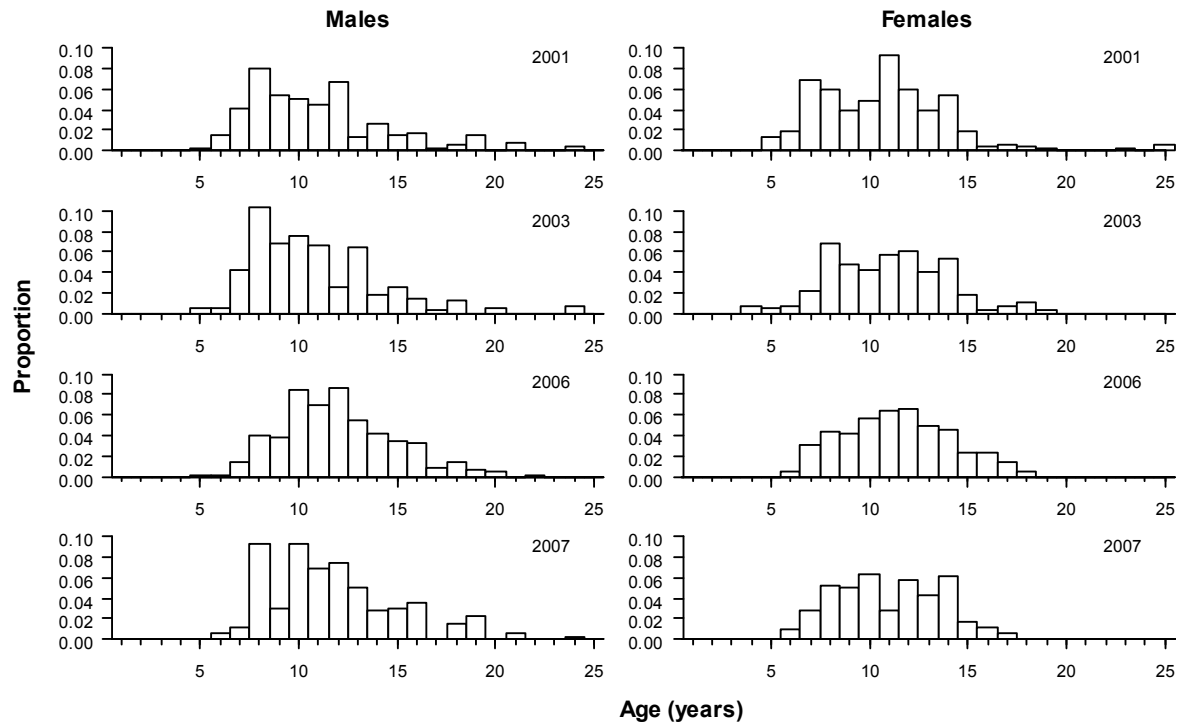


Figure B5: Age frequency distributions of ling from commercial catch-at-age data in the Cook Strait longline fishery, 2001 to 2015.

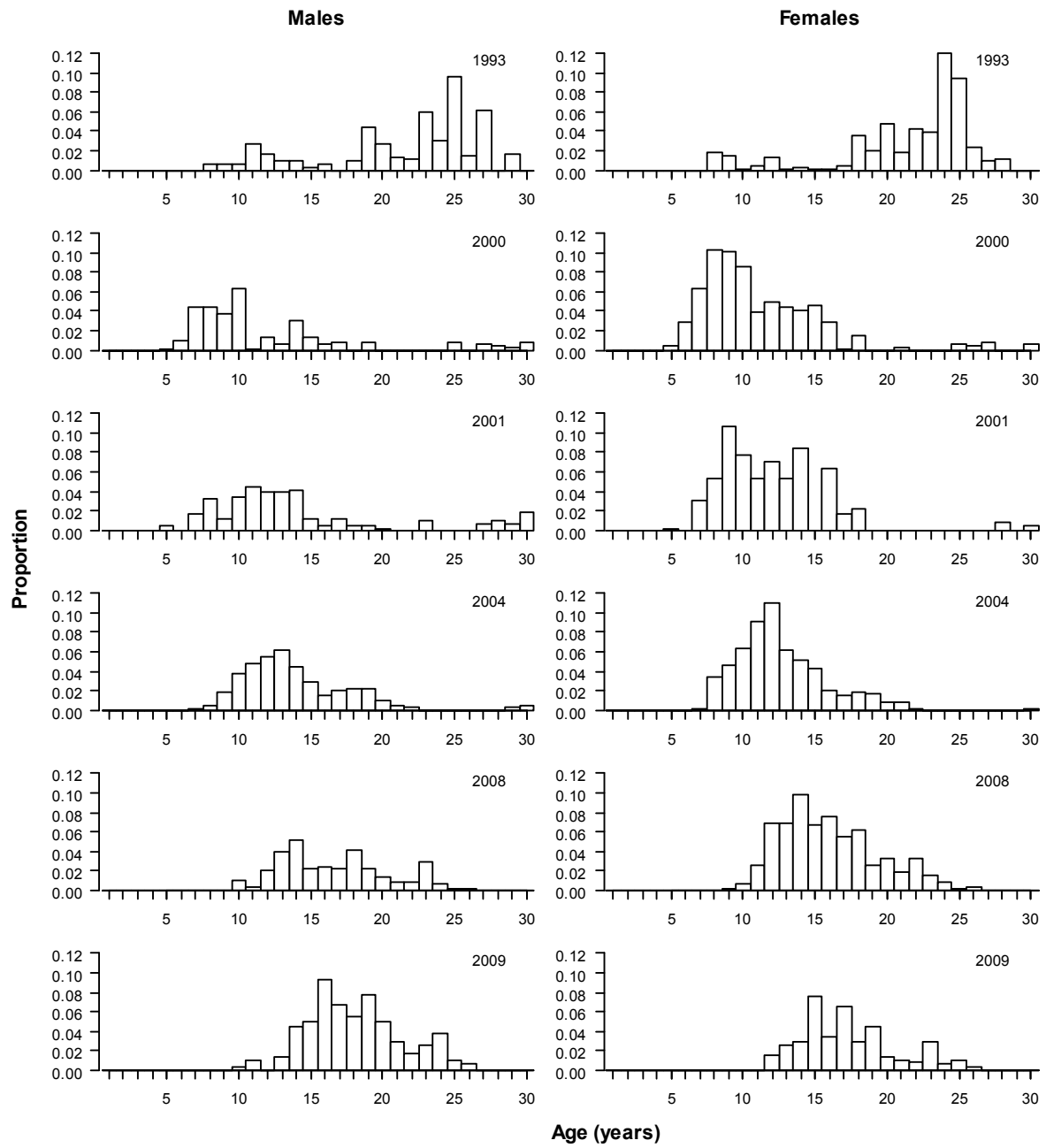


Figure B6: Age frequency distributions of ling from commercial catch-at-age data in the Bounty Plateau longline fishery, 1993 to 2015.

