



Catch-at-age for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) in the 2012–13 fishing year and from trawl surveys in 2013–14, 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. (2014). Catch-at-age for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) in the 2012–13 fishing year and from trawl surveys in 2013–14, 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 2012–13 fishing year (using data and otoliths collected at sea by observers), and from trawl surveys of hoki and middle depth species off the west coast South Island in August 2013 (TAN1308) and on the Chatham Rise in January 2014 (TAN1401). The target coefficient of variation (CV) for each estimated catch-at-age distribution from the observer samples and the two trawl surveys was 30% (mean weighted CV across all age classes).

For hake, the target CV was met for the two commercial fishery samples (west coast South Island, and Sub-Antarctic), but was not met for the two trawl surveys. There were insufficient data to estimate catch-at-age for the Chatham Rise commercial trawl fishery. Age distribution results suggest that strong year classes were spawned on the Chatham Rise in 1990–91 and 2001–02.

For ling, the target CV was met for the commercial trawl samples from Chatham Rise, west coast South Island, and the Sub-Antarctic, and the two trawl surveys. There were insufficient data collected to estimate catch-at-age for the 2013 Cook Strait commercial trawl fishery. Catch-at-age was also produced for the Chatham Rise ling longline fishery in 2012–13 (and the target CV was met). No samples from other longline fisheries were available.

It was not possible to improve the age distribution precision for both species by increasing the sample size, where the target CV was not met, because all available data and otoliths were used in the analyses. If observer coverage of the deepwater fleet increases, catch-at-age should be available from all the New Zealand fisheries each year. It would also 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. The areas and months for each fishery are listed in this document and summaries of all previous catch-at-age distributions made for hake and ling from trawl surveys and commercial fisheries are also provided.

1. INTRODUCTION

The work presented here aimed to determine catch-at-age from the main fisheries for hake and ling in the 2012–13 fishing year, and for hake and ling from trawl surveys conducted during 2013–14. 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 Objectives 3, 4, and 7 (part) of Project MID201001D “Routine age determination of hoki and middle depth species from commercial fisheries and trawl surveys”, funded by the Ministry for Primary Industries. Those objectives are:

3. To determine the catch-at-age from hake fisheries in HAK 1, 4 and 7 from samples collected at sea by the Observer Programme.
4. To determine the catch-at-age from ling fisheries in LIN 3 & 4, 5 & 6 and 7 from samples collected at sea by the Observer Programme, and from other sources.
7. To determine the age and size structure of hoki, hake, ling and jack mackerel from the trawl surveys.

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 number of aged otoliths in square brackets):

- HAK 1 — commercial trawl fishery, Sep 2012–May 2013 [600].
- HAK 4 — trawl survey, Jan 2014 (project HOK2010-02) [600].
- HAK 4 — commercial trawl fishery, Oct 2012–April 2013 [600].
- HAK 7 — trawl survey, Aug 2013 (project HOK2010-04) [600].

Only 325 hake were sampled by observers on the Chatham Rise (HAK 4), so a catch-at-age distribution was not able to be produced for that trawl fishery.

An additional commercial fishery catch-at-age distribution for HAK 7 was estimated using the age-length key derived previously from the August 2013 west coast South Island trawl survey plus age data from 138 observer-collected otoliths to better represent hake sizes that were under-sampled by the survey.

HAK 7 — commercial trawl fishery, Jun–Sep 2013.

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

- LIN 3&4 — trawl survey, Jan 2014 (project HOK2010-02) [640].
- LIN 3&4 — commercial longline fishery, Jun–Oct 2013 [580].
- LIN 5&6 — commercial longline fishery, spawning, Puysegur, Oct–Dec 2012 [500].
- LIN 5&6 — commercial longline fishery, non-spawning, Campbell, Feb–Jul 2013 [500].
- LIN 6B — commercial longline fishery, Nov 2012–March 2013 [500].
- LIN 7 — trawl survey, Aug 2013 (project HOK2010-04) [600].

LIN 7&2 — commercial trawl fishery, Cook Strait, Jun–Sep 2013 [500].

No observer otoliths were available from the ling longline fisheries in the Sub-Antarctic (LIN 5&6) or Bounty Plateau (LIN 6B). Also, only 3 ling were sampled by observers from the winter 2013 Cook Strait trawl fishery (LIN 7&2), so a catch-at-age distribution was not able to be produced for those fisheries.

The following additional commercial fishery catch-at-age distributions for ling were estimated using age-length keys derived previously from the January 2013 Chatham Rise trawl survey (LIN 3&4) and the August 2013 WCSI trawl survey (LIN 7). The LIN 7 age-length key included 146 additional age data from observer-collected otoliths to better represent ling sizes that were under-sampled by the survey.

LIN 3&4 — commercial trawl fishery, Oct 2012–May 2013.

LIN 7 — commercial trawl fishery, Jun–Sep 2013.

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 total length frequency was applied to the age-length key. 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 have 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.

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.

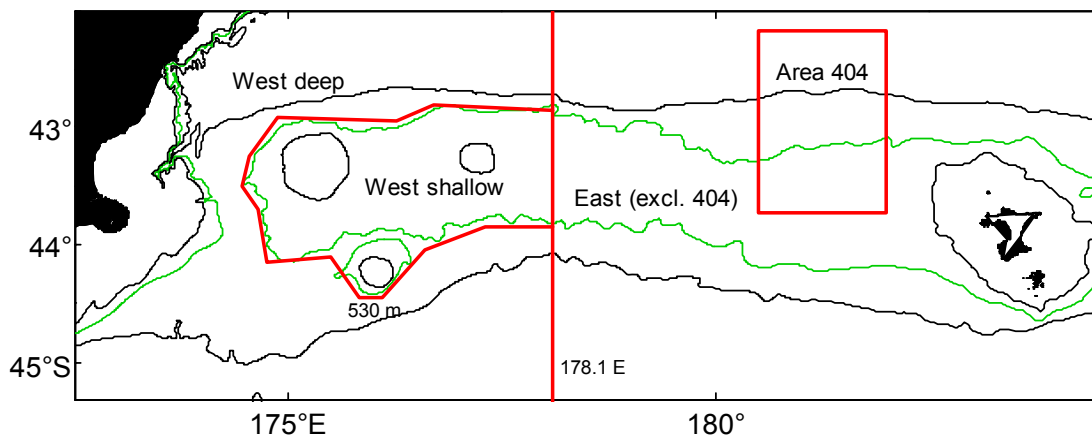


Figure 1: Strata defined for the Chatham Rise hake fishery. The stratum boundary defined by depth (530 m) is shown only approximately. Isobaths at 1000, 500, and 250 m are also shown.

Observer data from each fishery 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 2012–13 fishing year, insufficient length data ($n = 148$ from west and 177 from east) and otoliths were available to calculate a catch-at-age distribution for either of the fisheries.

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 (Mal) and female (Fem) 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.

Fishing year	Measured								Aged	
	West				East				Mal	Fem
	Mal	Fem	Tows	CV	Mal	Fem	Tows	CV		
1991–92	2 112	2 636	163	21.9	170	247	25	43.2	233	230
1992–93									0	0
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

3.1.2 Sub-Antarctic

There is 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, 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 2 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 2012–13 fishing year are in Table 3. The mean weighted CV of 20% 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).

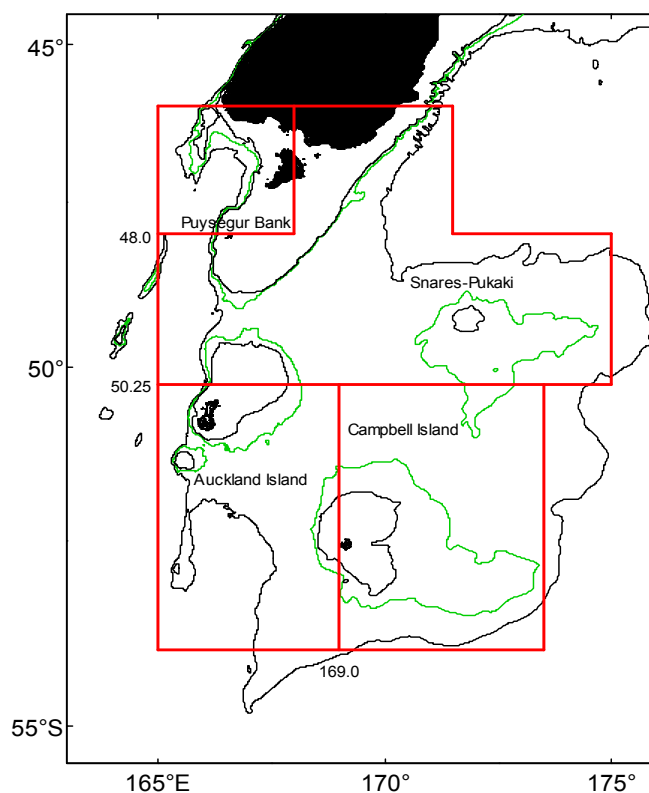


Figure 2: Fishery strata defined for the Sub-Antarctic hake fishery. Numbers show latitudes and longitudes of fishery boundaries. Isobaths at 1000, 500, and 250 m are also shown.

Table 2: 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

Table 3: Calculated numbers at age, separately by sex, with CVs, for hake sampled by observers during commercial trawl operations in the Sub-Antarctic during September 2012–May 2013. Summary statistics for the samples are also presented.

Age	Male	CV	Female	CV
3	8	1.200	17	0.936
4	317	0.687	455	0.395
5	2 568	0.314	574	0.377
6	13 564	0.196	923	0.391
7	25 280	0.169	2 852	0.272
8	26 869	0.156	11 020	0.176
9	27 586	0.156	16 507	0.157
10	11 901	0.232	15 002	0.153
11	7 661	0.287	8 500	0.225
12	4 808	0.350	6 238	0.279
13	3 578	0.407	6 076	0.268
14	4 977	0.375	4 638	0.295
15	9 924	0.270	4 110	0.300
16	6 592	0.354	2 272	0.428
17	2 119	0.575	2 337	0.510
18	5 326	0.374	2 154	0.469
19	3 926	0.392	1 896	0.570
20	2 448	0.557	2 139	0.478
21	1 382	0.604	916	0.767
22	491	0.977	0	–
23	491	1.128	197	1.841
24	801	1.091	382	1.077
25	0	–	548	0.974
26	0	–	0	–
27	564	1.077	0	–
28	0	–	0	–
29	0	–	0	–
30	0	–	0	–
31	564	1.122	0	–
Measured males			2 555	
Measured females			1 306	
Aged males			412	
Aged females			666	
No. of tows sampled			100	
Mean weighted CV (sexes pooled)			19.5	

3.1.3 West coast South Island (WCSI)

The fishery off WCSI was stratified 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 4 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 2012–13 fishing year are in Table 5. The measured sample size was much larger than in all previous years, and the mean weighted CV of 14% was well within the target of 30%. The age-length key used to derive the 2012–13 fishery age distribution included all the age data obtained from the

research survey in July–August 2013, plus 138 additional otoliths, mostly from large fish taken by the commercial fishery. The additional otoliths were chosen to provide age data for hake length classes that did not occur in the survey samples, or were under-represented relative to their abundance in the trawl fishery sample.

All estimated proportion-at-age-distributions from the WCSI trawl fishery are presented in Appendix A (Figure A4). The three year classes that showed up relatively strongly as 2-year-olds in catches from 2005, 2006, and 2007 appear to comprise a high proportion of the catch from 2010 to 2012, particularly for females.

Table 4: 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

Table 5: Calculated numbers at age, separately by sex, with CVs, for hake sampled by observers during commercial trawl operations off the WCSI during June–September 2013. Summary statistics for the samples are also presented.

Age	Male	CV	Female	CV
1	13 840	0.243	9 193	0.231
2	2 564	0.410	4 142	0.342
3	3 003	0.413	1 355	0.568
4	26 823	0.266	1 036	0.553
5	169 399	0.124	26 380	0.212
6	220 542	0.111	79 976	0.124
7	136 030	0.139	108 209	0.115
8	89 577	0.171	96 696	0.115
9	35 111	0.357	41 117	0.177
10	12 451	0.501	27 491	0.194
11	6 163	0.649	10 928	0.332
12	8 765	0.716	3 171	0.394
13	3 151	0.899	4 624	0.534
14	17 444	0.477	8 441	0.389
15	14 513	0.658	2 983	0.535
16	4 023	0.765	6 770	0.531
17	373	1.049	1 225	0.883
18	5 454	0.710	548	0.978
19	0	–	354	0.875
20	0	–	0	–
21	0	–	335	1.075
Measured males			12 352	
Measured females			8 417	
Aged males			325	
Aged females			443	
No. of tows sampled			493	
Mean weighted CV (sexes pooled)			14.3	

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 6 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 hake caught in the January 2014 trawl survey are given in Table 7. The mean weighted CV of 55% did not meet the target of 30%. This value cannot be improved as all available length data and otoliths were used in the analysis. The 30% target was met in only one of the 20 surveys (TAN9106, see Table 6).

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 6: 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

Table 7: 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 2014 (TAN1401). Summary statistics for the samples are also presented.

Age	Male	CV	Female	CV
2	2 196	3.272	6 744	1.618
3	11 941	0.902	9 965	0.835
4	15 471	0.484	13 876	0.615
5	1 646	1.796	23 180	0.502
6	3 554	1.068	5 636	0.828
7	11 504	0.637	16 891	0.529
8	11 226	0.517	22 087	0.443
9	6 787	0.793	23 247	0.546
10	11 375	0.633	38 300	0.387
11	595	1.799	12 379	0.778
12	8 289	0.816	5 474	1.103
13	0	–	11 172	0.851
14	4 010	1.725	0	–
15	0	–	14 242	0.775
16	0	–	0	–
17	2 915	1.516	0	–
18	9 052	0.749	12 211	0.945
19	0	–	4 972	0.956
Measured males			38	
Measured females			65	
Aged males			88	
Aged females			91	
No. of tows sampled			46	
Mean weighted CV (sexes pooled)			55.4	

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 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 8 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. No survey of this area was conducted in November–December 2012.

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 8: 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
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. in prep.), 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 9 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. The estimated catch-at-age distribution for hake caught in the 2013 trawl survey is in Table 10. The mean weighted CV of 34% was slightly higher than the target of 30%.

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

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 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

Table 10: Calculated numbers at age in the survey area, separately by sex, with CVs, for hake caught during a trawl survey of the west coast South Island in August 2013 (TAN1308). Summary statistics for the samples are also presented.

Age	Male	CV	Female	CV
1	6 610	0.514	3 943	0.502
2	285	1.364	799	1.478
3	0	–	1 491	0.702
4	1 127	0.697	678	1.029
5	4 793	0.353	3 032	0.408
6	6 004	0.321	8 693	0.294
7	4 092	0.371	12 671	0.272
8	2 634	0.457	10 216	0.252
9	677	0.758	4 790	0.265
10	306	0.814	4 293	0.323
11	112	0.952	1 109	0.495
12	217	1.172	633	0.675
13	95	2.192	395	0.766
14	351	1.186	725	0.605
15	297	1.264	513	0.678
16	18	2.217	823	0.659
17	0	–	438	1.195
18	18	2.121	164	1.318
19	0	–	0	–
20	0	–	0	–
21	0	–	173	1.438
Measured males				94
Measured females				213
Aged males				255
Aged females				371
No. of tows sampled				34
Mean weighted CV (sexes pooled)				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 data collected from the Chatham Rise ling longline fishery in 2010–2012. The estimated catch-at-age distribution for line-caught ling in the 2012–13 fishing year are in Table 12. The mean weighted CV of 26% was within the target value of 30%.

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

Year	Males		Females		Sets	Mean CV
	Measured	Aged	Measured	Aged		
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
2008	574	216	570	262	84	25.9
2009	619	283	798	413	147	21.5
2013	314	112	655	252	50	25.9

Table 12: Calculated numbers at age, separately by sex, with CVs, for ling sampled by observers during commercial longline operations on the Chatham Rise (LIN 3&4) in June–October 2013. Summary statistics for the samples are also presented.

Age	Male	CV	Female	CV
6	170	1.325	0	–
7	526	0.772	59	1.790
8	2 898	0.356	911	0.613
9	3 039	0.365	2 118	0.426
10	2 101	0.394	3 088	0.342
11	2 608	0.353	4 688	0.247
12	2 097	0.360	3 739	0.291
13	1 536	0.431	6 966	0.201
14	1 318	0.465	7 829	0.175
15	1 555	0.508	6 905	0.219
16	1 604	0.446	4 825	0.219
17	1 851	0.443	2 954	0.311
18	1 811	0.375	3 916	0.259
19	1 870	0.500	1 771	0.435
20	227	1.245	1 431	0.460
21	255	0.880	888	0.526
22	0	–	907	0.574
23	341	0.815	0	–
24	410	0.947	961	0.576
Measured males				314
Measured females				655
Aged males				112
Aged females				252
No. of sets sampled				50
Mean weighted CV (sexes pooled)				25.9

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 are analysed separately from Sub-Antarctic ling because they are believed to comprise a distinct biological stock (Horn 2005).

Table 13 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. There was no observer sampling of either spawning or non-spawning Sub-Antarctic longline-caught ling in the 2012–13 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 13: Numbers of measured male and female ling, age data used in the age-length key, 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		Sets	Mean CV
	Measured	Aged	Measured	Aged		
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
2008	227	68	198	62	24	44.3
2010	89	51	361	177	45	34.0
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
2009	165	61	454	196	49	28.0
2010	151	78	424	214	49	29.0
2011	180	60	823	267	64	27.3
2012	316	109	979	320	91	23.7

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 14 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 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. There was no sampling of WCSI longline-caught ling in the 2012–13 fishing year. All estimated proportion-at-age distributions from the WCSI longline fishery are presented in Appendix B (Figure B4).