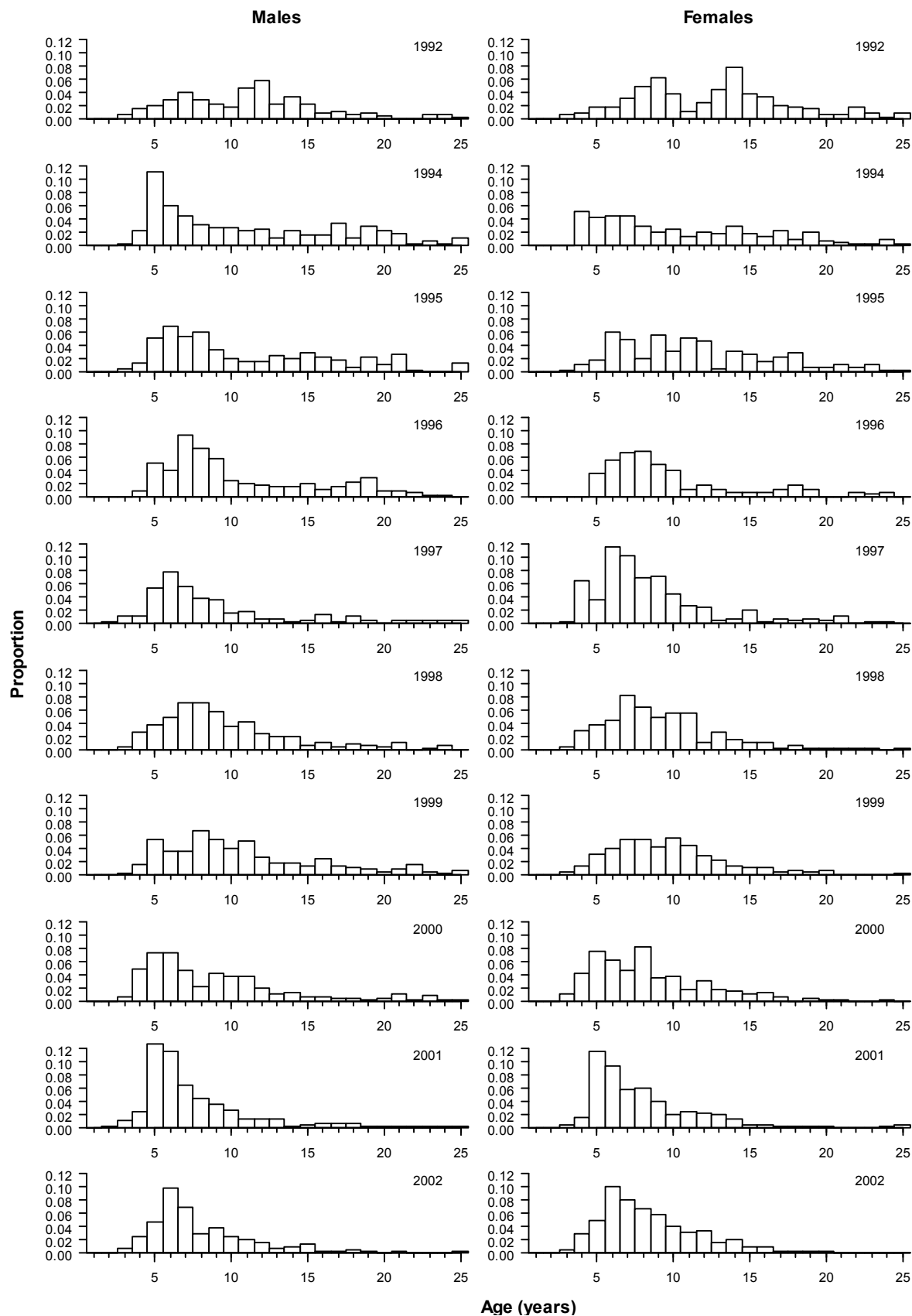


Figure B7: Age frequency distributions of ling from commercial catch-at-age data in the Chatham Rise trawl fishery, 1992 to 2015. Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “2002” denotes the October 2001–May 2002 sample.