Table 14: Numbers of measured male and female ling, age data used in the age-length key, sets sampled, and estimated mean weighted CV (%) by age, for the west coast South Island longline fishery.

Year	Males		Females		Sets	Mean CV
	Measured	Aged	Measured	Aged		
2003	123	215	148	246	24	37.9
2006	104	191	301	329	24	35.0
2007	109	119	192	169	28	42.2
2012	190	246	379	311	31	29.3

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 2012–13 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, and sets sampled, and estimated mean weighted CV (%) by age, for the Cook Strait longline fishery.

Year	Males		Females		Sets	Mean CV
	Measured	Aged	Measured	Aged		
2001	315	179	356	194	17	29.8
2003	165	164	145	142	31	33.1
2006	607	319	538	275	116	19.3
2007	238	125	180	92	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 2012–13 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, sets sampled, and estimated mean weighted CV (%) by age, for the Bounty Plateau longline fishery.

Year	Males		Females		Sets	Mean CV
	Measured	Aged	Measured	Aged		
1992–93	201	52	237	69	24	50.4
1999–2000	1 102	106	2 184	185	41	26.9
2000–01	405	50	713	66	20	43.6
2003–04	1 155	200	1 628	300	272	20.0
2007–08	308	156	562	271	86	25.3
2008–09	262	116	213	88	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 2012–13 fishing year are given in Table 18. The mean weighted CV of 24% was within 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

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 2012–May 2013. Summary statistics for the samples are also presented.

Age	Male	CV	Female	CV
2	285	1.851	0	–
3	1 496	0.572	2 847	0.775
4	9 183	0.355	9 394	0.537
5	23 419	0.224	18 019	0.213
6	18 225	0.256	10 121	0.295
7	15 773	0.242	11 440	0.279
8	20 977	0.282	16 262	0.209
9	9 698	0.322	17 154	0.197
10	11 077	0.299	6 732	0.368
11	8 423	0.301	12 500	0.235
12	4 990	0.377	4 286	0.386
13	5 132	0.375	4 117	0.421
14	5 729	0.353	4 151	0.356
15	2 203	0.474	3 667	0.417
16	741	0.716	3 014	0.458
17	2 115	0.497	4 002	0.410
18	1 567	0.629	1 918	0.389
19	1 693	0.495	3 104	0.368
20	668	0.803	177	0.956
21	1 011	0.600	554	0.816
22	1 507	0.590	450	0.674
23	252	1.236	437	0.876
24	956	0.982	233	1.069
25	972	0.999	164	0.925
26	484	1.157	155	1.184
27	0	–	222	1.579
28	305	1.166	0	–
29	0	7.827	49	1.882
30	0	–	0	2.700
31	0	–	0	–
32	0	7.934	0	–
38	0	5.721	0	–
Measured males				981
Measured females				1 083
Aged males				278
Aged females				315
No. of tows sampled				130
Mean weighted CV (sexes pooled)				24.1

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 2012–13 fishing year are given in Table 20. The mean weighted CV of 22% was within 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, and 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

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 2012–April 2013. Summary statistics for the samples are also presented.

Age	Male	CV	Female	CV
2	0	–	440	1.418
3	707	0.742	779	0.586
4	4 246	0.527	3 708	0.487
5	23 849	0.240	28 548	0.311
6	93 032	0.167	100 102	0.215
7	89 087	0.203	151 892	0.203
8	120 993	0.190	167 540	0.192
9	113 556	0.222	139 275	0.191
10	91 393	0.272	91 531	0.290
11	66 513	0.334	103 028	0.256
12	42 795	0.383	59 181	0.372
13	39 607	0.418	33 424	0.503
14	44 289	0.399	59 219	0.327
15	13 246	0.568	48 649	0.332
16	30 537	0.556	65 096	0.306
17	29 069	0.413	47 907	0.348
18	20 982	0.498	56 298	0.321
19	24 120	0.589	26 822	0.344
20	19 051	0.502	20 790	0.585
21	15 224	0.464	8 438	0.540
22	5 560	0.608	7 073	0.713
23	13 781	0.635	7 210	0.804
24	8 080	0.633	833	1.459
25	0	–	15 185	0.542
26	0	–	2 430	1.044
27	3 901	1.103	684	1.026
28	0	–	358	1.284
29	0	–	1 443	1.213
30	0	–	3 862	1.016
31	0	–	0	–
32	0	–	147	2.137
Measured males				4 565
Measured females				5 542
Aged males				286
Aged females				317
No. of tows sampled				275
Mean weighted CV (sexes pooled)				21.6

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 ≥ 498 m).
2. North shallow (bottom depth < 498 m, latitude $< 42.42^\circ$ S).
3. South shallow (bottom depth < 498 m, latitude $\geq 42.42^\circ$ 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. In the 2012–13 fishing year, the trawl fishery age-length key was derived using all the age data from the winter 2013 research trawl survey, plus 146 additional age data points derived from otoliths sampled from the commercial trawl fishery. The additional otoliths were chosen to provide age data for ling length classes that did not occur in the survey samples, or were under-represented relative to their abundance in the trawl fishery sample. The details of the estimated catch-at-age distribution for trawl-caught ling in the 2012–13 fishing year are given in Table 22. The mean weighted CV of 24% was within 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

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 2013. Summary statistics for the samples are also presented.

Age	Male	CV	Female	CV
2	159	1.801	107	1.848
3	516	0.980	1 267	0.721
4	11 950	0.374	9 554	0.372
5	9 020	0.354	6 770	0.340
6	4 211	0.388	5 194	0.373
7	5 595	0.375	6 446	0.386
8	17 956	0.275	10 942	0.333
9	18 828	0.280	18 904	0.247
10	22 674	0.252	14 446	0.288
11	11 495	0.325	15 376	0.258
12	10 414	0.292	16 120	0.213
13	7 068	0.363	12 692	0.264
14	4 767	0.428	6 544	0.316
15	1 593	0.580	4 743	0.326
16	1 373	0.876	2 749	0.448
17	1 076	0.850	1 500	0.469
18	939	0.637	2 108	0.455
19	527	0.840	1 993	0.429
20	1 660	0.590	1 027	0.489
21	481	0.902	2 219	0.524
22	1 026	0.842	891	0.531
23	269	1.356	897	0.746
24	522	0.762	581	0.627
25	0	–	59	1.456
26	102	1.380	38	1.754
27	106	1.464	275	1.109
28	0	–	118	1.474
Measured males				1 270
Measured females				1 302
Aged males				283
Aged females				376
No. of tows sampled				153
Mean weighted CV (sexes pooled)				23.9

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 2013 (i.e., only 3 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: 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

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 2014 trawl survey are given in Table 25. The mean weighted CV of 26% was within the target of 30%.

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

Table 25: Calculated numbers at age in the survey area, separately by sex, with CVs, for ling caught during trawl surveys of the Chatham Rise in January 2014 (survey TAN1401). Summary statistics for the samples are also presented.

Age	Male	CV	Female	CV
2	0	–	3 685	2.188
3	116 321	0.438	118 310	0.429
4	147 442	0.244	125 177	0.252
5	112 596	0.264	98 391	0.270
6	194 775	0.206	113 677	0.260
7	99 269	0.254	89 518	0.277
8	97 938	0.252	119 734	0.240
9	77 632	0.268	58 252	0.324
10	64 800	0.322	101 404	0.266
11	65 266	0.295	44 557	0.381
12	58 712	0.300	39 493	0.393
13	54 319	0.334	39 010	0.428
14	49 582	0.333	32 728	0.405
15	13 690	0.621	34 326	0.399
16	40 413	0.380	17 691	0.571
17	35 222	0.391	32 174	0.400
18	36 477	0.414	25 404	0.486
19	6 750	0.884	1 841	1.221
20	6 438	1.057	9 550	0.666
21	12 669	0.634	7 082	0.870
22	7 392	1.061	6 492	1.152
23	14 325	0.719	4 512	0.937
24	10 693	0.844	3 151	1.312
25	4 850	1.042	0	–
26	2 893	1.362	4 662	1.025
27	11 943	0.785	2 217	1.505
28	4 409	1.369	0	–
29	0	–	2 041	1.398
30	0	–	0	–
31	2 908	1.499	4 596	1.142
32	3 468	1.429	0	–
33	0	–	0	–
34	0	–	0	–
35	0	–	3 155	1.408
36	3 219	1.652	0	–
37	4 122	1.139	0	–
Measured males				515
Measured females				482
Aged males				322
Aged females				275
No. of tows sampled				82
Mean weighted CV (sexes pooled)				26.4

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 of this area conducted in November–December 2013.

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	25.9
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. in prep.), 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. The details of the estimated catch-at-age distribution for ling caught in the 2013 survey are given in Table 28. The mean weighted CV of 30% met the target of 30%.

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

Table 28: Calculated numbers at age in the survey area, separately by sex, with CVs, for ling caught during a trawl survey of the west coast South Island in August 2013 (survey TAN1308). Summary statistics for the samples are also presented.

Age	Male	CV	Female	CV
2	1 144	1.110	0	–
3	3 818	0.479	8 234	0.490
4	14 684	0.271	13 637	0.282
5	12 970	0.268	5 839	0.373
6	5 446	0.442	6 430	0.339
7	10 744	0.312	6 200	0.391
8	27 119	0.250	5 471	0.353
9	32 219	0.298	8 846	0.293
10	38 120	0.289	12 244	0.334
11	17 254	0.394	13 530	0.323
12	13 556	0.374	21 290	0.282
13	11 853	0.437	16 191	0.343
14	7 496	0.480	10 247	0.351
15	2 427	0.723	6 951	0.436
16	3 314	0.814	5 410	0.439
17	1 636	1.051	3 843	0.461
18	3 572	0.574	5 283	0.507
19	2 809	0.682	5 961	0.393
20	4 928	0.537	2 991	0.518
21	0	–	4 946	0.530
22	2 409	0.745	1 766	0.502
23	0	–	904	0.885
24	1 723	0.731	1 122	0.827
25	0	–	0	–
26	662	1.144	311	1.335
27	249	1.436	1 273	0.974
Measured males			1 026	
Measured females			768	
Aged males			224	
Aged females			298	
No. of tows sampled			53	
Mean weighted CV (sexes pooled)			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, and the HAK 1 fishery in the Sub-Antarctic. The target has almost always been met for samples in the WCSI fishery (see Table 4). The sampling intensity in the HAK 7 (WCSI) commercial trawl fishery was much higher in 2012–13 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 2) and the sampling intensity of this fishery in 2012–13 was relatively high. Hake on Chatham Rise were analysed as two separate fisheries (see Table 1), but sampling intensity in 2012–13 was too low to enable estimation of catch-at-age distribution for either fishery.

The Chatham Rise survey in January 2014 produced low numbers of hake (103 measured fish in the core strata), and consequently the catch-at-age distribution for the trawl survey had a mean weighted CV much higher than the target of 30% (55%). No improvements in the precision can be achieved, however, as all available data were included in the analysis. The target of 30% was met in only one of the surveys in this series. There was no survey of the Sub-Antarctic trawl in December 2013.

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 appear to be about evenly abundant in all areas except Statistical Area 404, where males dominate the catch (Horn & Sutton 2009). Some year class progressions are apparent. The year class 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 is a clear year class progression apparent in the Chatham Rise survey distributions from 2004 to 2011 (Figure A5). The year class spawned in late 2001 (aged 2+ years in January 2004) clearly progresses 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) are moderately strong.

In the Sub-Antarctic, there are 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, and aged 6 in 1998 through to age 12 years in 2004.

The WCSI trawl catch is 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 are taken by the fishery, but these do not always manifest as strong cohorts in later years. However, it does appear that the relatively abundant 2-year-old fish in catches from 2005, 2006, and 2007 have progressed to comprise a high proportion of the catch from 2010 to 2012. A characteristic of most of the WCSI distributions is that numbers of fish aged 3 and 4 years 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

Catch-at-age distributions were produced for one commercial longline fishery in 2012–13 (Chatham Rise), and the target CV was met. Catch-at-age distributions were scheduled to be produced for the Sub-Antarctic and Bounty Plateau fisheries, but they were not sampled by observers in 2012–13. 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 Chatham Rise distribution used observer length data applied to age-length keys obtained from a trawl survey, i.e., Chatham Rise length data collected from October 2012 to May 2013 were applied to the age-length key from the January 2013 (TAN1301) trawl survey of the Chatham Rise. 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 2012 to April 2013 were applied to the age-length key from the December 2012 (TAN1215) trawl survey of the Sub-Antarctic. The estimated catch-at-age distributions had mean weighted CVs well within the target of 30%. Most distributions calculated for both these fisheries in previous years were within the target. The level of observer sampling of ling from the WCSI commercial fishery was good in 2012–13, in contrast to recent previous years when sampling was inadequate to estimate fishery age structure (see Table 21). The estimated catch-at-age distribution had a mean weighted CV well within the target of 30%. An estimate of catch-at-age for the ling bycatch from the Cook Strait hoki spawning fisheries was not able to be produced for 2013 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 trawl surveys of WCSI (August 2013) and Chatham Rise (January 2014) to meet the mean weighted CV target. The target was met in all previous surveys of these areas, except for Chatham Rise in 2011 (see Tables 24 and 27).

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 longline fisheries (i.e., at about 5 years), and most of the catch is 13 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 2008). 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

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

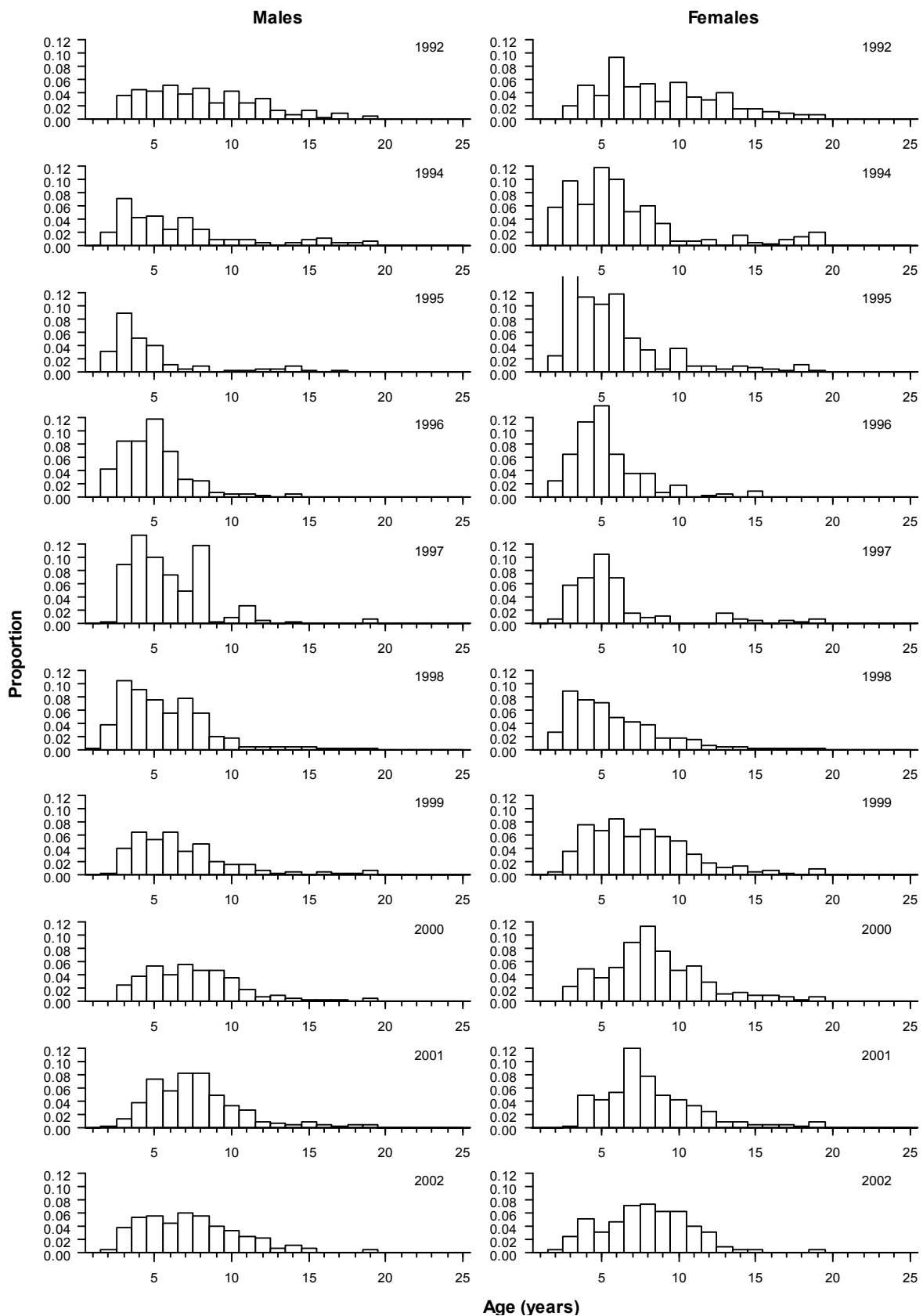


Figure A1: Available age frequencies of hake from commercial catch-at-age data in the Chatham Rise (west) trawl fishery, 1992 to 2013. Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “2002” denotes the October 2001–April 2002 sample.