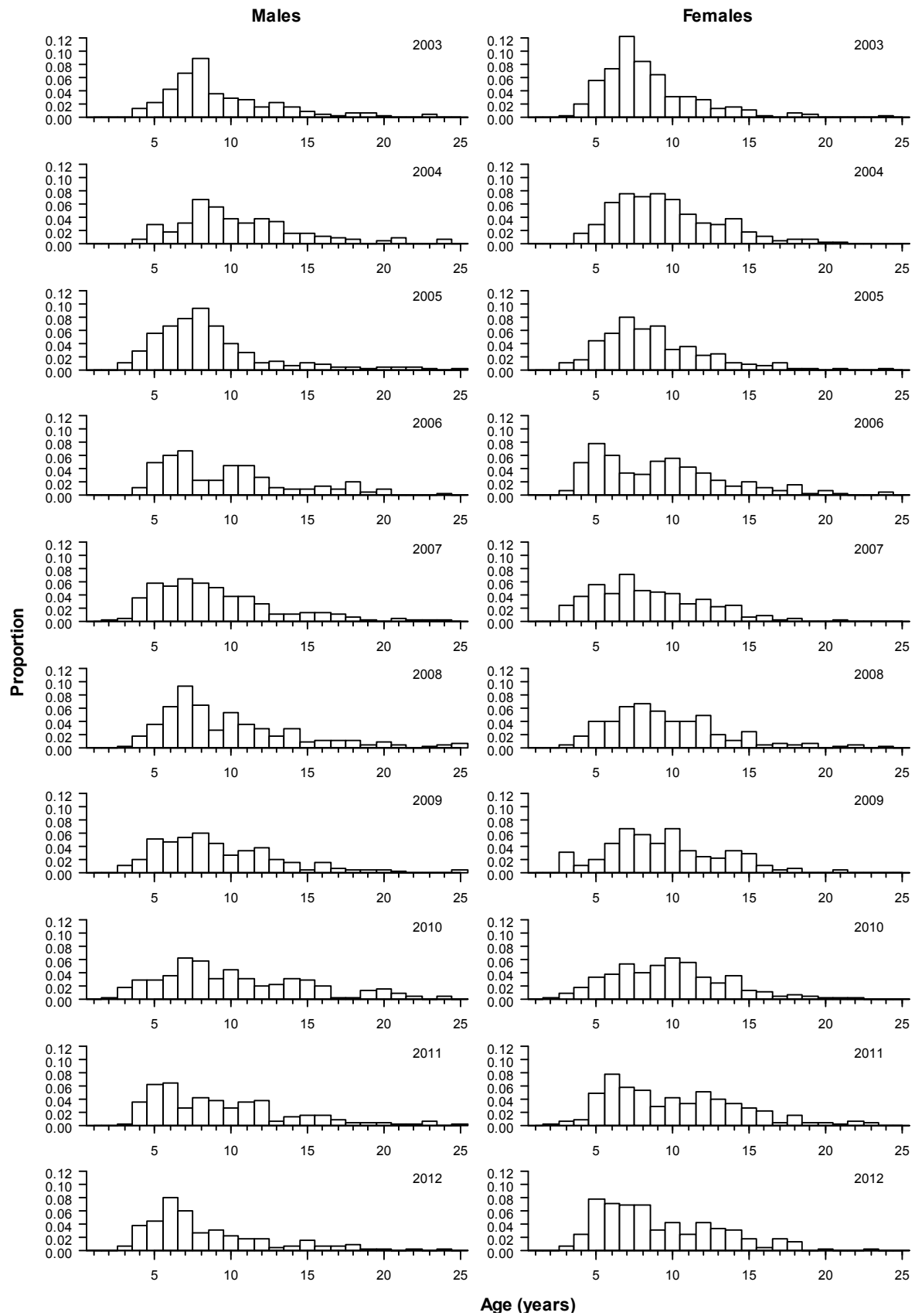


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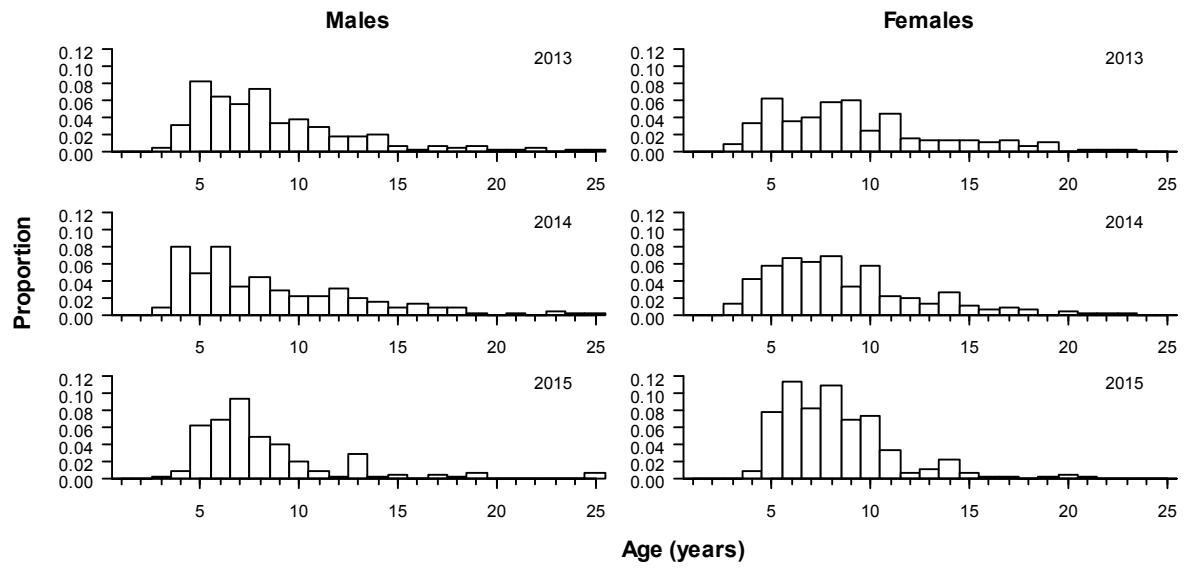


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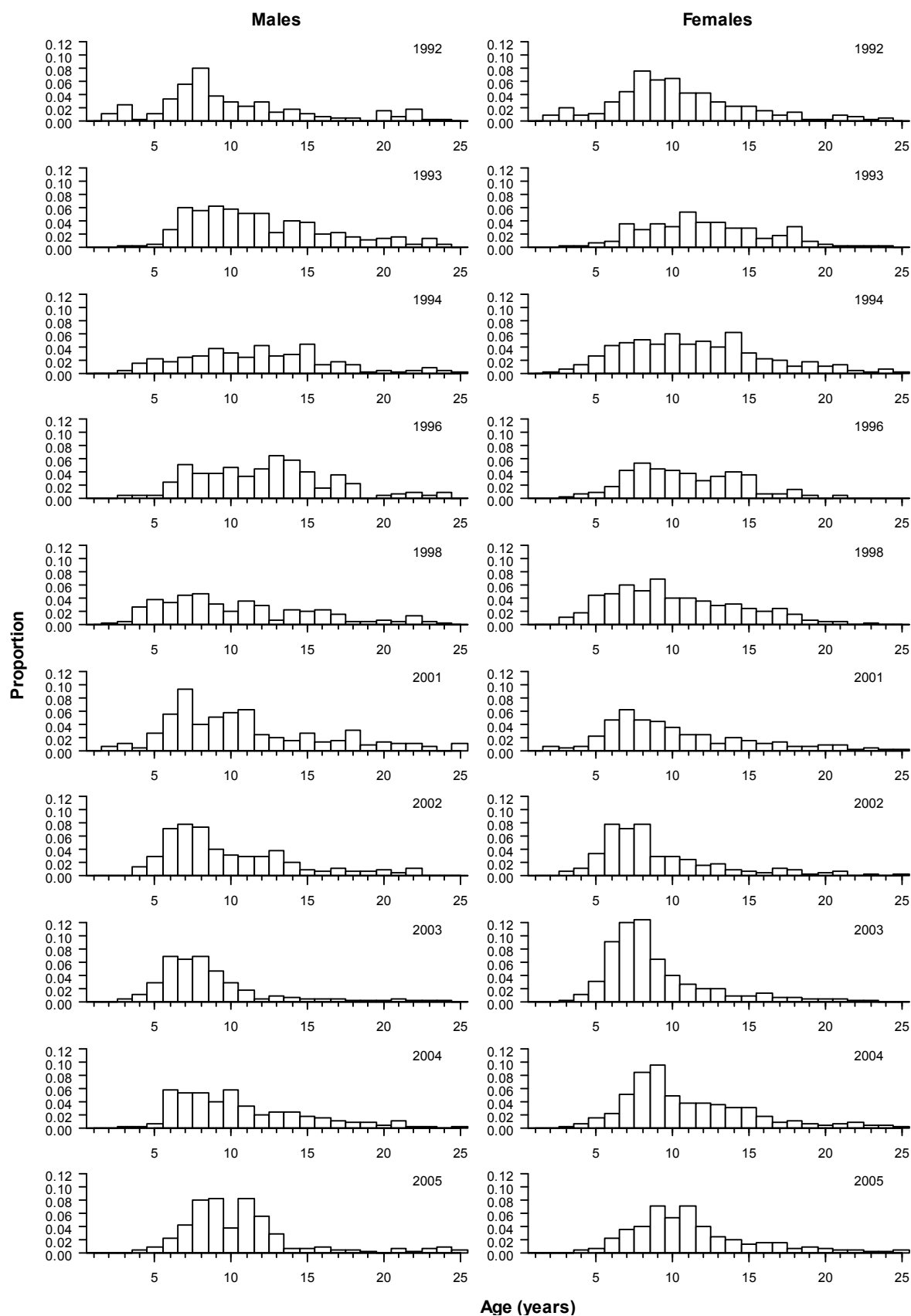


Figure B8: Age frequency distributions of ling from commercial catch-at-age data in the Sub-Antarctic trawl fishery, 1992 to 2015. Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “2005” denotes the September 2004–April 2005 sample.

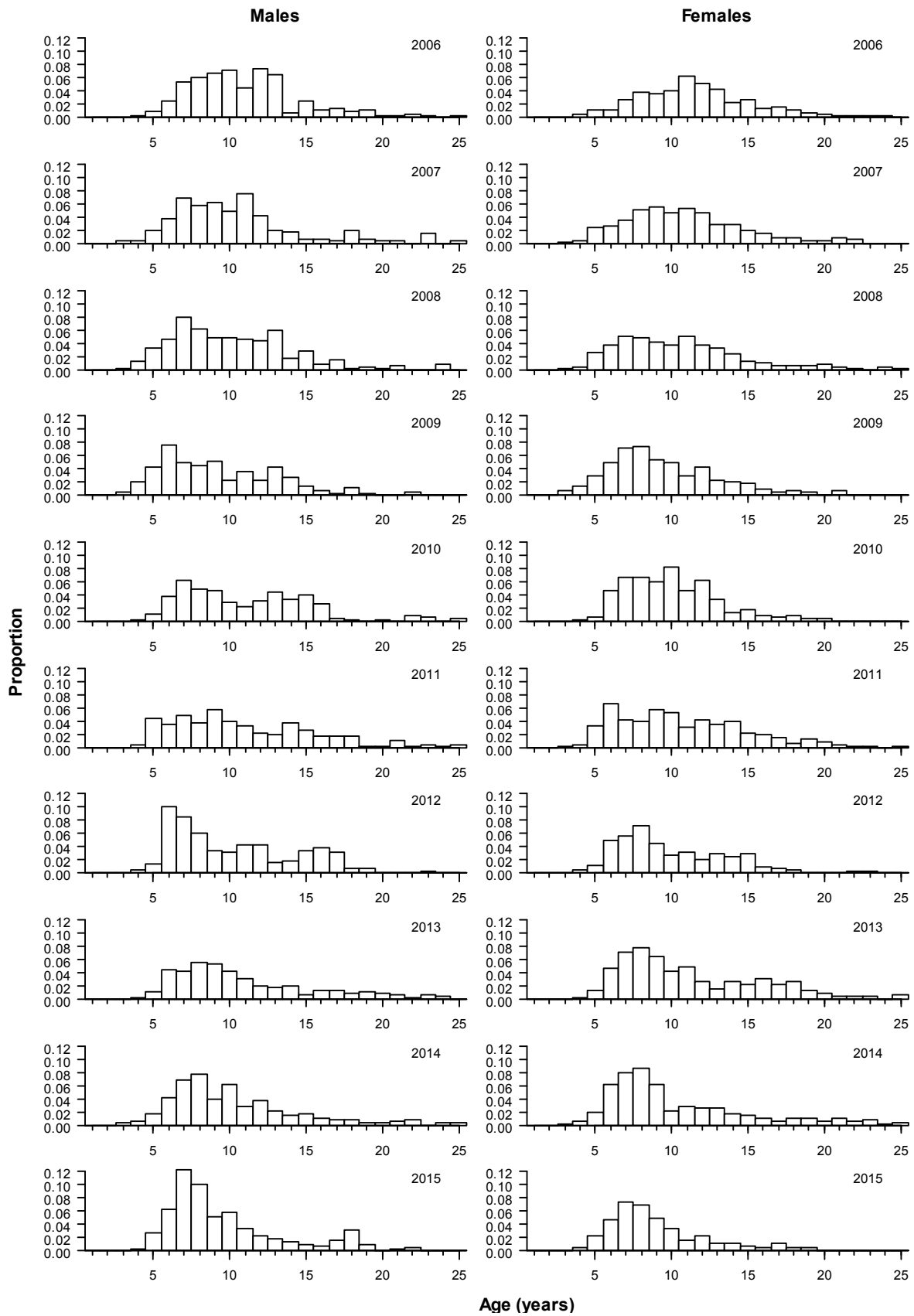


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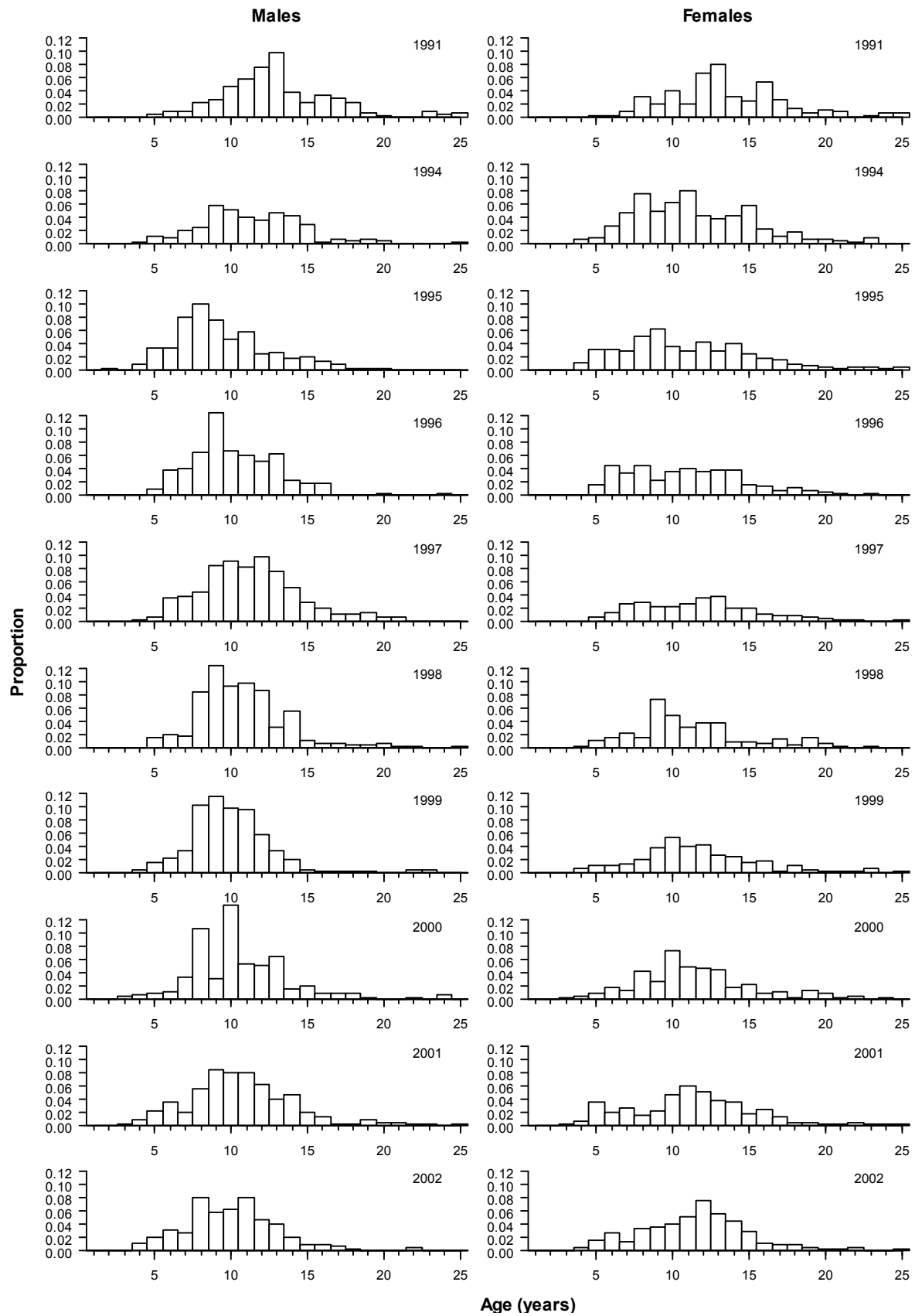


Figure B9: Age frequency distributions of ling from commercial catch-at-age data in the WCSI trawl fishery, 1991 to 2015.