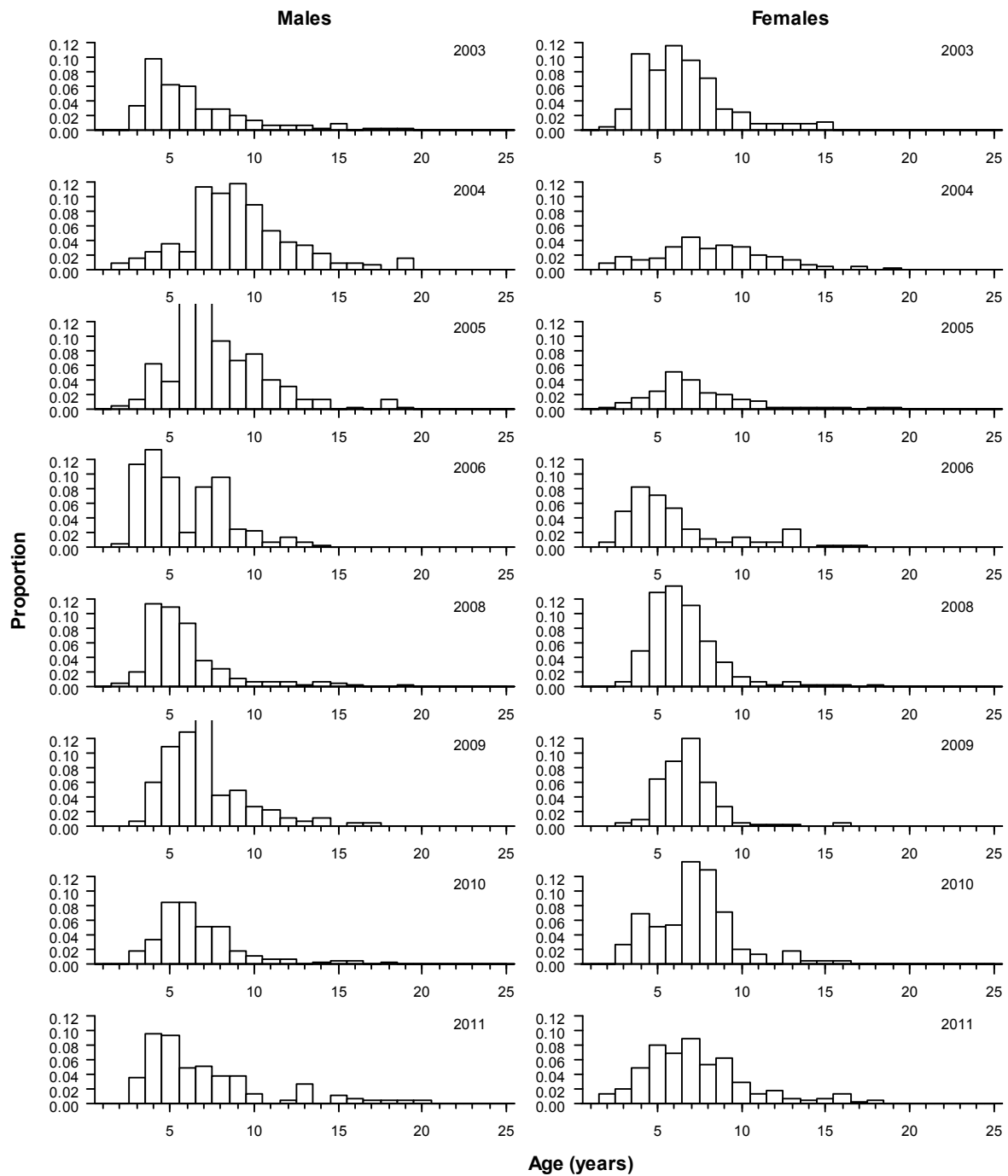


Figure A1 ctd.

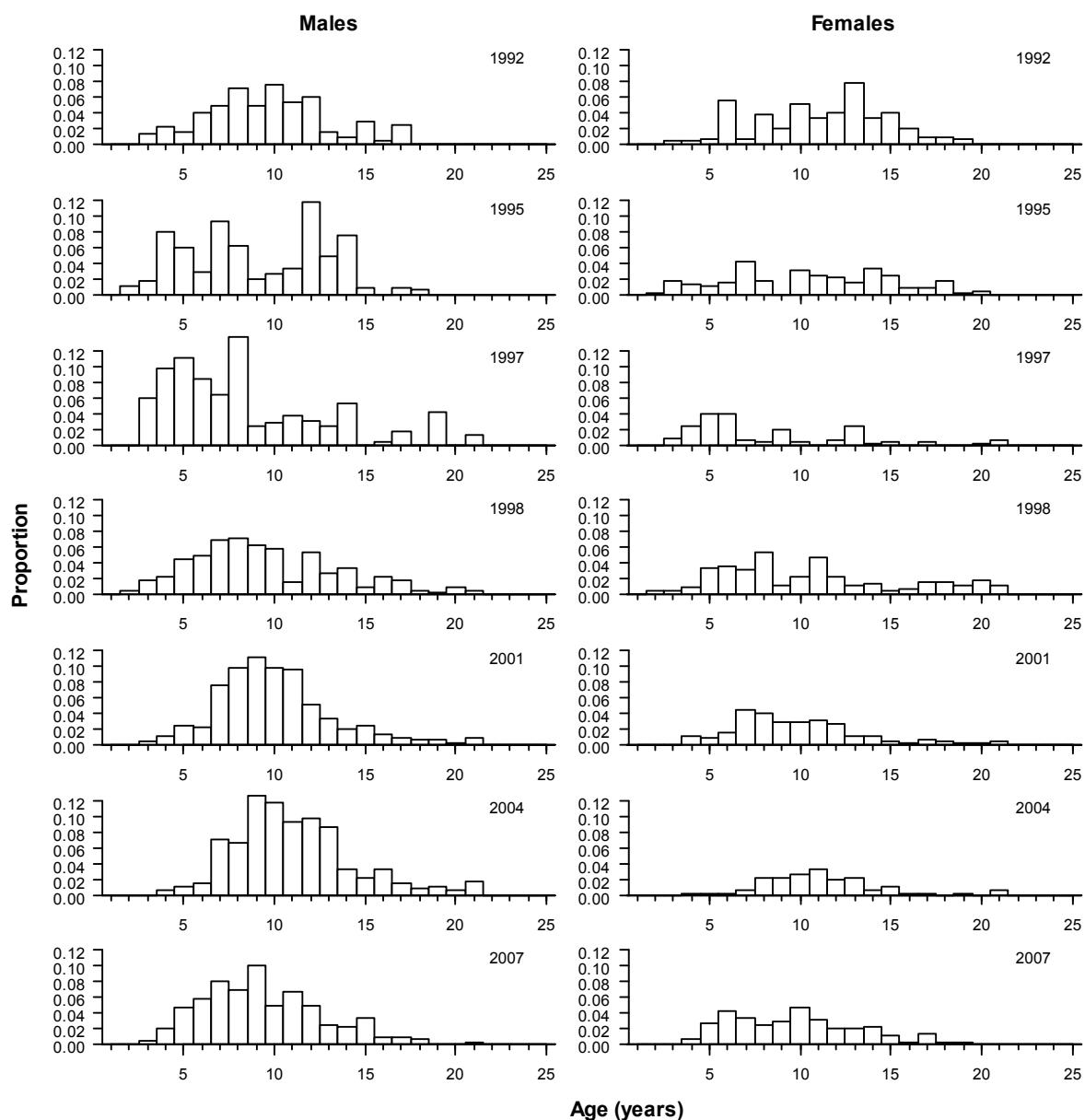


Figure A2: Available age frequencies of hake from commercial catch-at-age data in the Chatham Rise (east) trawl fishery, 1992 to 2013. Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “1992” denotes the October 1991–April 1992 sample.

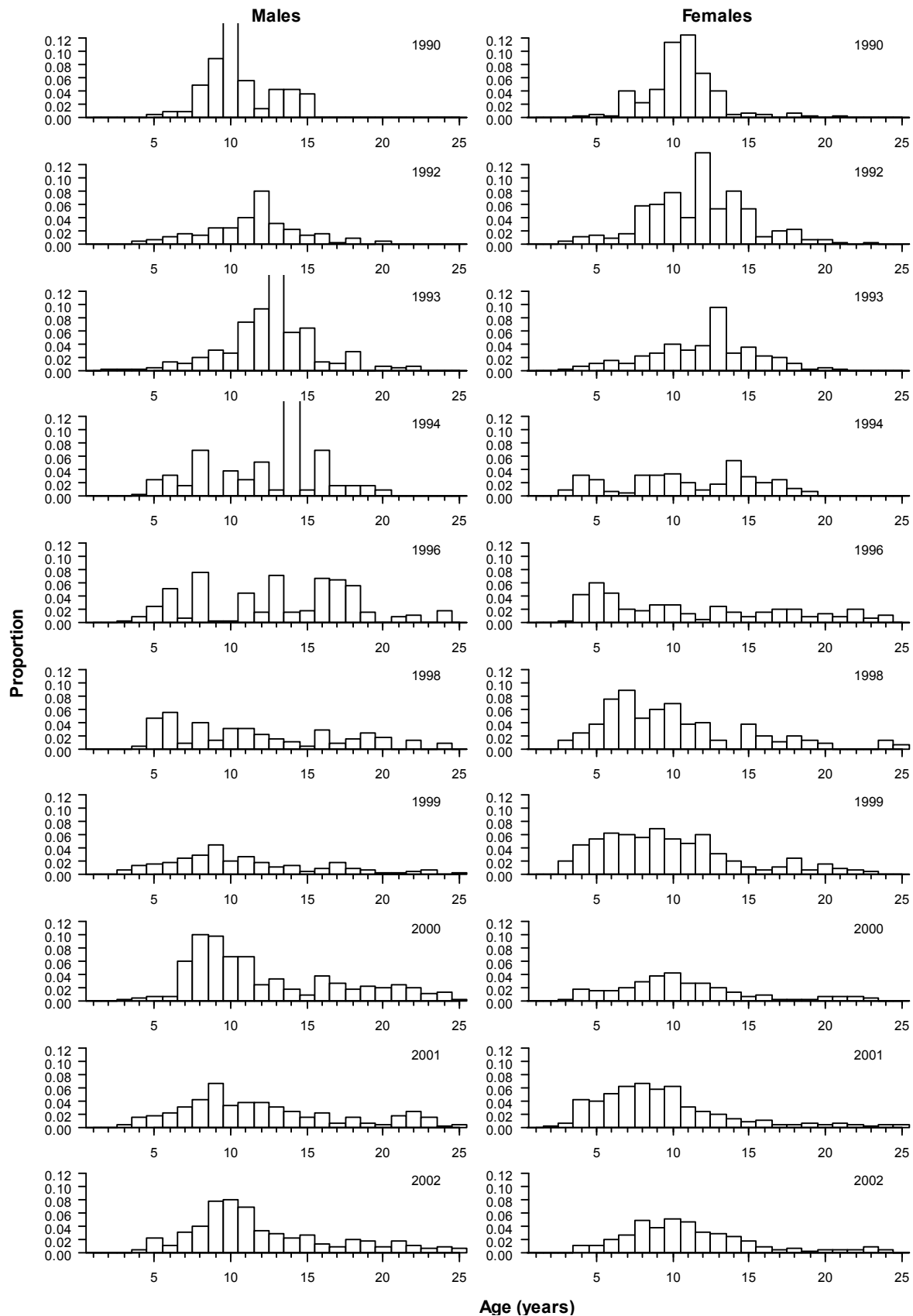


Figure A3: Available age frequencies of hake from commercial catch-at-age data in the Sub-Antarctic trawl fishery, 1990 to 2013. Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “2002” denotes the September 2001–May 2002 sample.

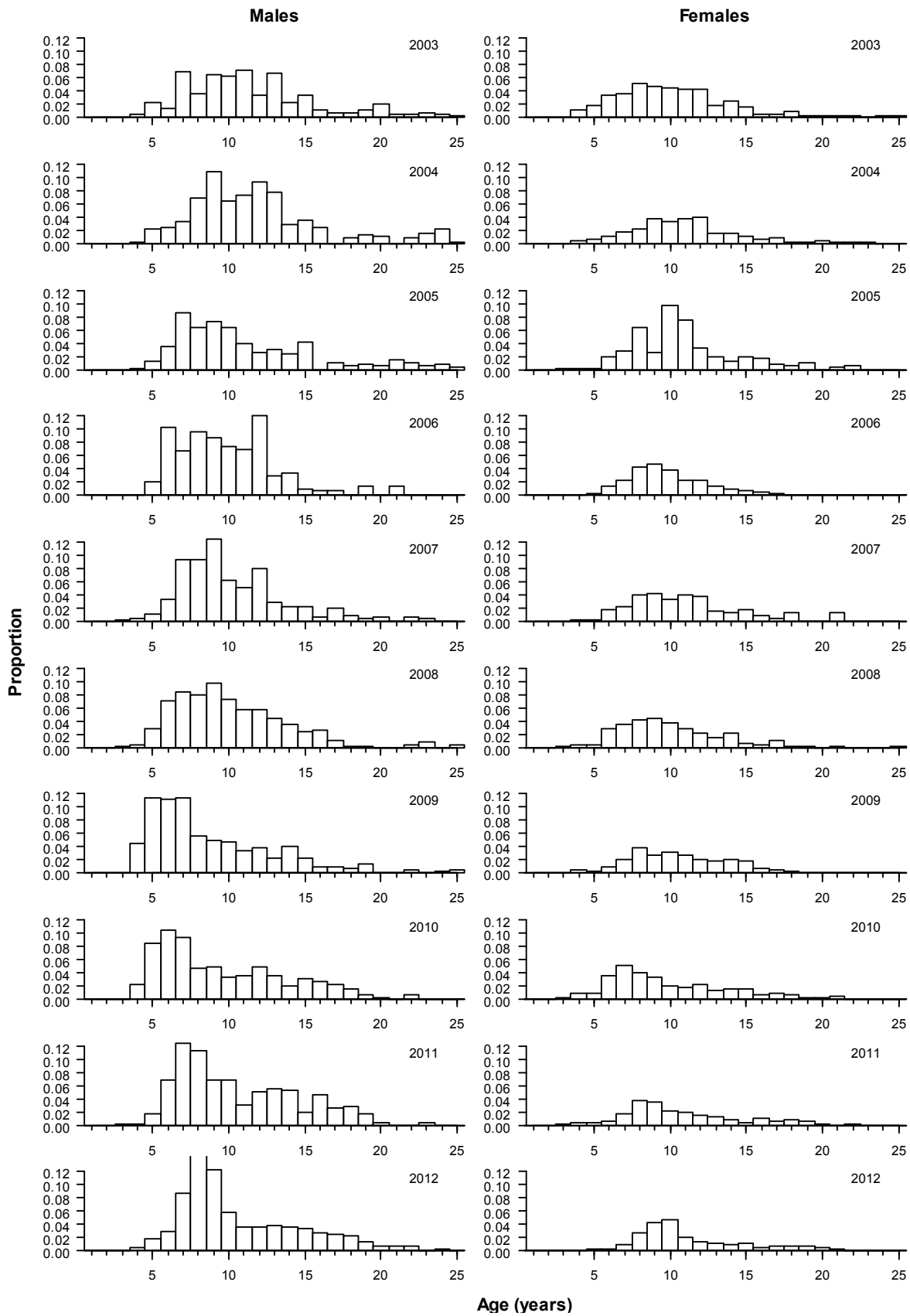


Figure A3 ctd.

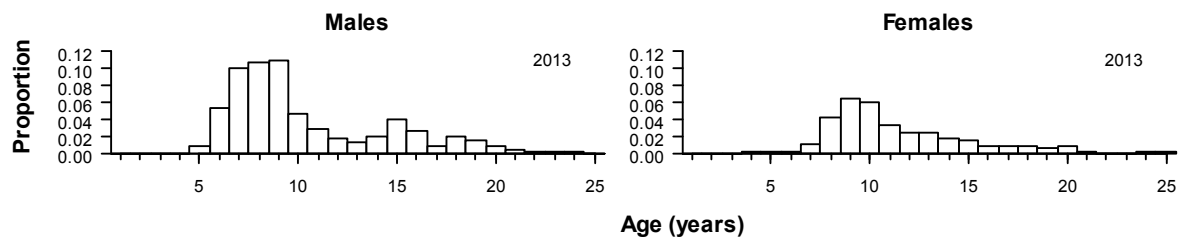


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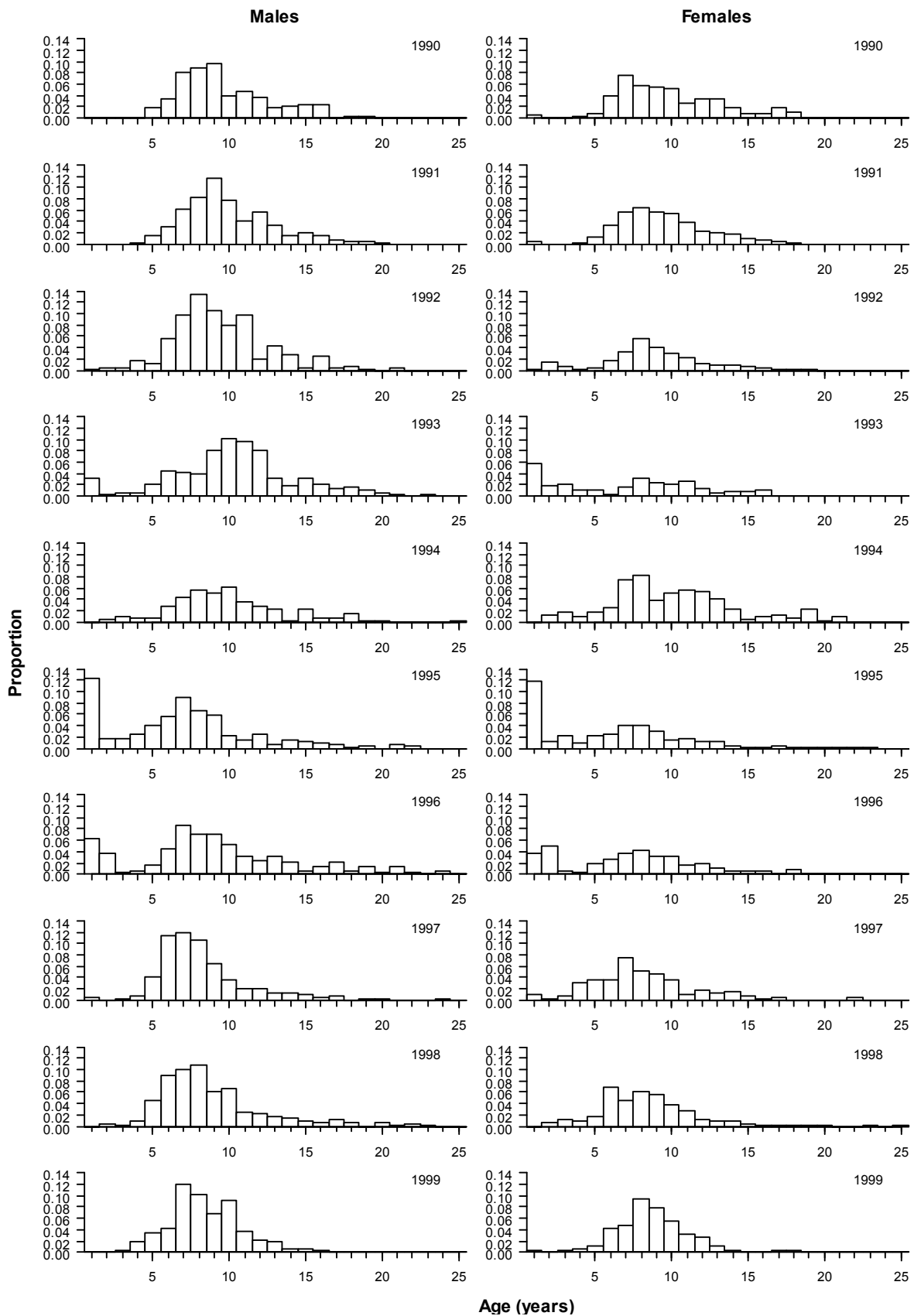


Figure A4: Available age frequencies of hake from commercial catch-at-age data in the WCSI trawl fishery, 1990 to 2013.