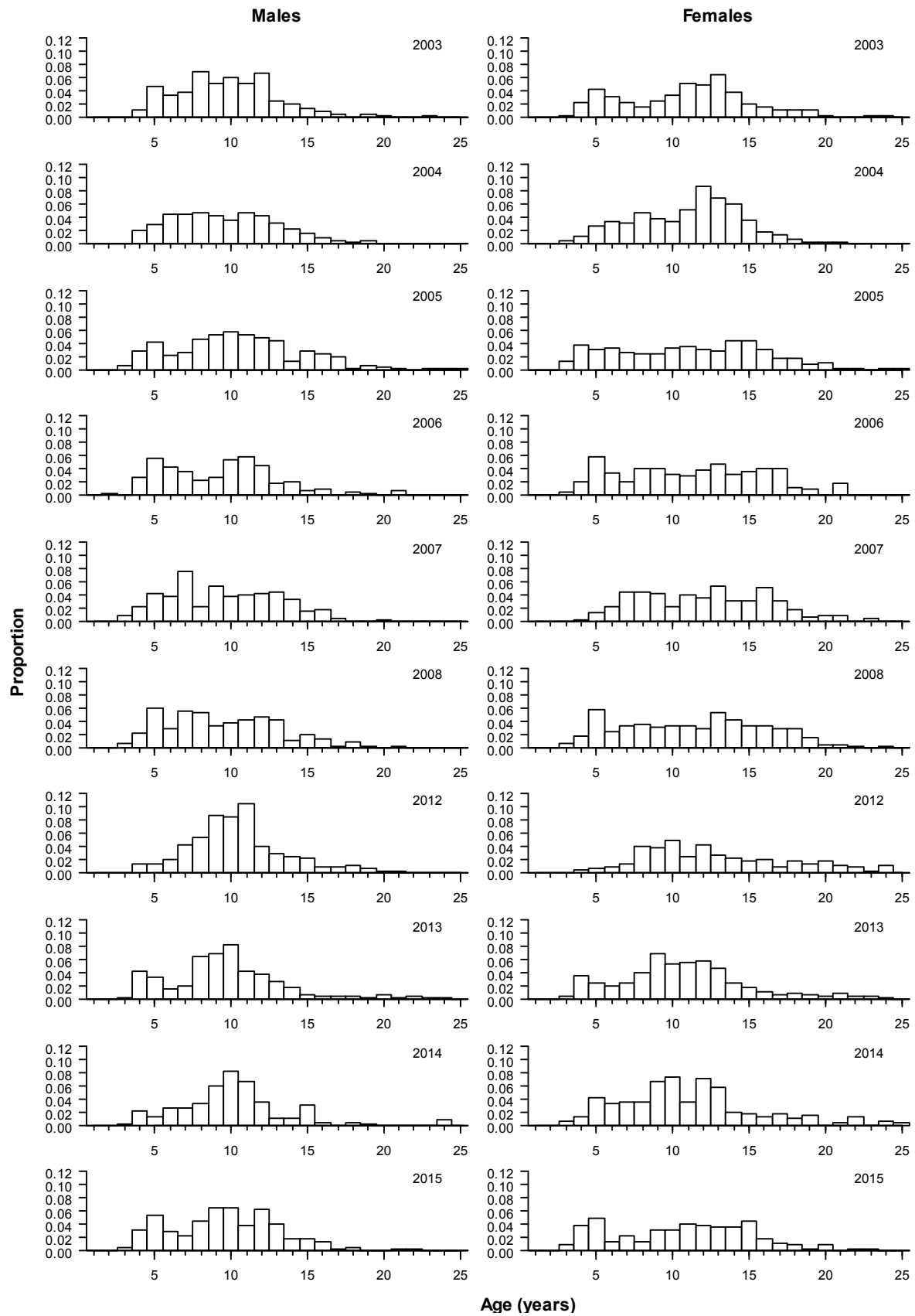


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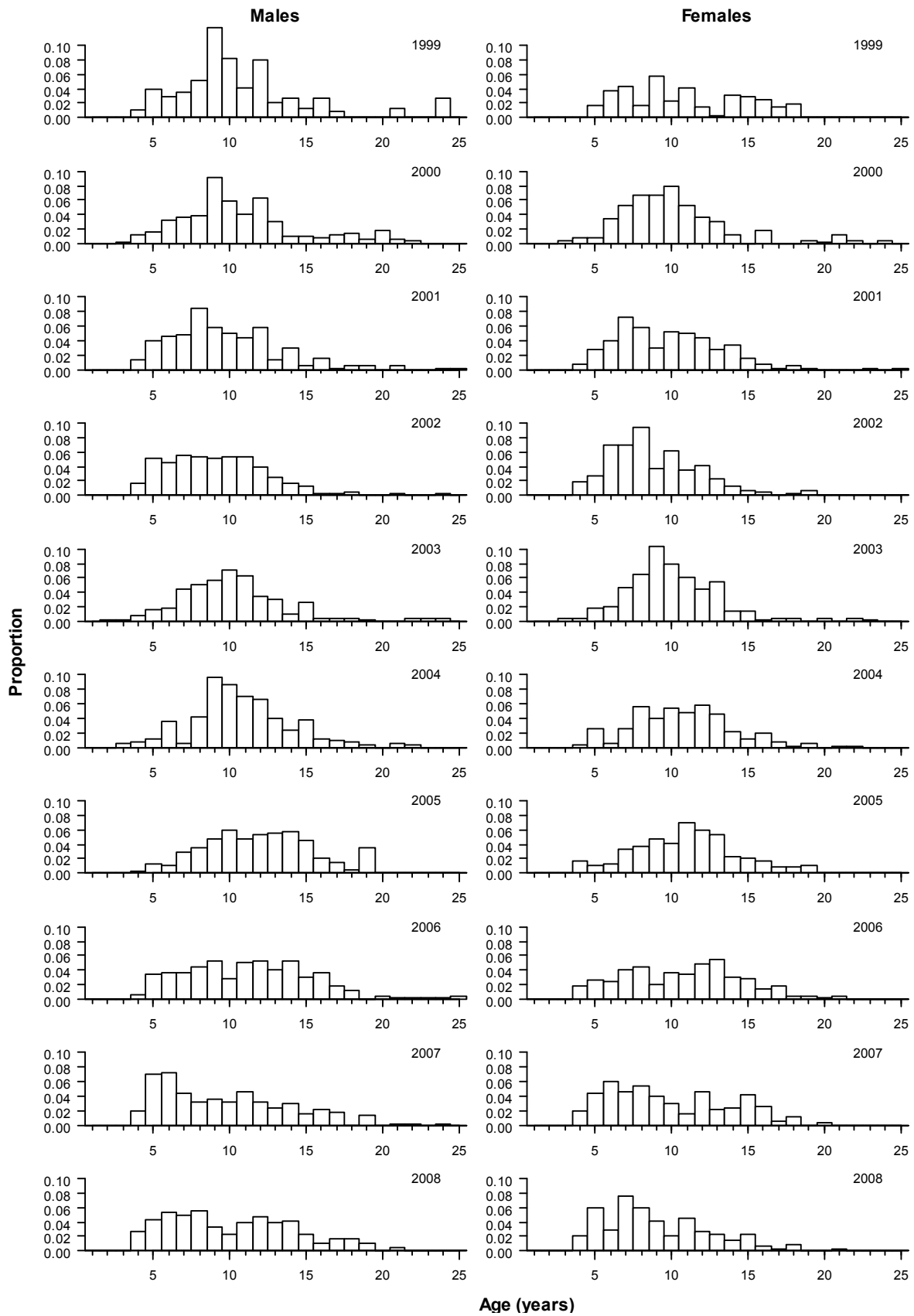


Figure B10: Age frequency distributions of ling from commercial catch-at-age data in the Cook Strait trawl fishery, 1999 to 2015.