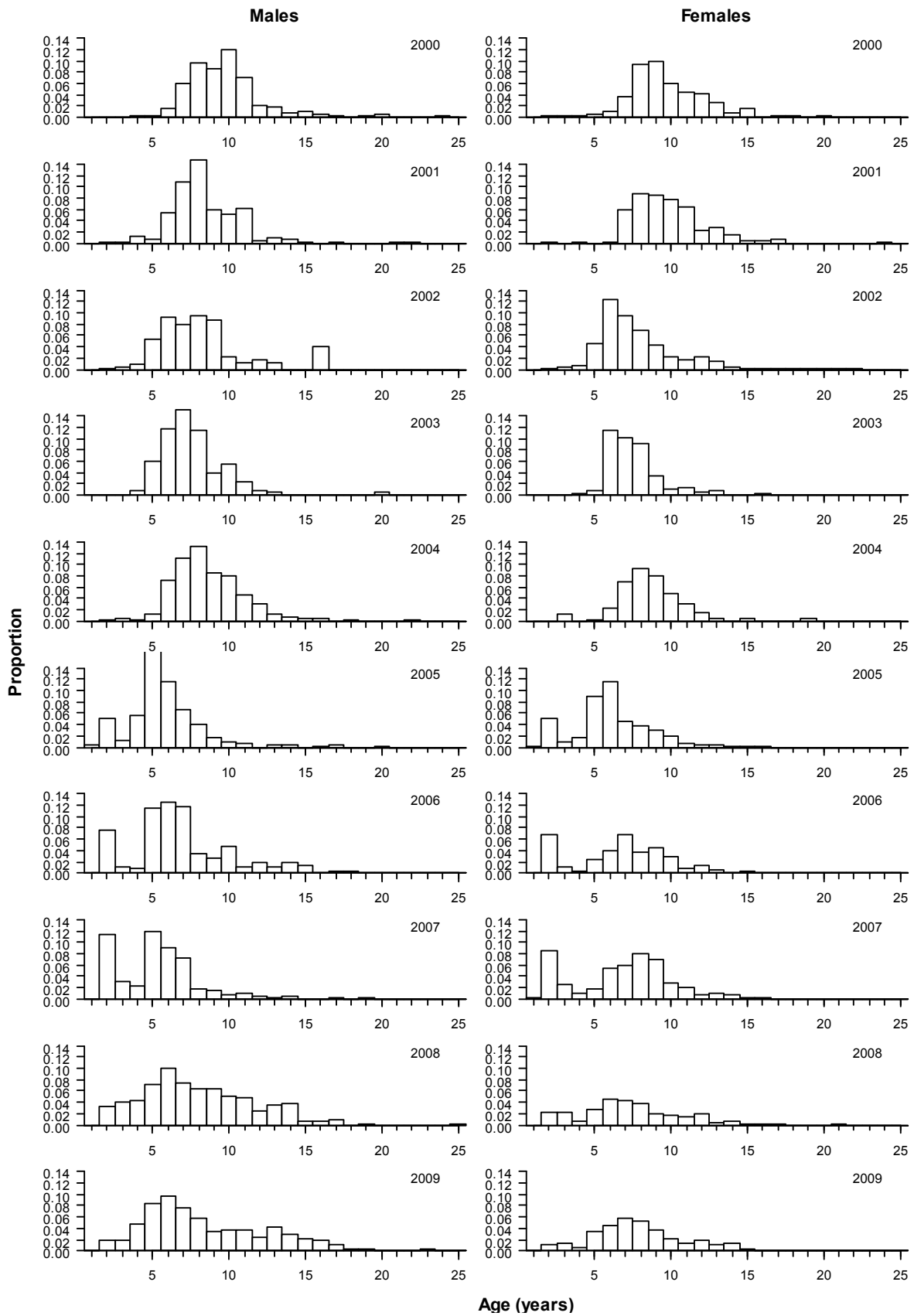


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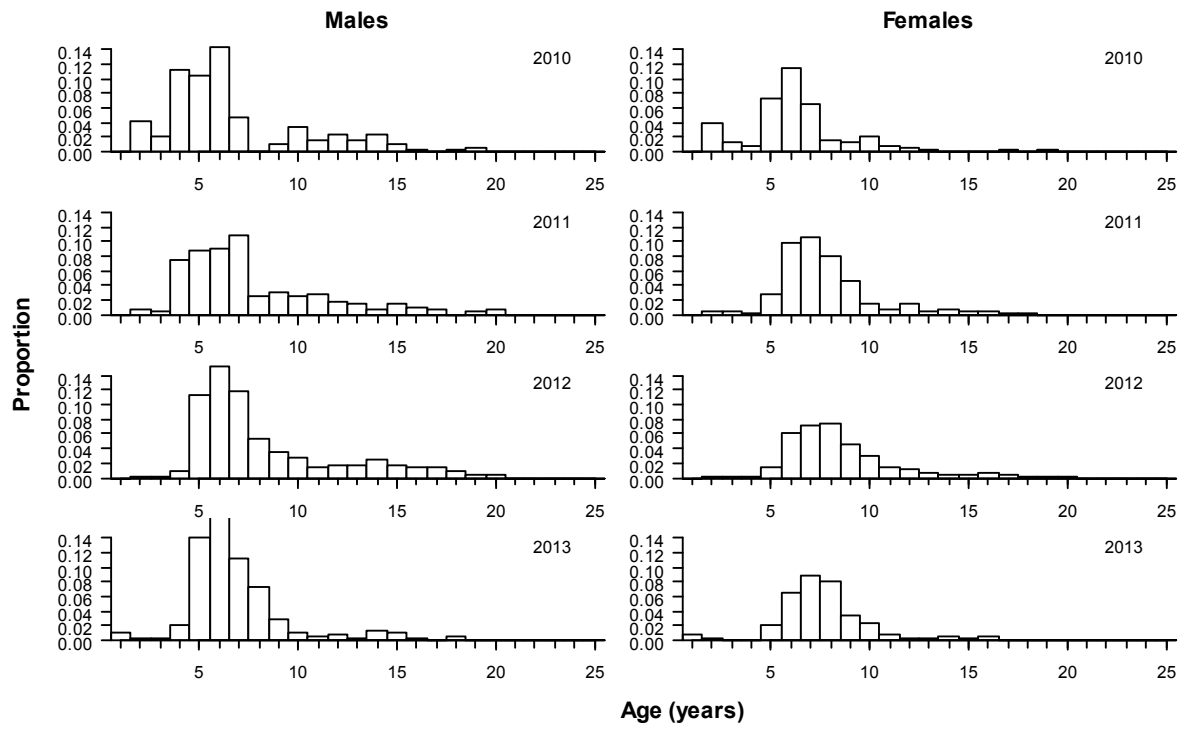


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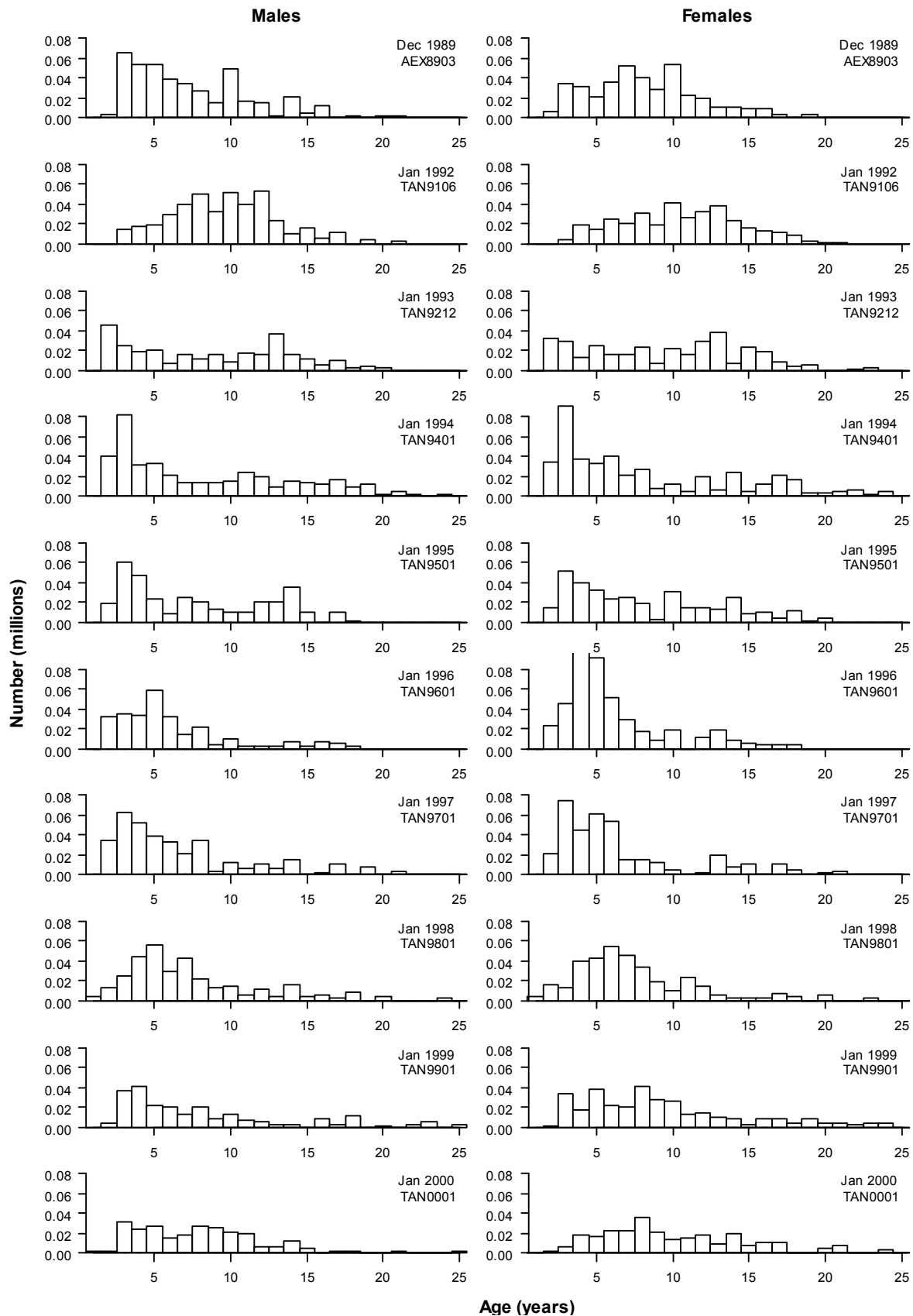


Figure A5: Available age frequencies of hake (ages 1 to 25) from resource surveys in the Chatham Rise, 1989–90 to 2013–14.

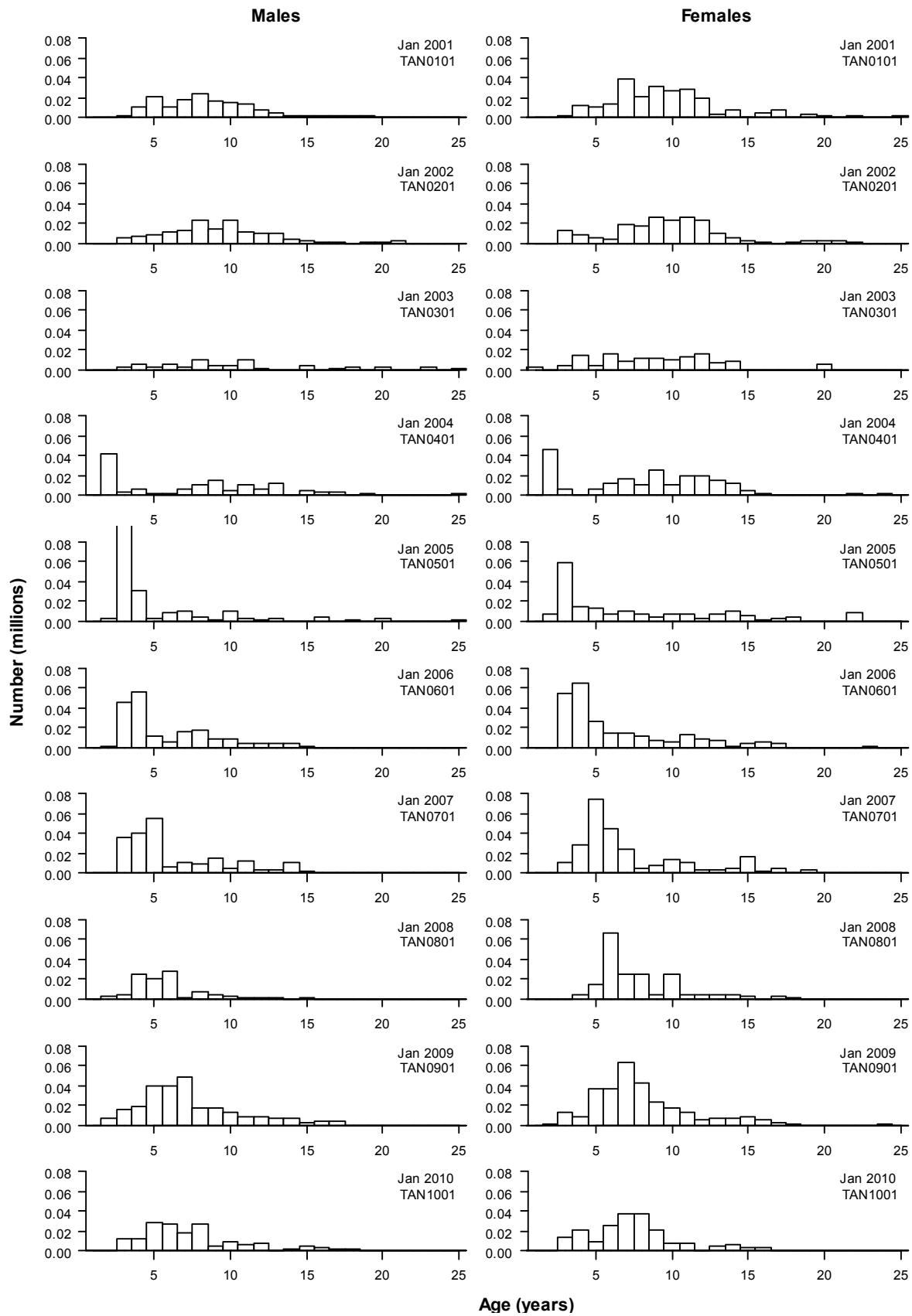


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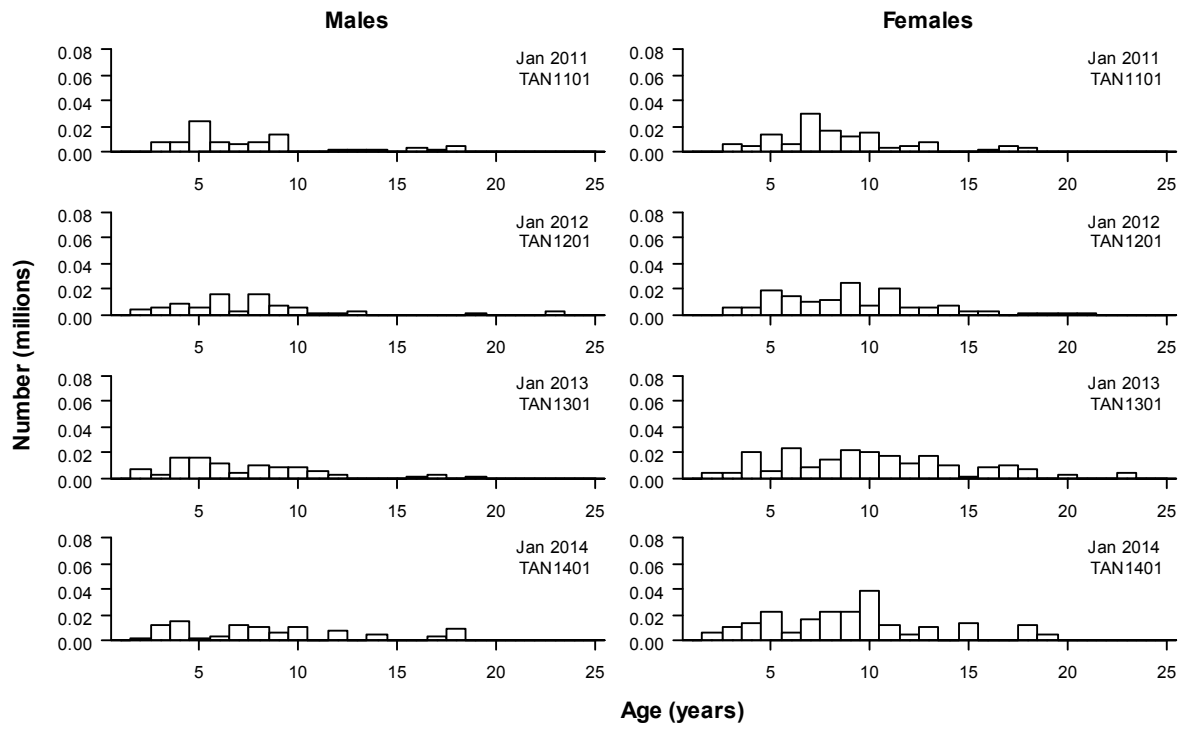


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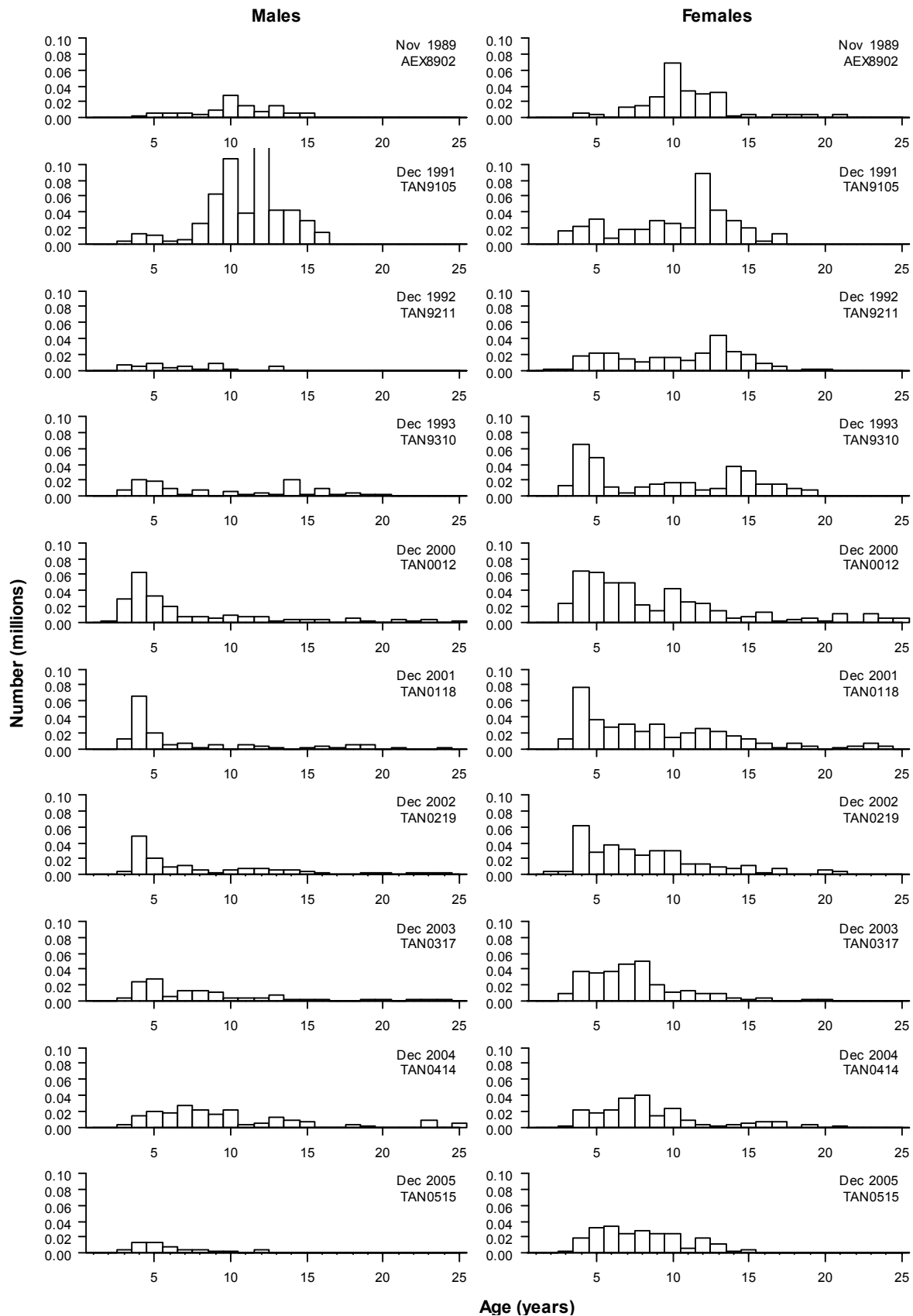


Figure A6: Available age frequencies of hake (ages 1 to 25) from summer resource surveys in the Sub-Antarctic, 1989 to 2013.

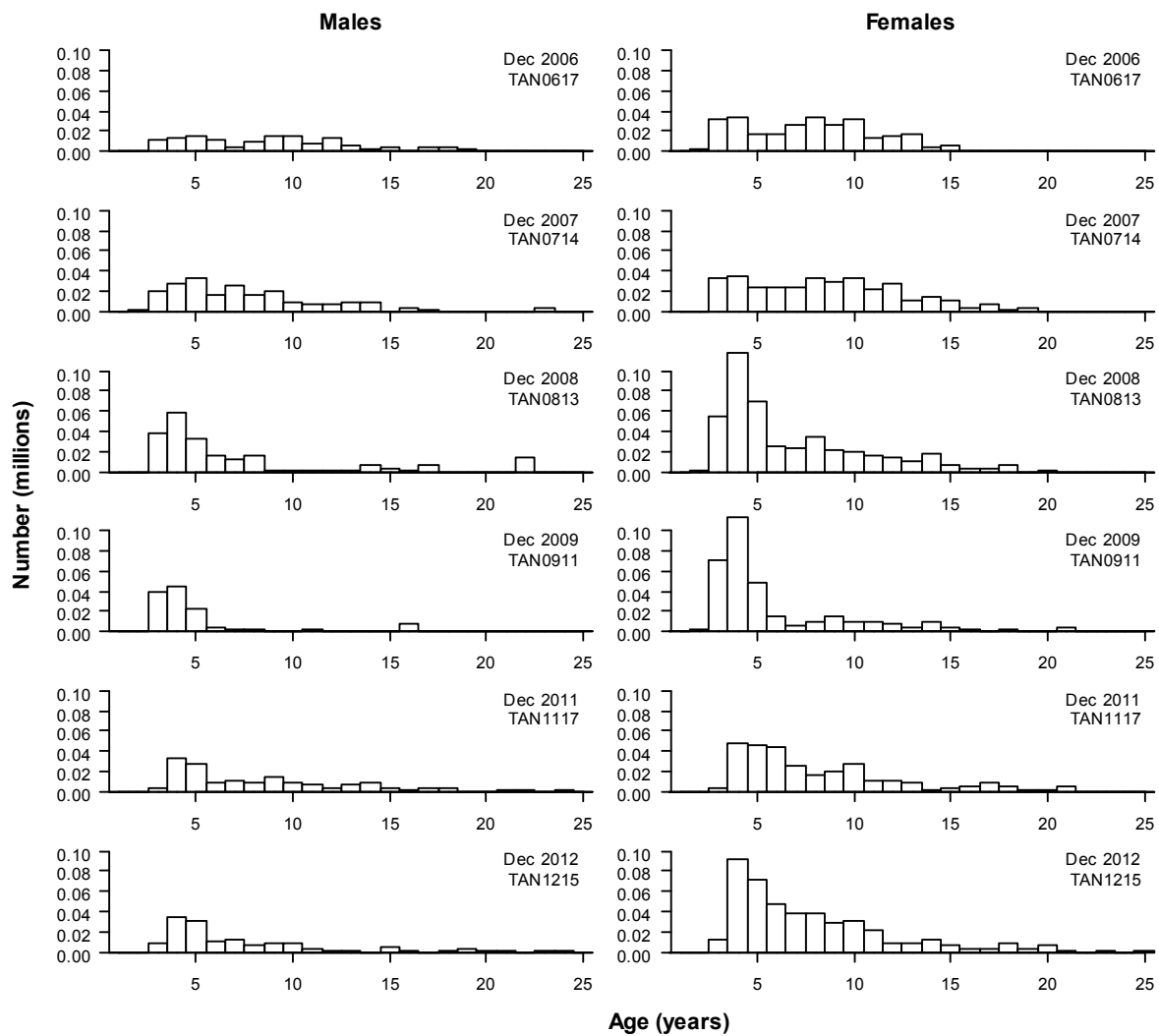


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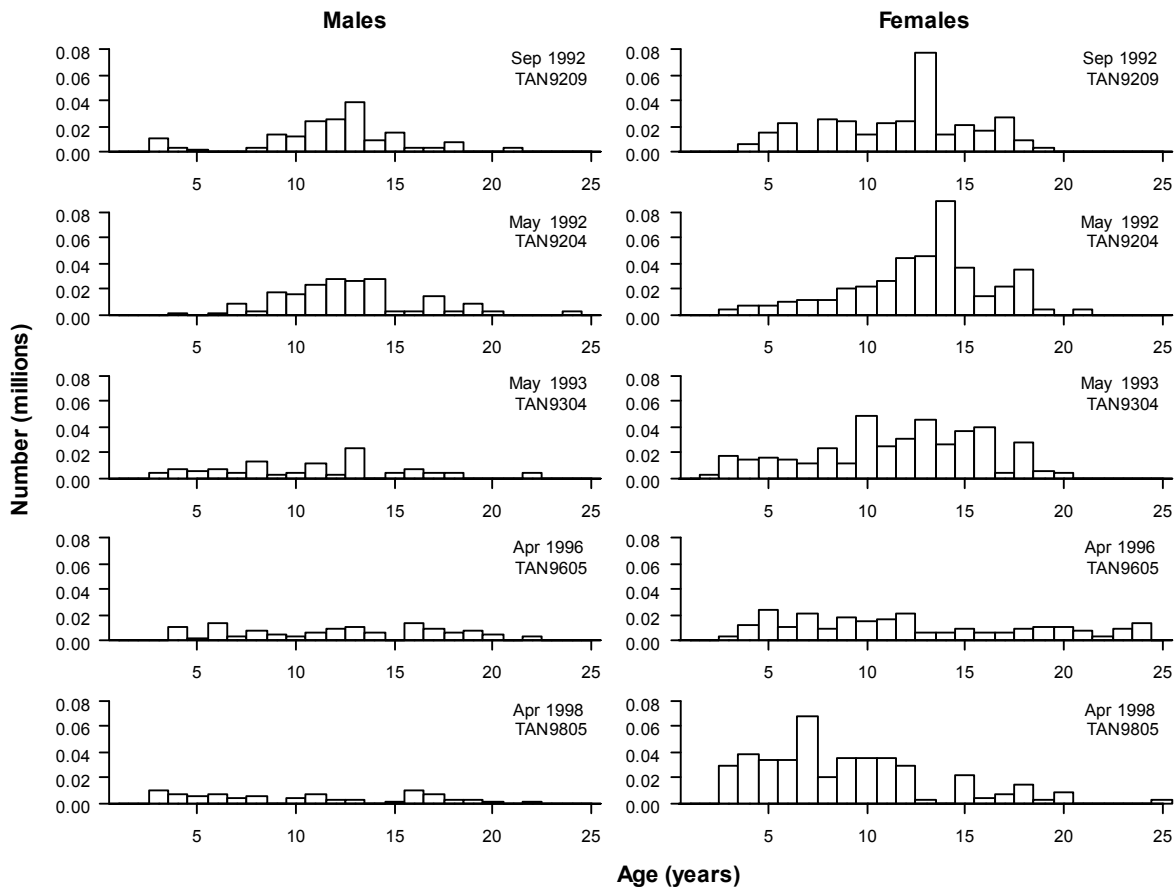


Figure A7: Available age frequencies of hake (ages 1 to 25) from spring and autumn resource surveys in the Sub-Antarctic, 1992 to 1998.

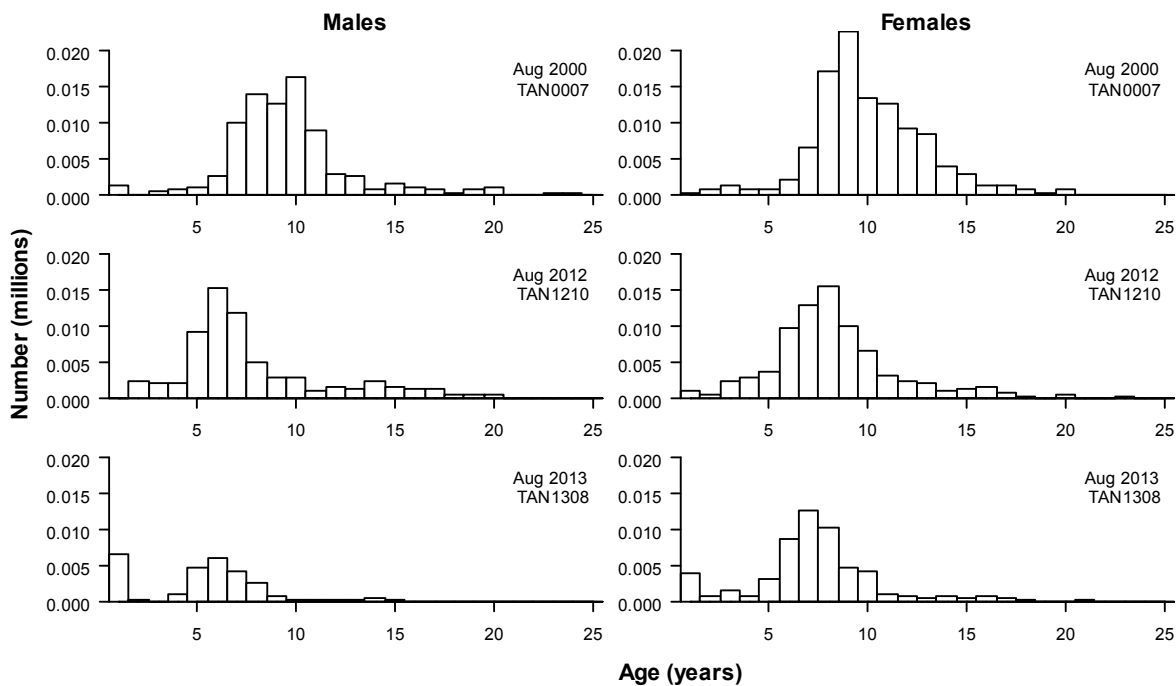


Figure A8: Available age frequencies of hake (ages 1 to 25) from resource surveys off WCSI, from 2000 to 2013.