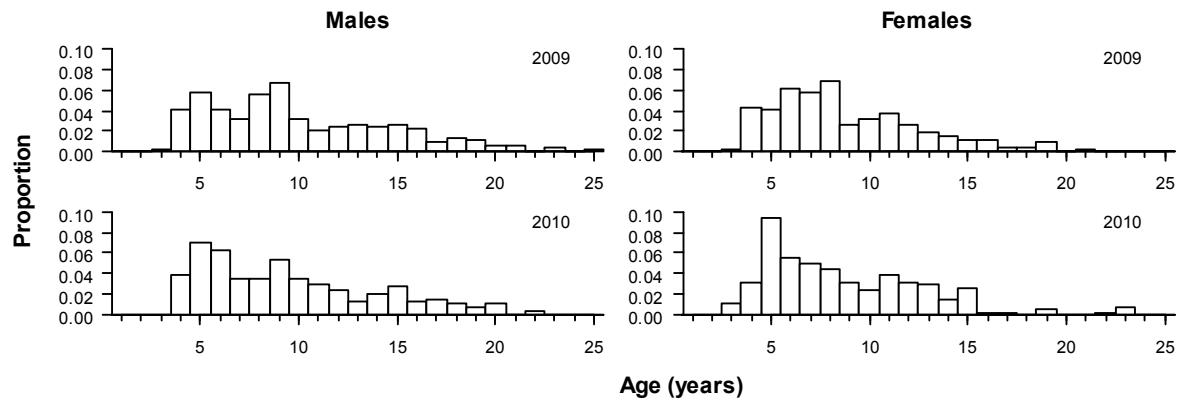


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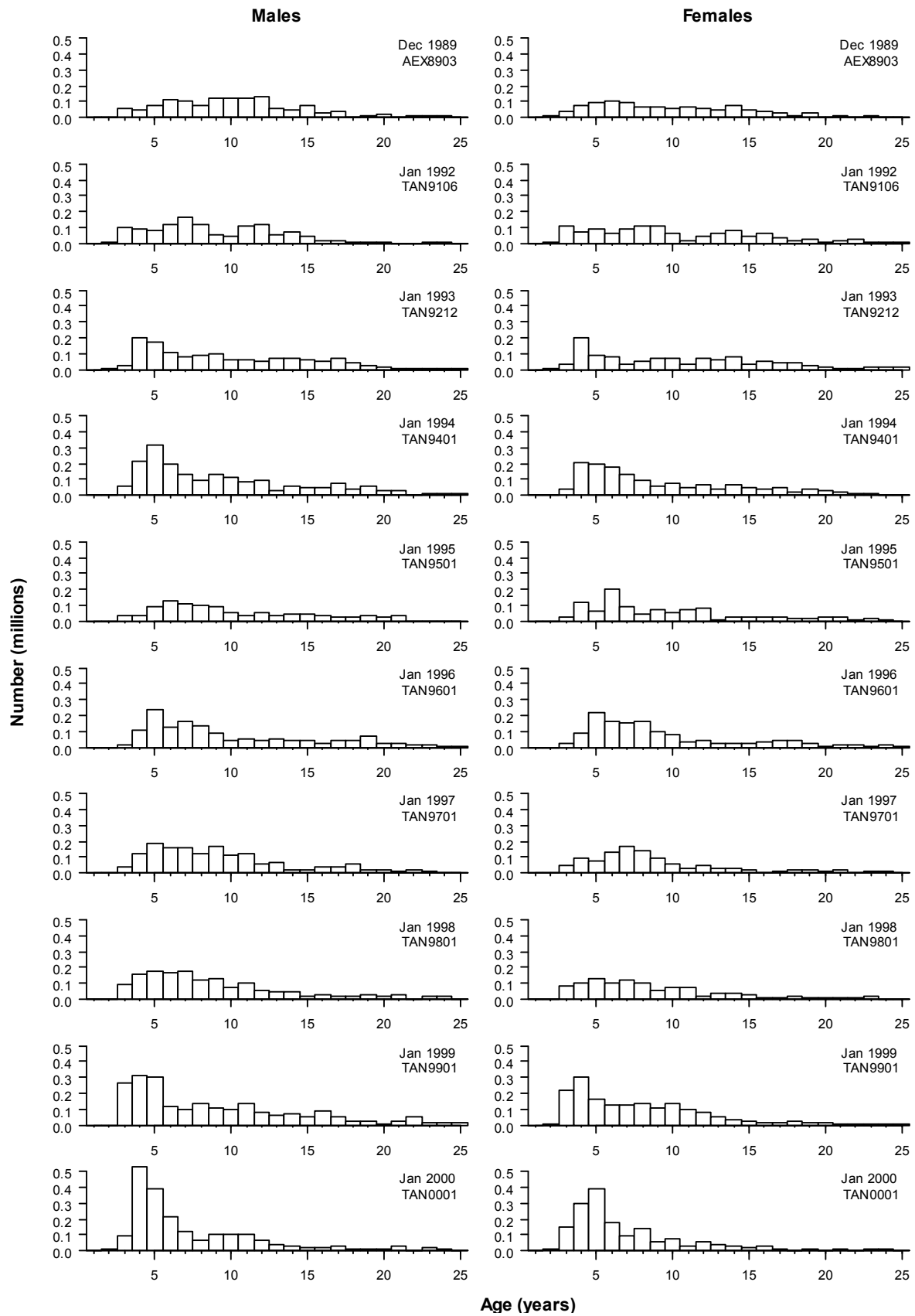


Figure B11: Age frequency distributions of ling (ages 1 to 25) from resource surveys in the Chatham Rise, 1989-90 to 2015-16.