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

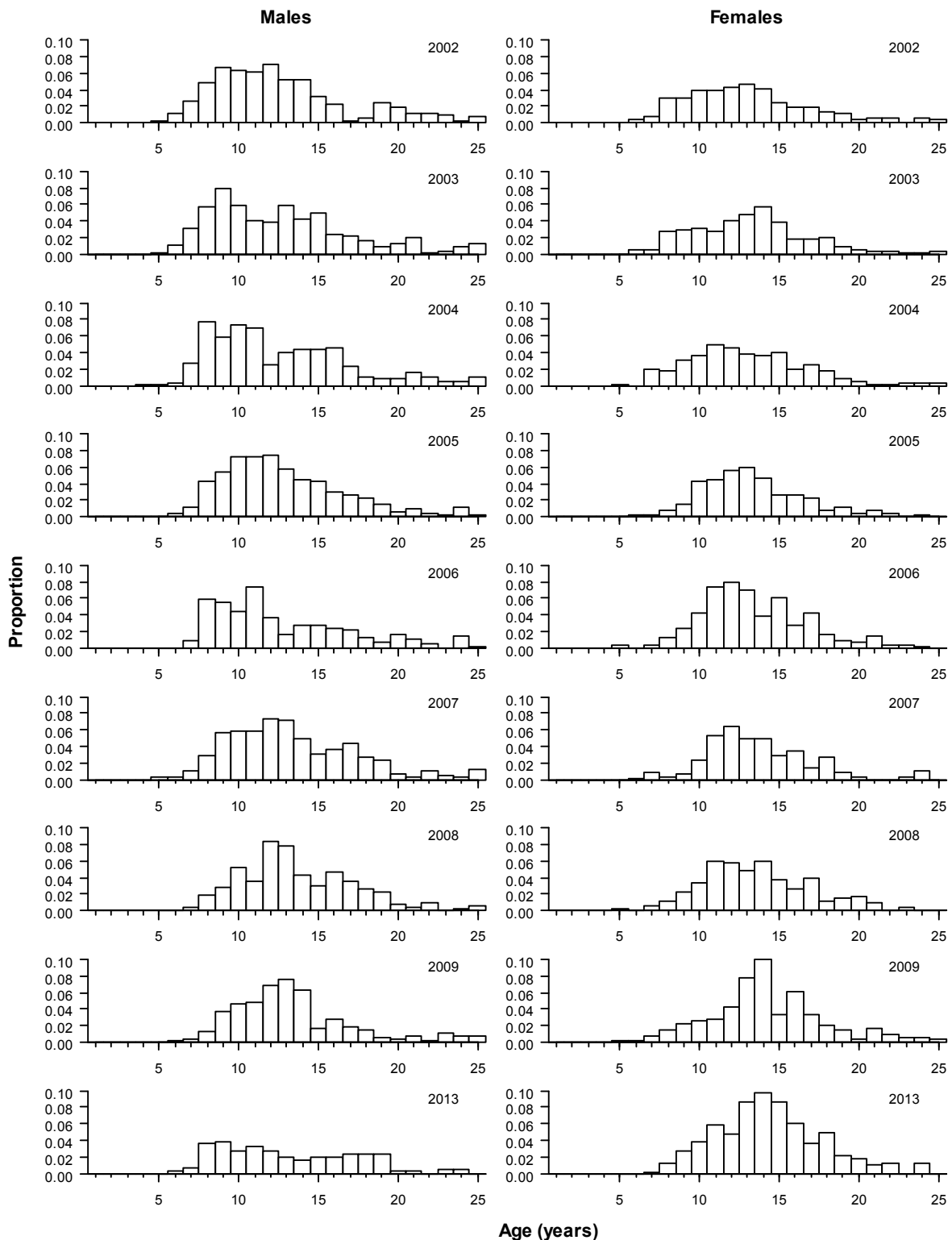


Figure B1: Available age frequencies of ling from commercial catch-at-age data in the Chatham Rise longline fishery, 2002 to 2013.

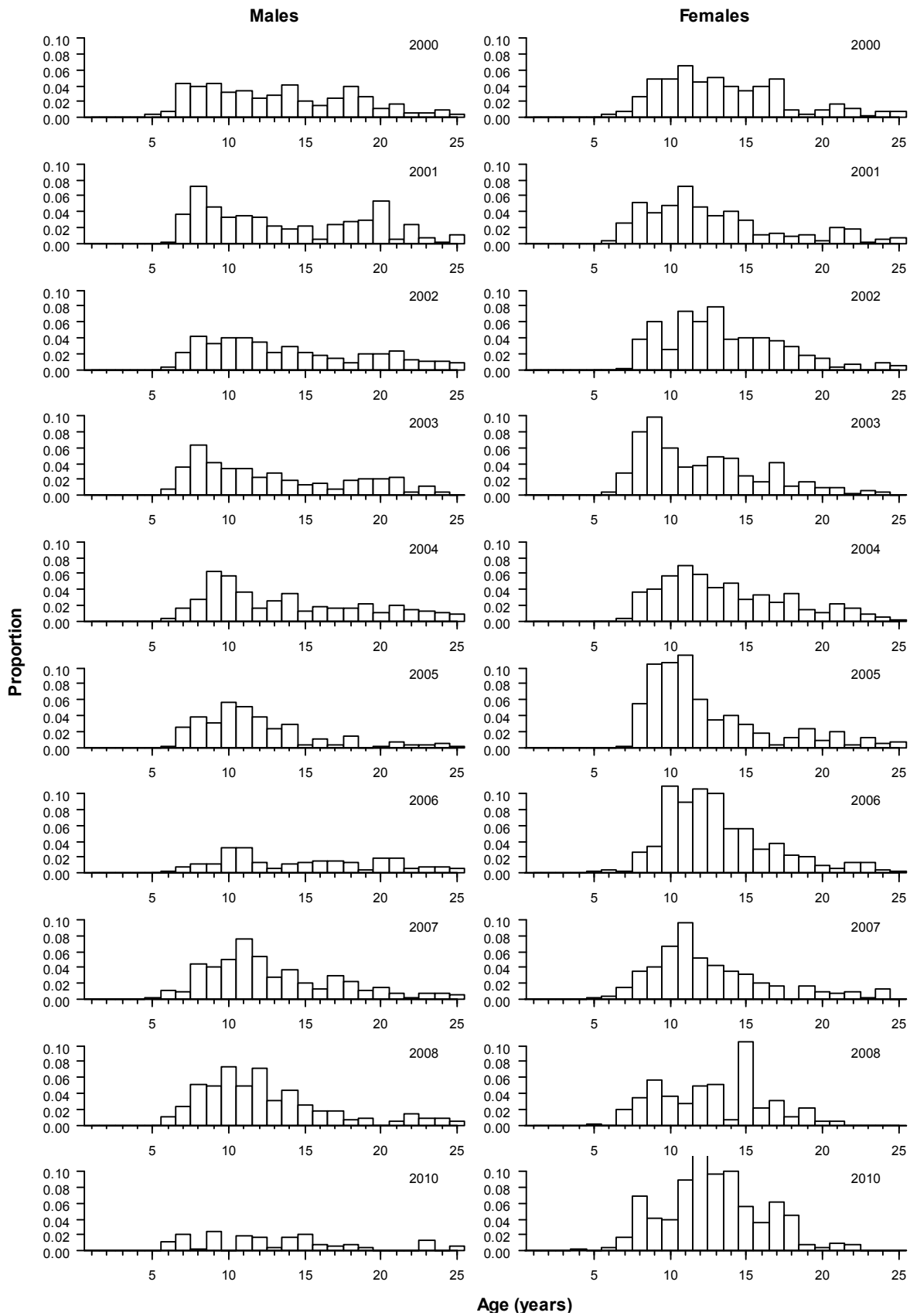


Figure B2: Available age frequencies of ling from commercial catch-at-age data in the Sub-Antarctic (spawning season) longline fishery, 2000 to 2013.

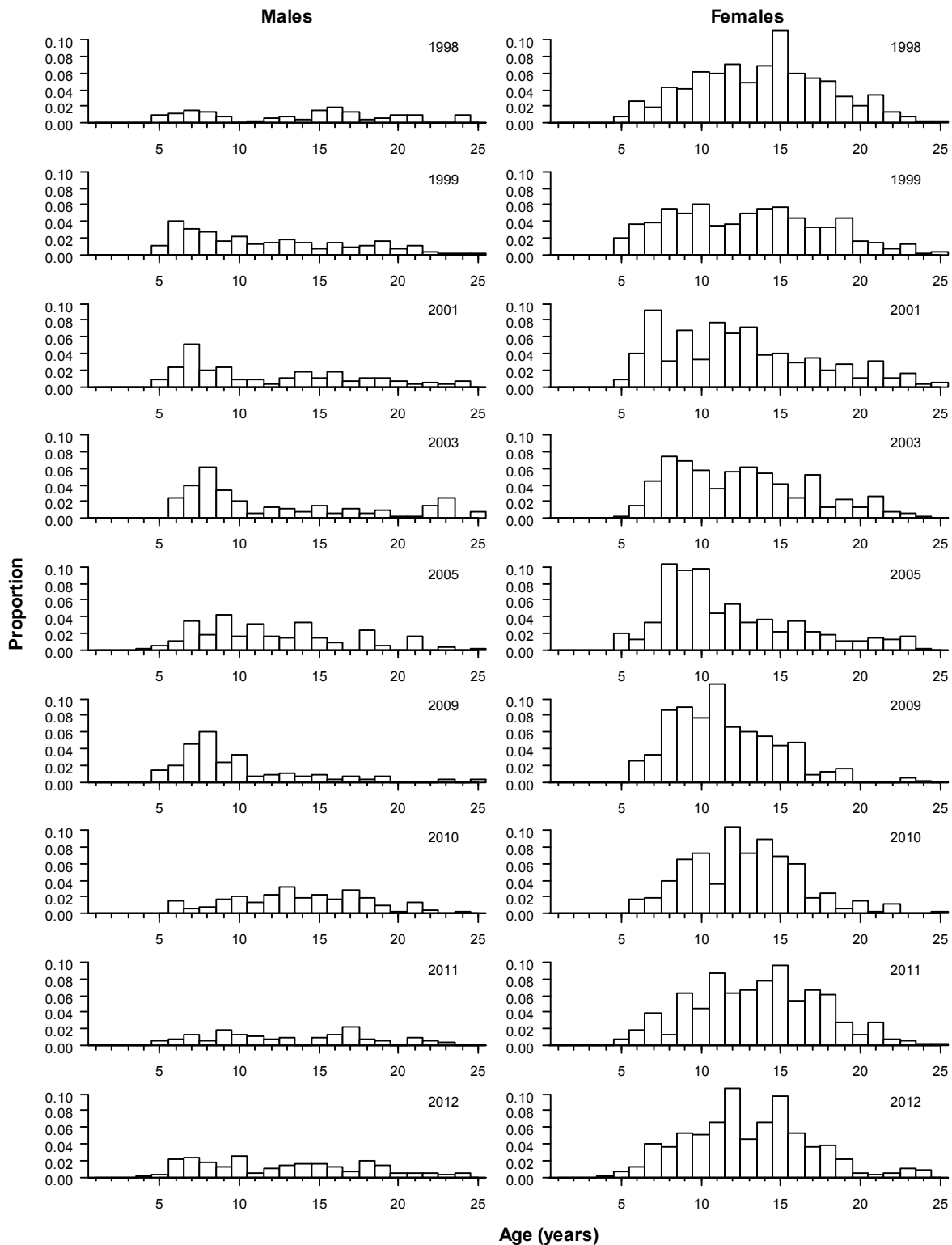


Figure B3: Available age frequencies of ling from commercial catch-at-age data in the Sub-Antarctic (non-spawning season) longline fishery, 1998 to 2013.

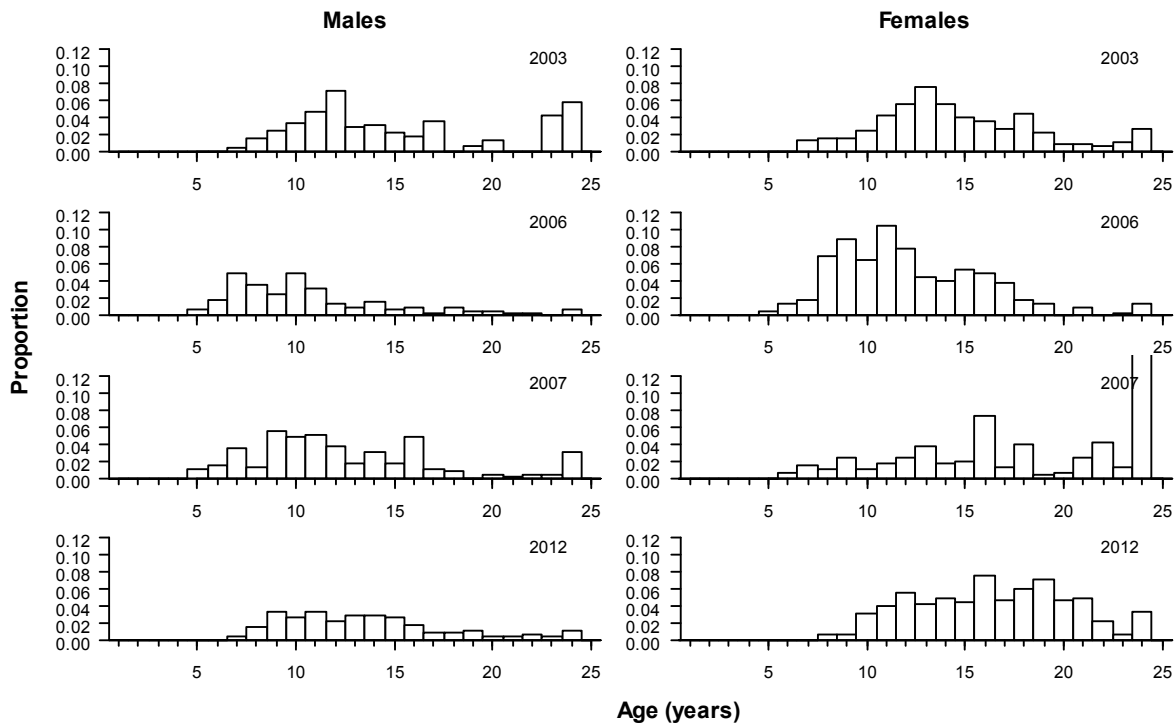


Figure B4: Available age frequencies of ling from commercial catch-at-age data in the west coast South Island line fishery, 2003 to 2013.

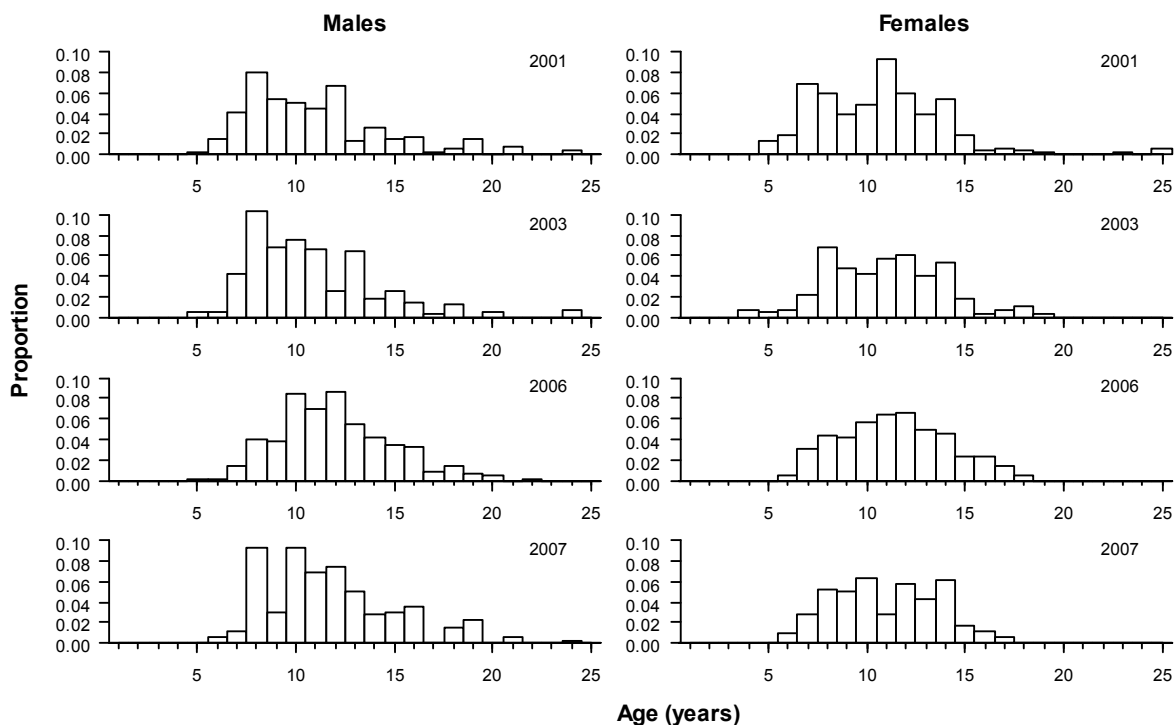


Figure B5: Available age frequencies of ling from commercial catch-at-age data in the Cook Strait longline fishery, 2001 to 2013.

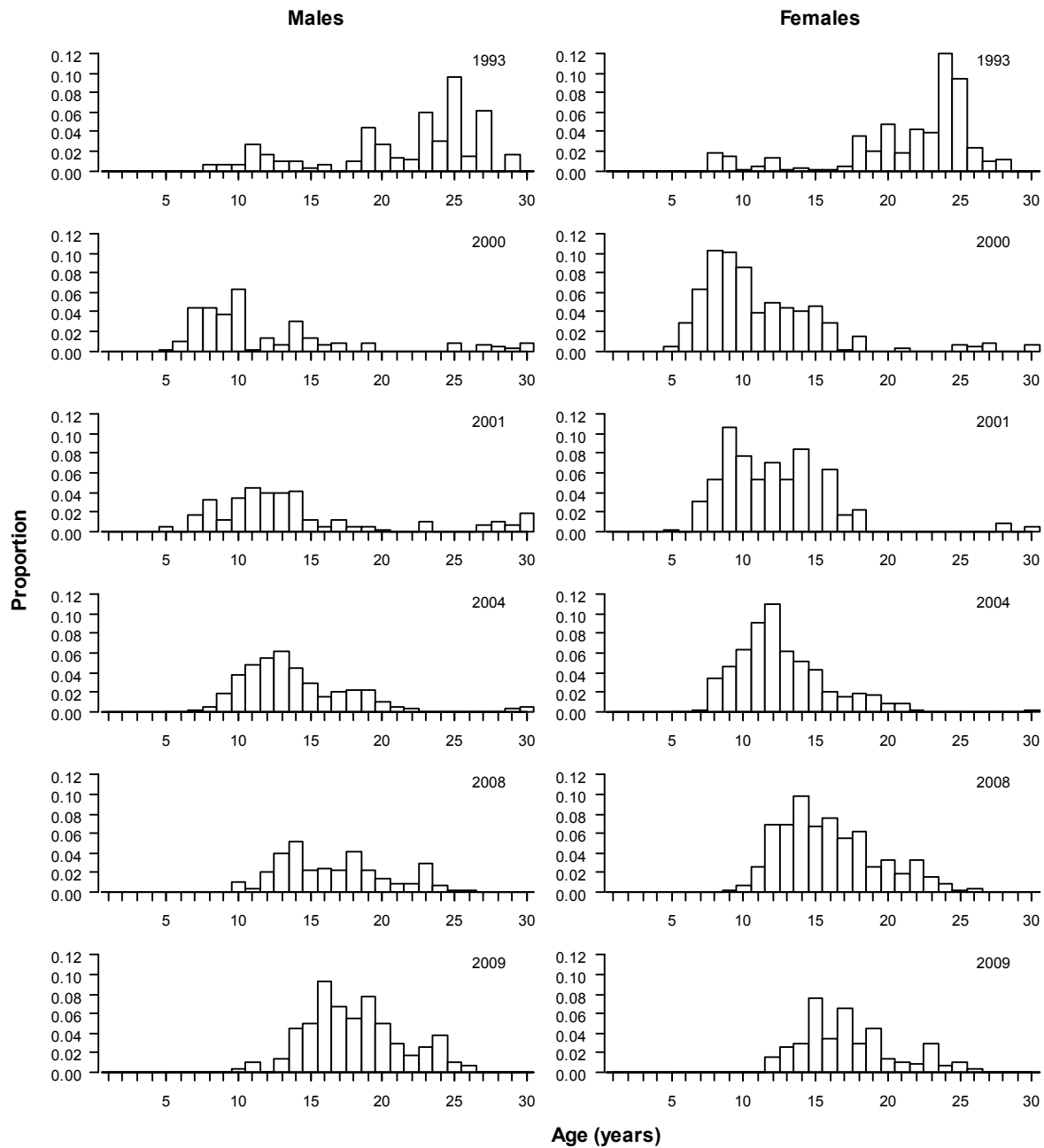


Figure B6: Available age frequencies of ling from commercial catch-at-age data in the Bounty Plateau longline fishery, 1993 to 2013.