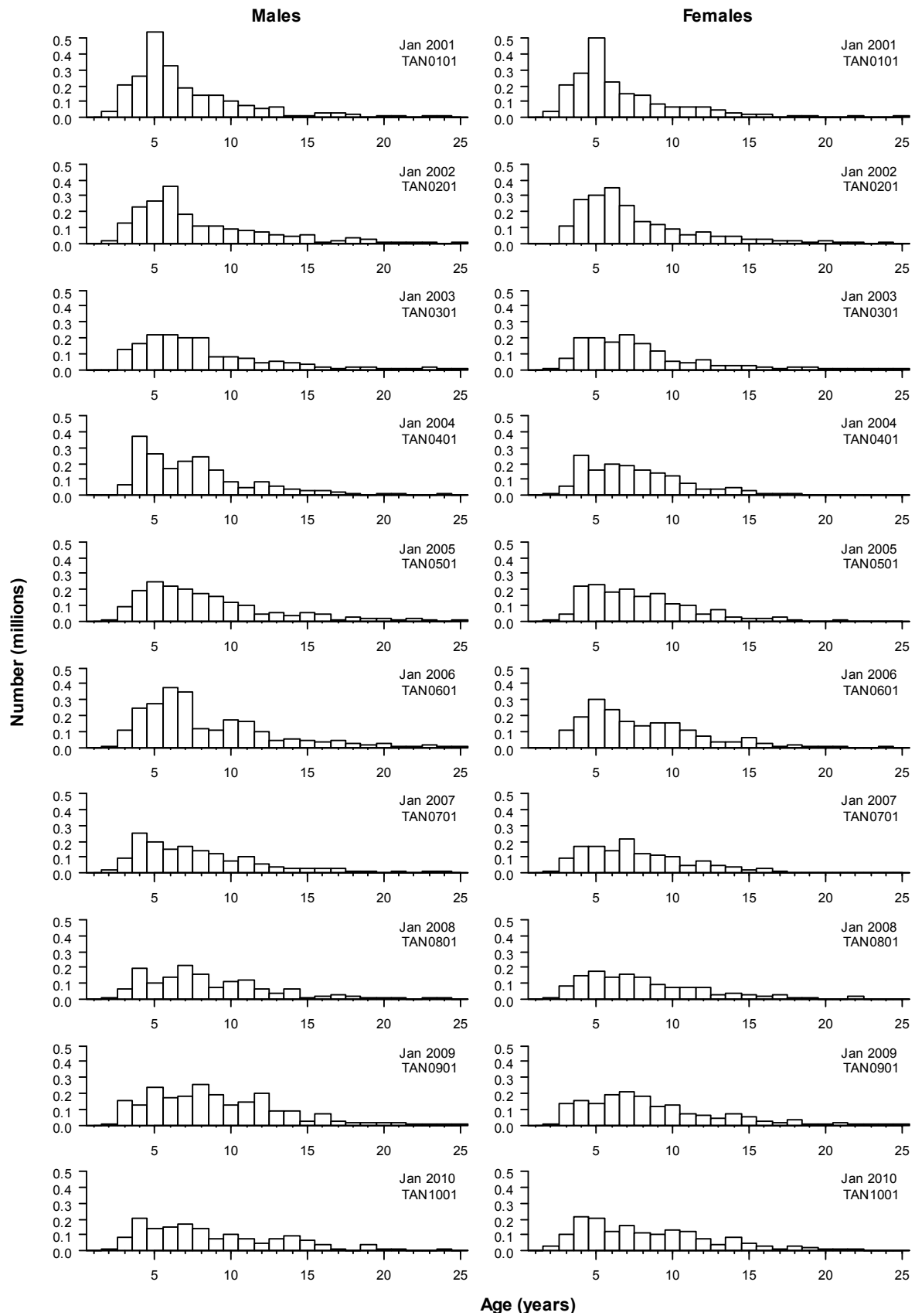


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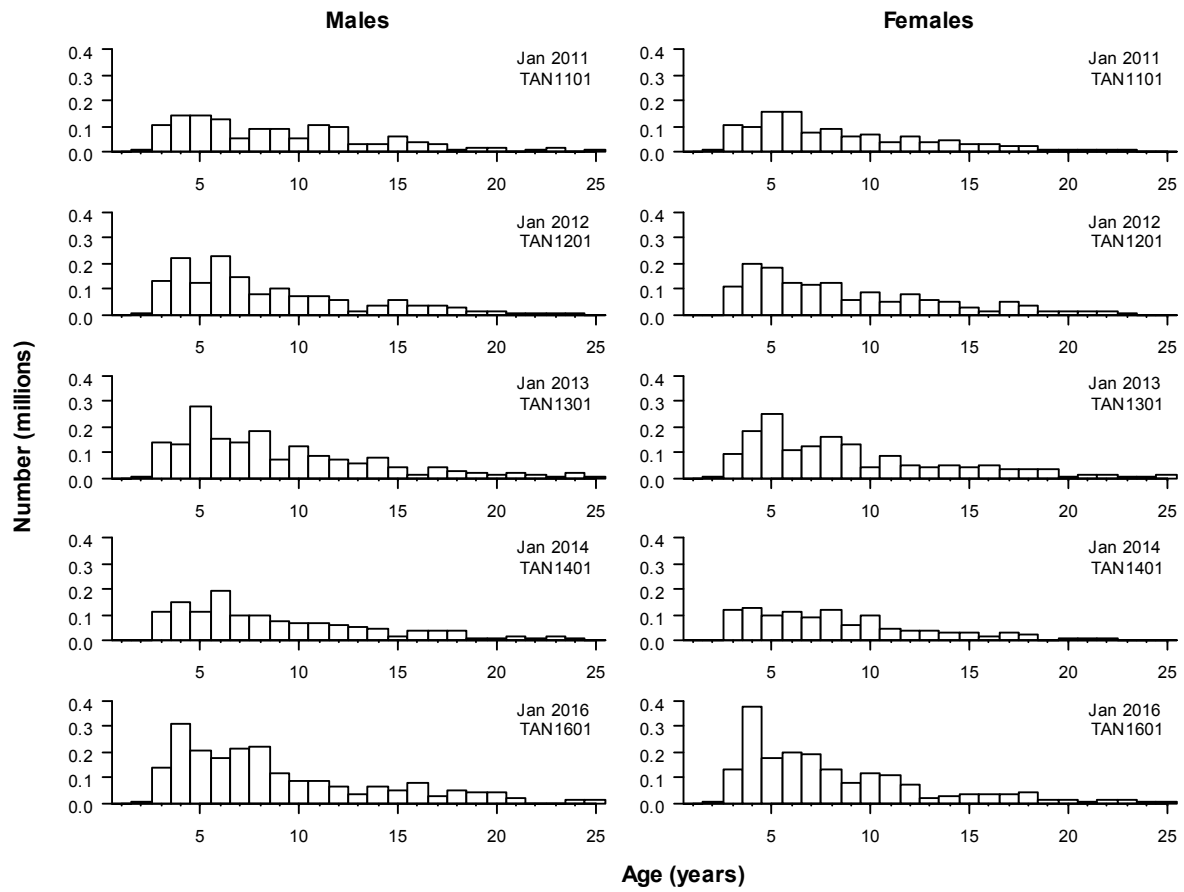


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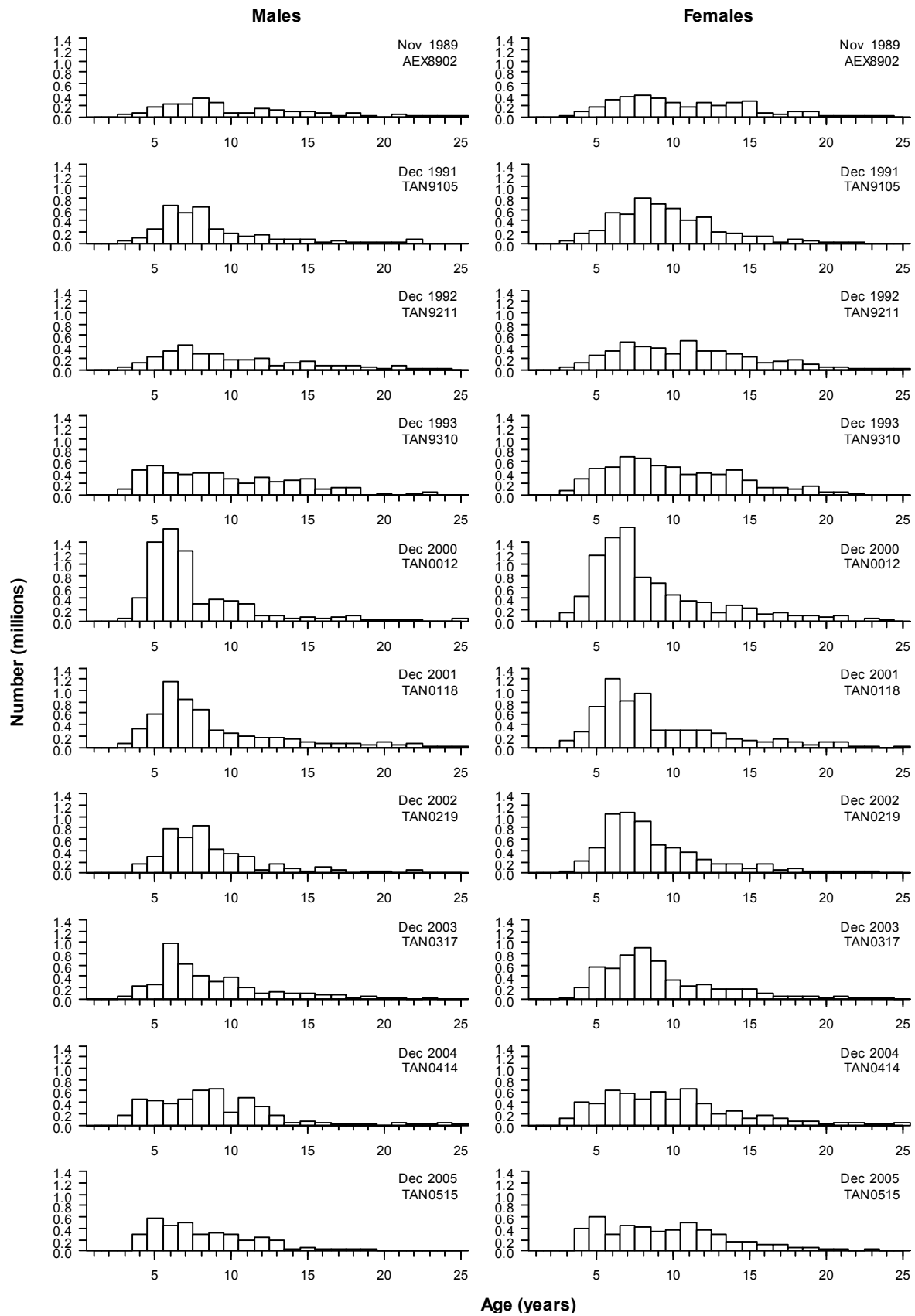


Figure B12: Age frequency distributions of ling (ages 1 to 25) from summer resource surveys in the Sub-Antarctic, 1989 to 2015.