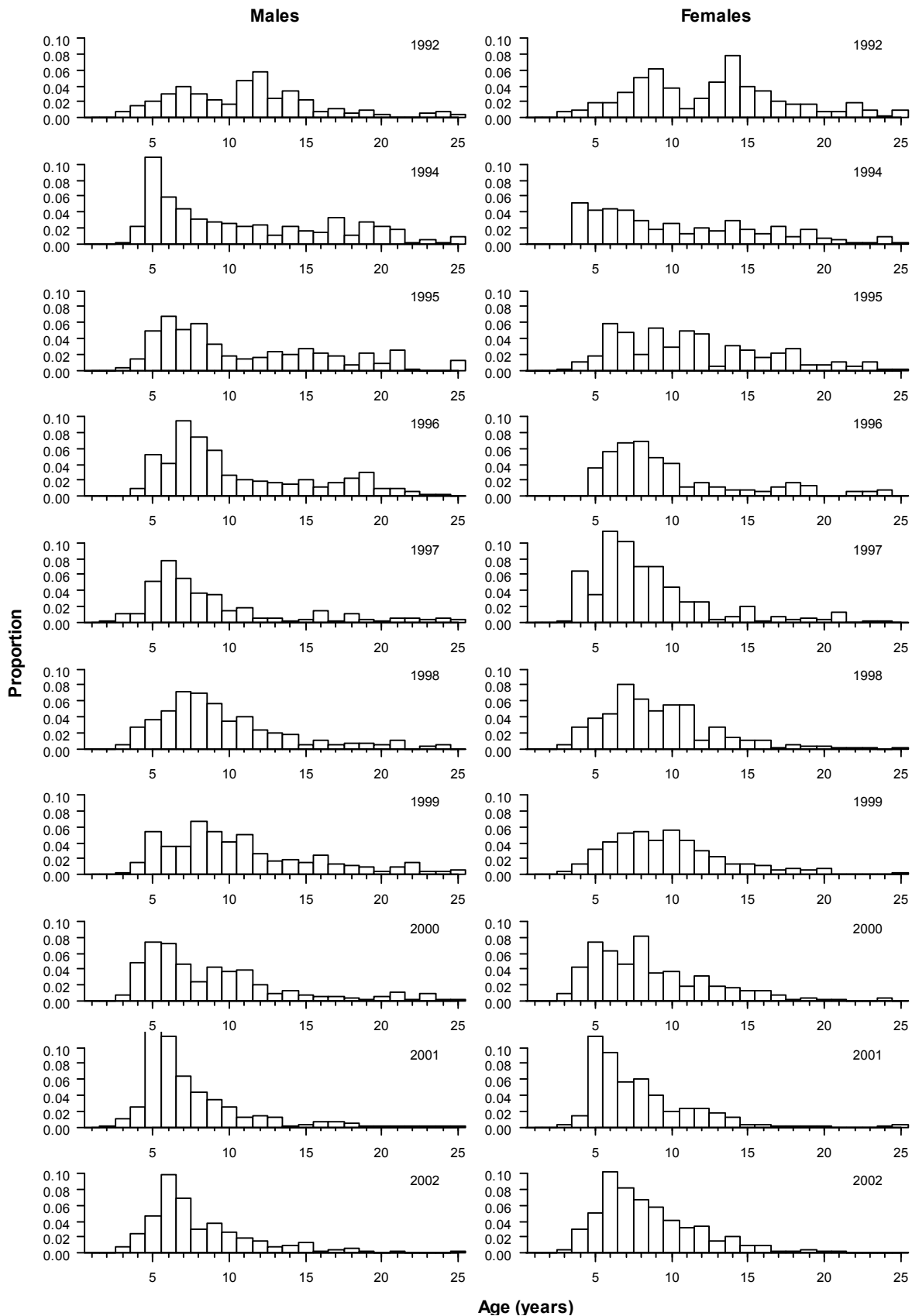


Figure B7: Available age frequencies of ling from commercial catch-at-age data in the Chatham Rise trawl fishery, 1992 to 2013. Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “2002” denotes the October 2001–May 2002 sample.

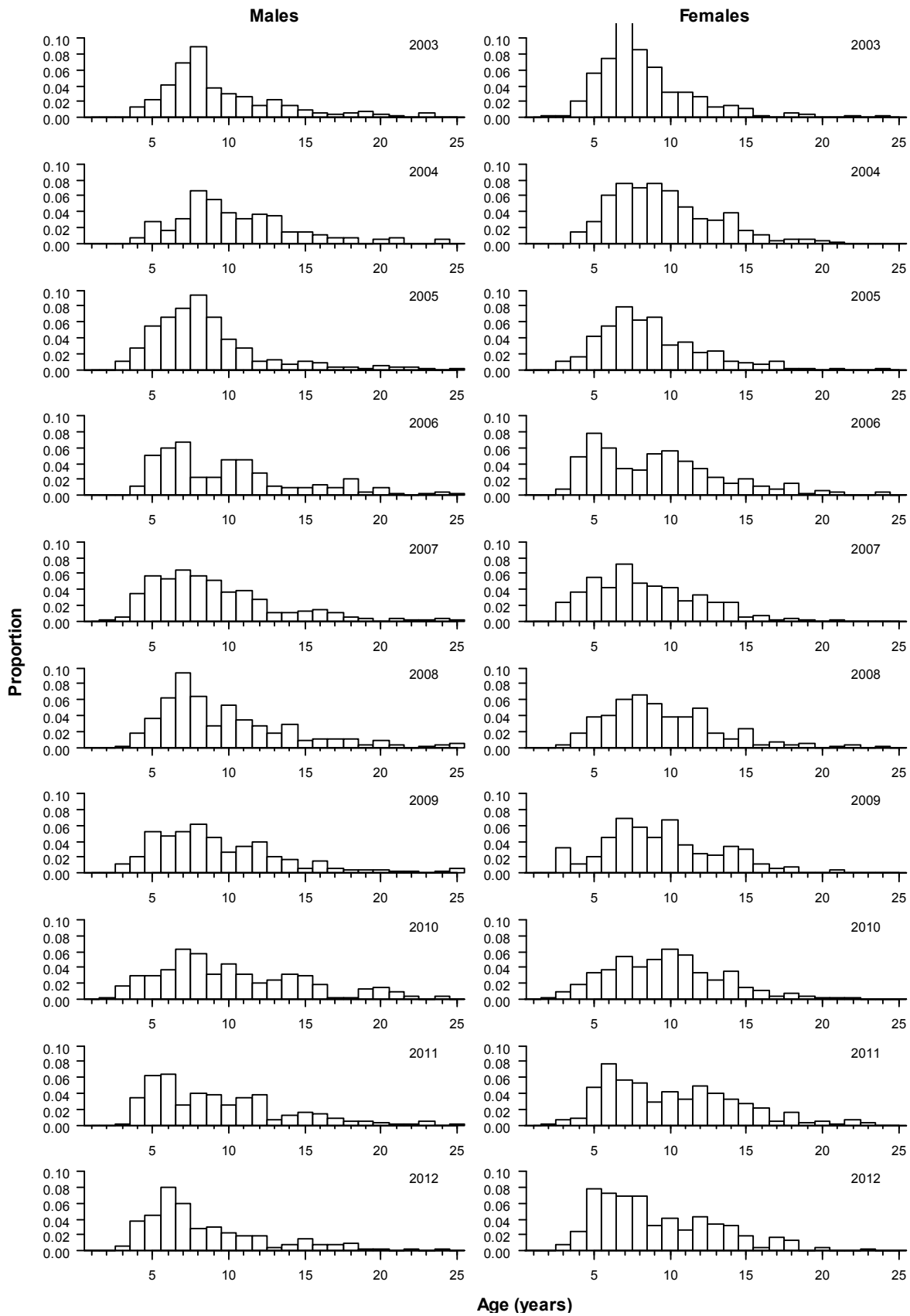


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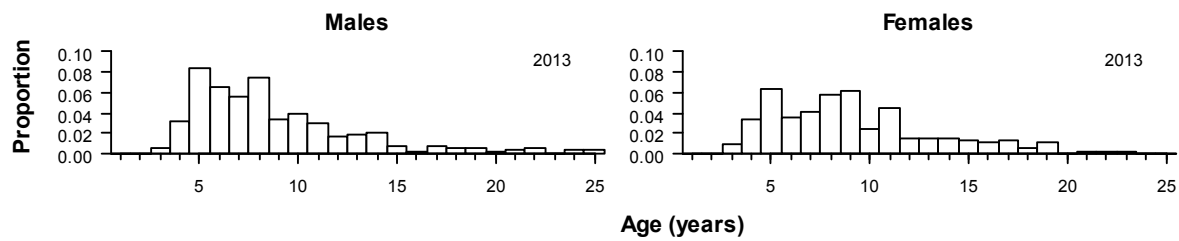


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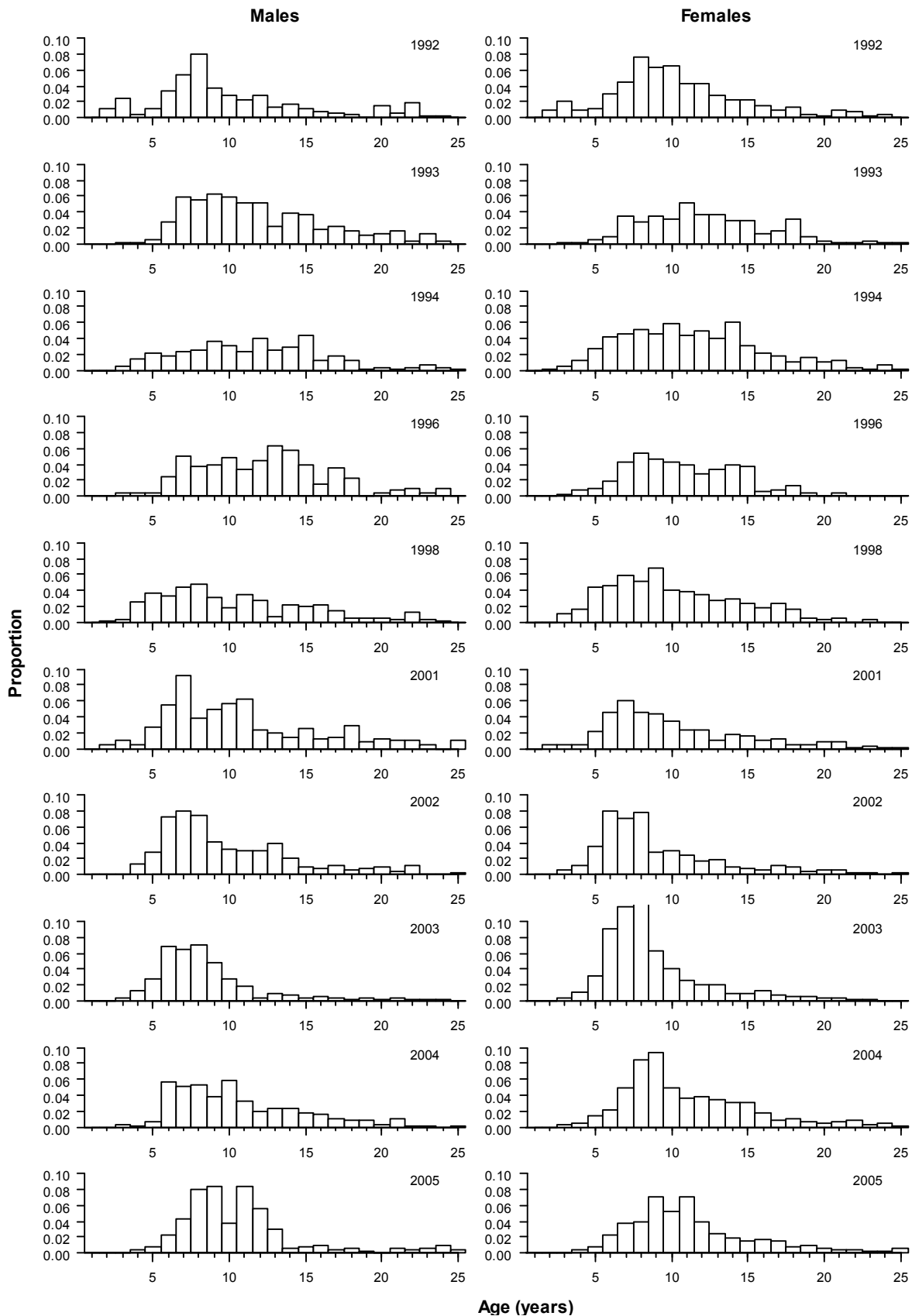


Figure B8: Available age frequencies of ling from commercial catch-at-age data in the Sub-Antarctic trawl fishery, 1992 to 2013. Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “2005” denotes the September 2004–April 2005 sample.