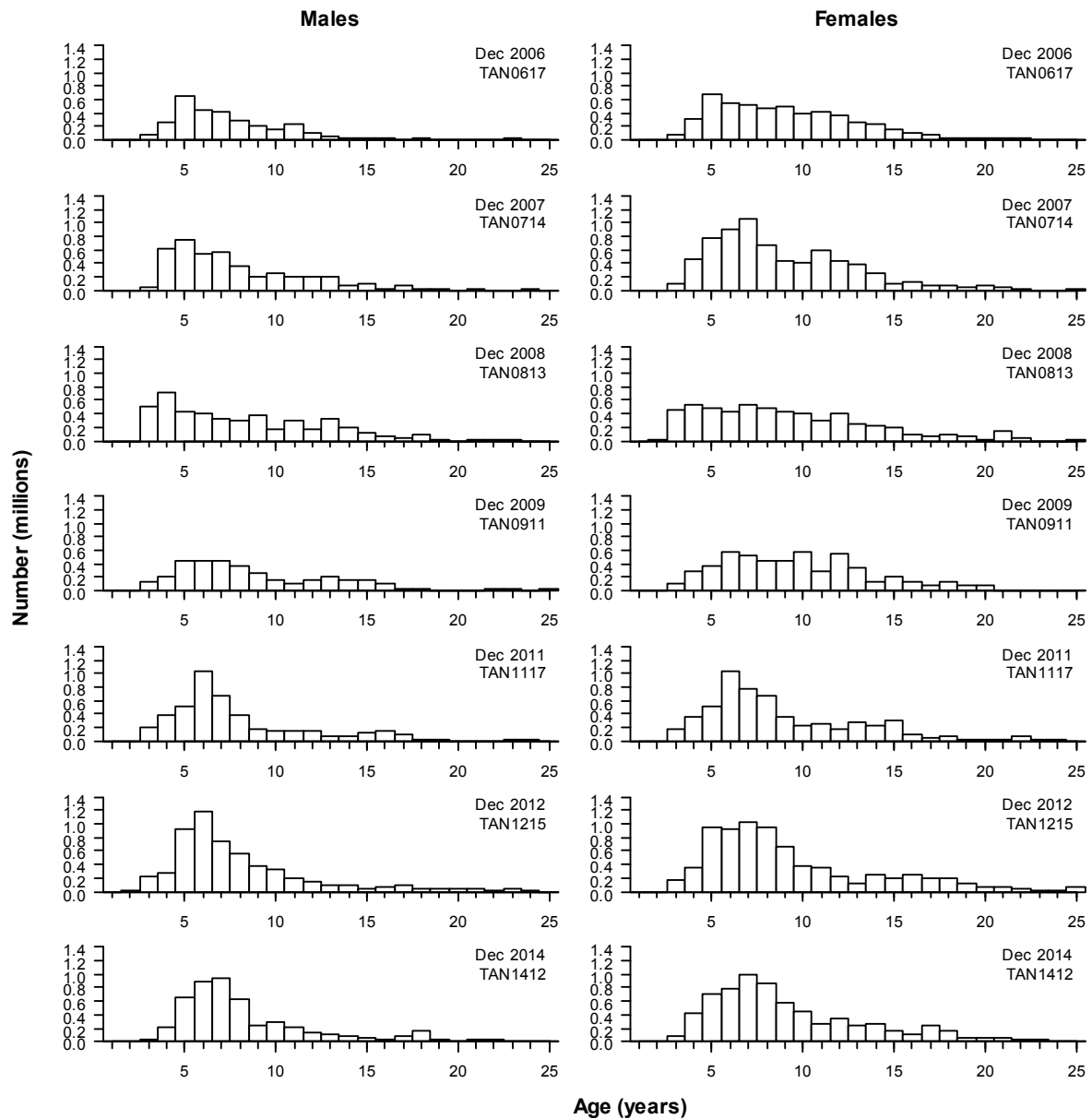


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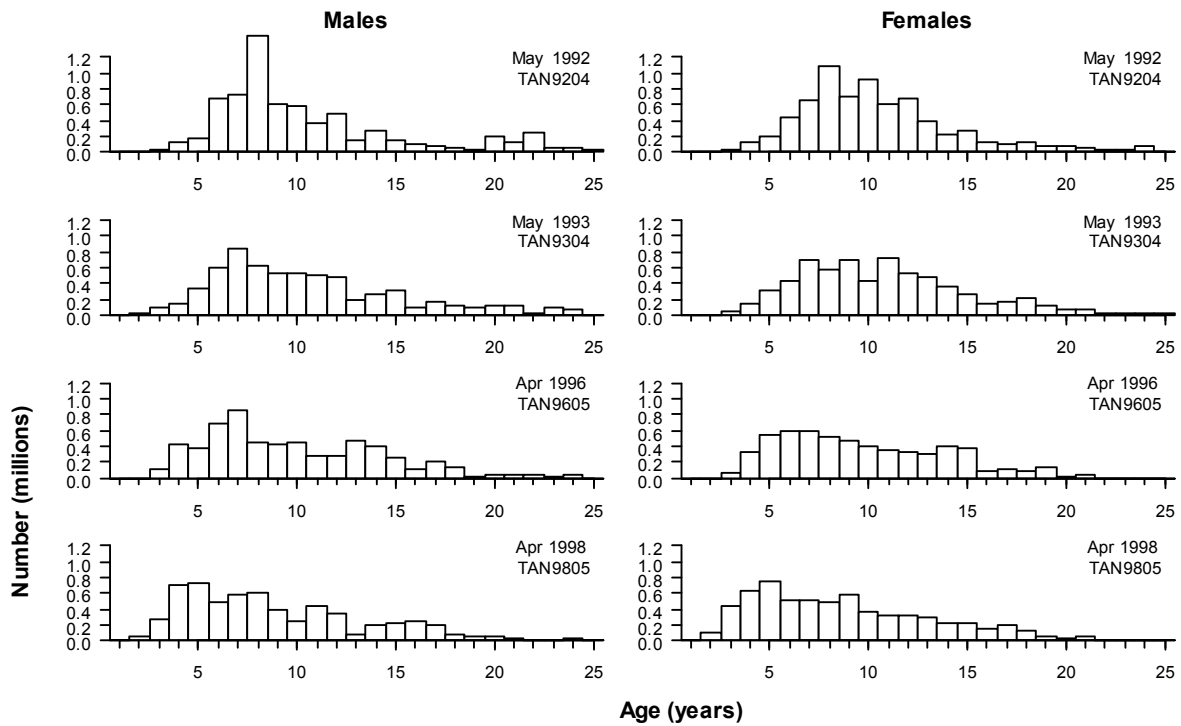


Figure B13: Age frequency distributions of ling (ages 1 to 25) from autumn resource surveys in the Sub-Antarctic, 1992 to 1998.

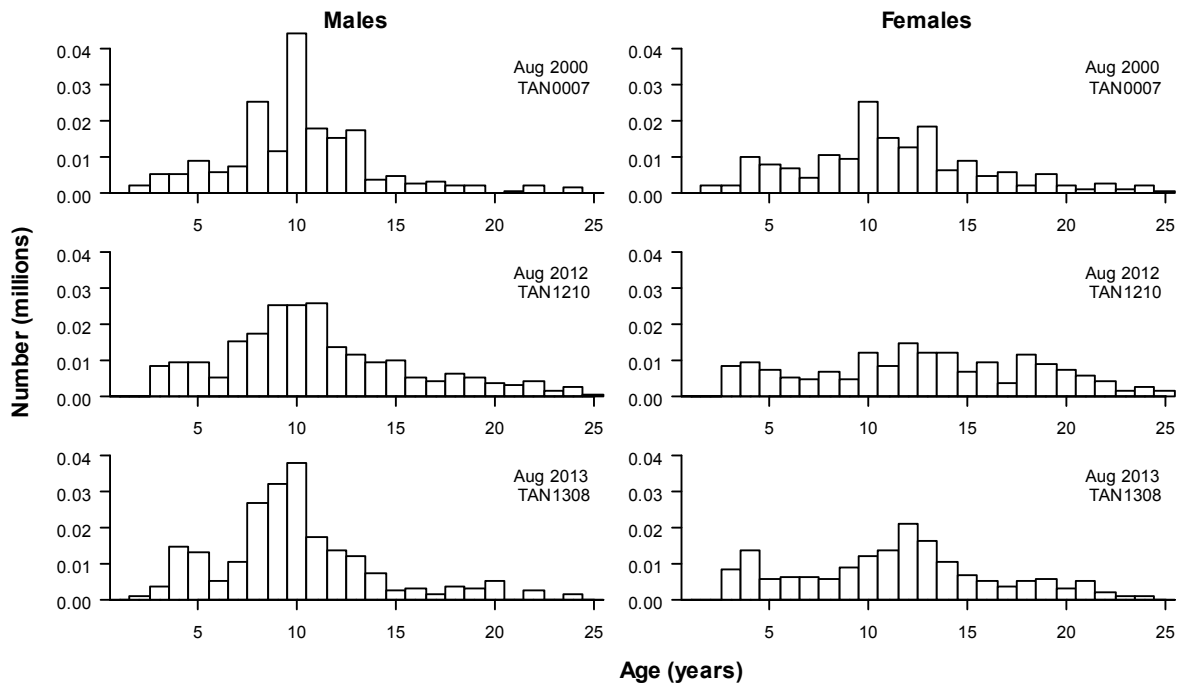


Figure B14: Age frequency distributions of ling (ages 1 to 25) from winter resource surveys off WCSI, 2000 to 2013.