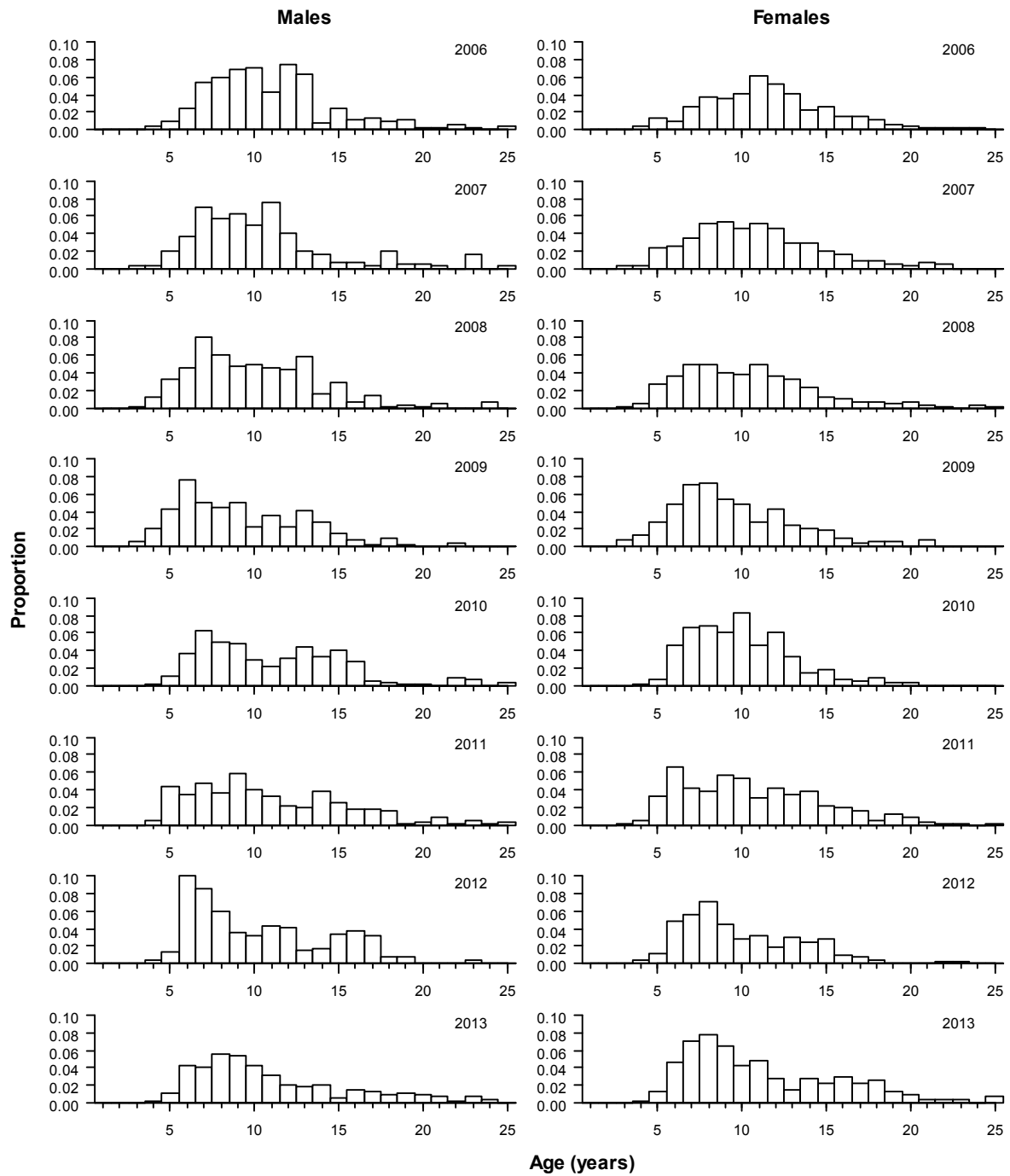


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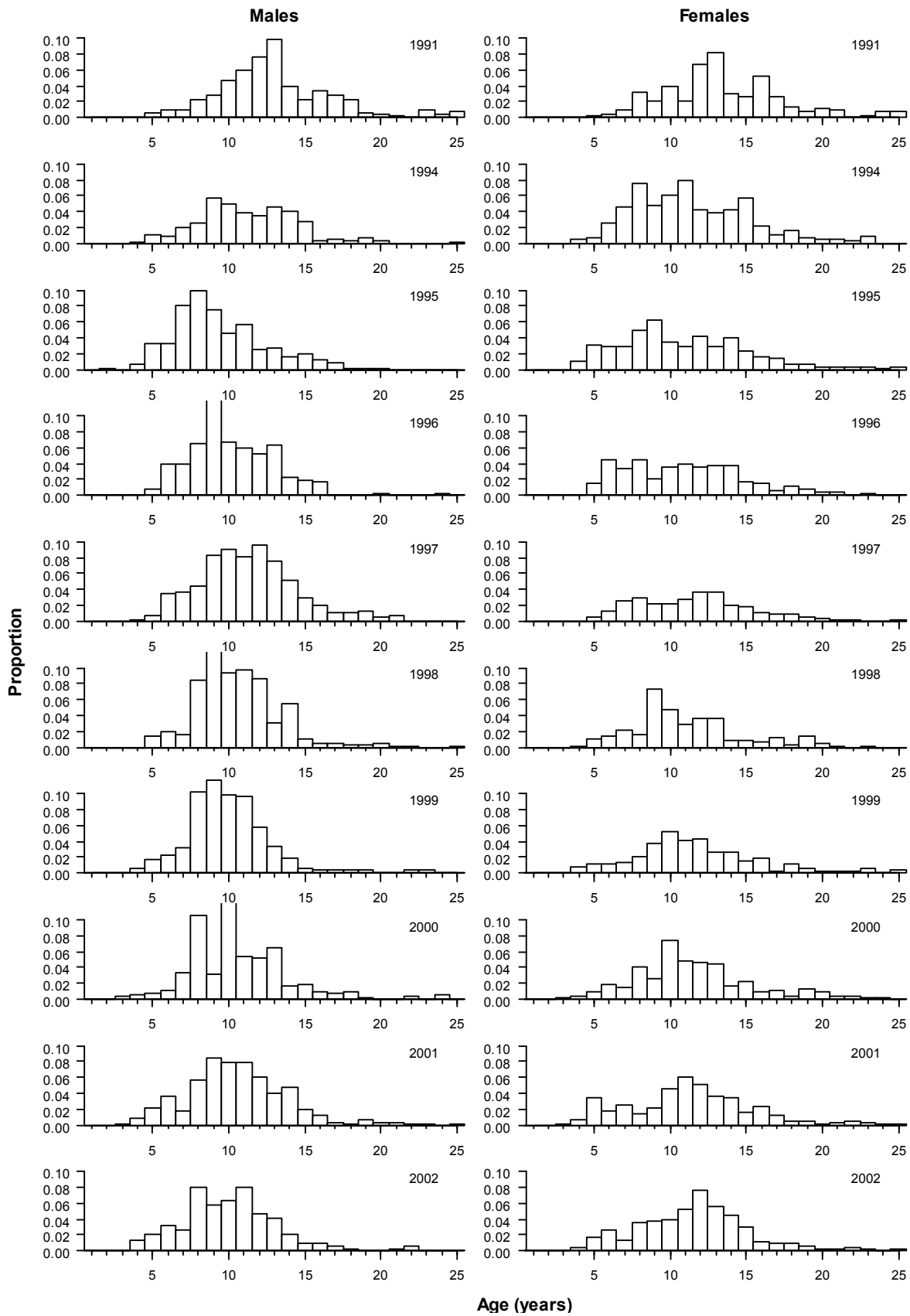


Figure B9: Available age frequencies of ling from commercial catch-at-age data in the WCSI trawl fishery, 1991 to 2013.

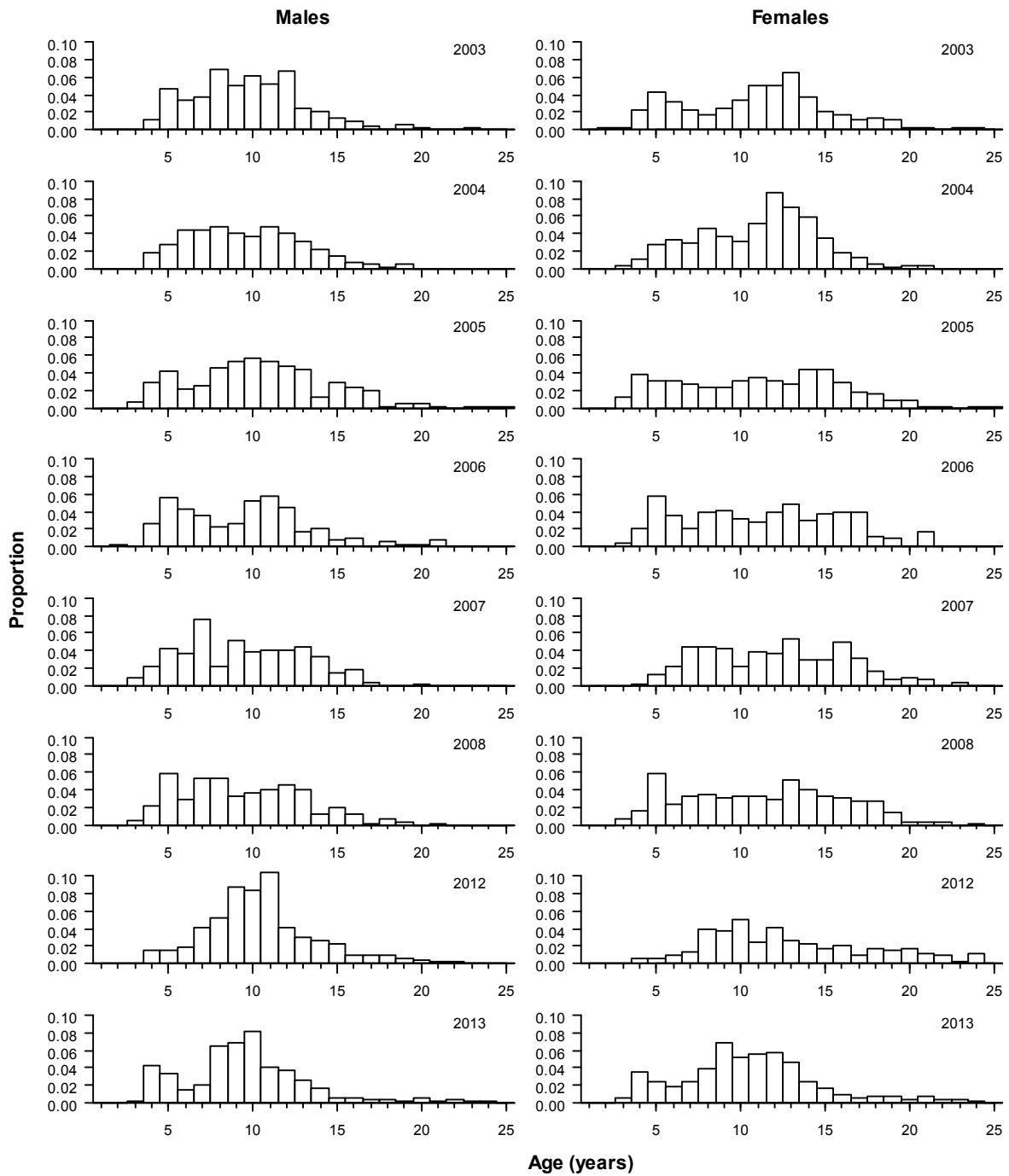


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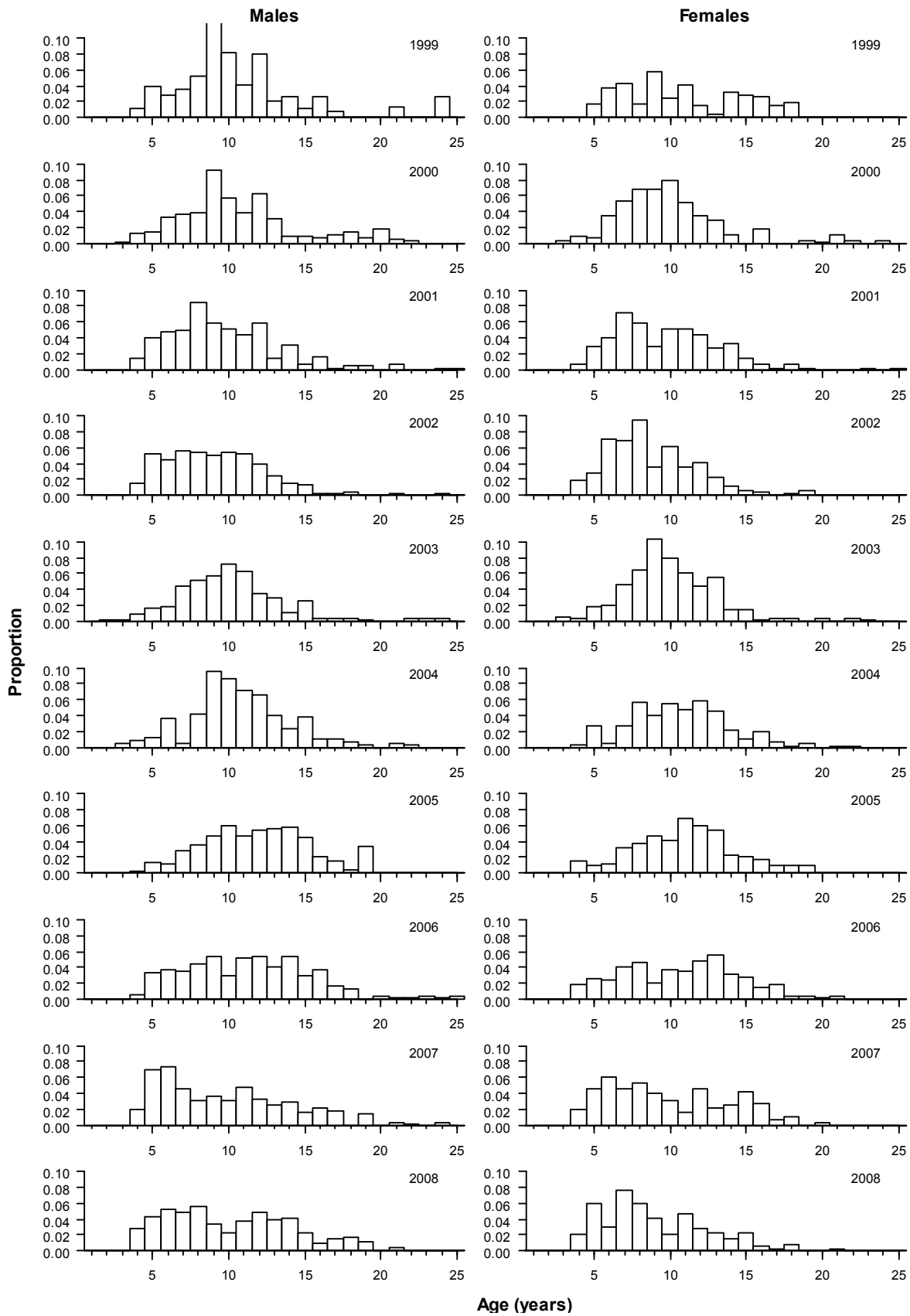


Figure B10: Available age frequencies of ling from commercial catch-at-age data in the Cook Strait trawl fishery, 1999 to 2013.

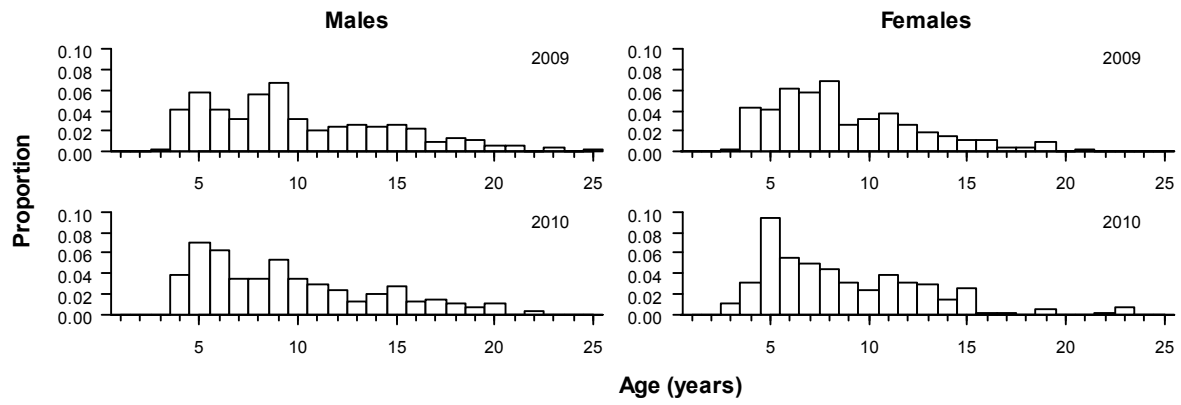


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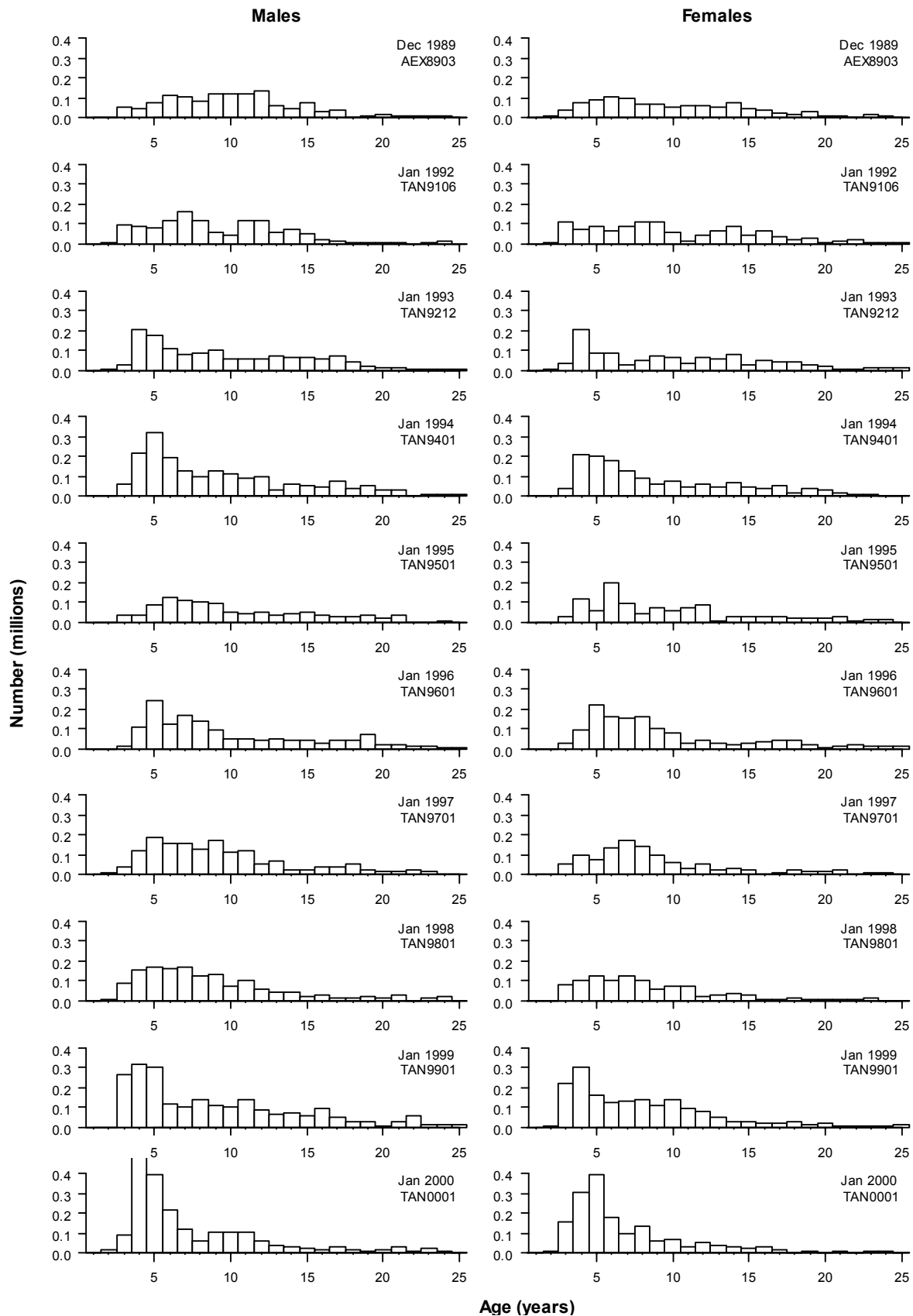


Figure B11: Available age frequencies of ling (ages 1 to 25) from resource surveys in the Chatham Rise, 1989–90 to 2013–14.

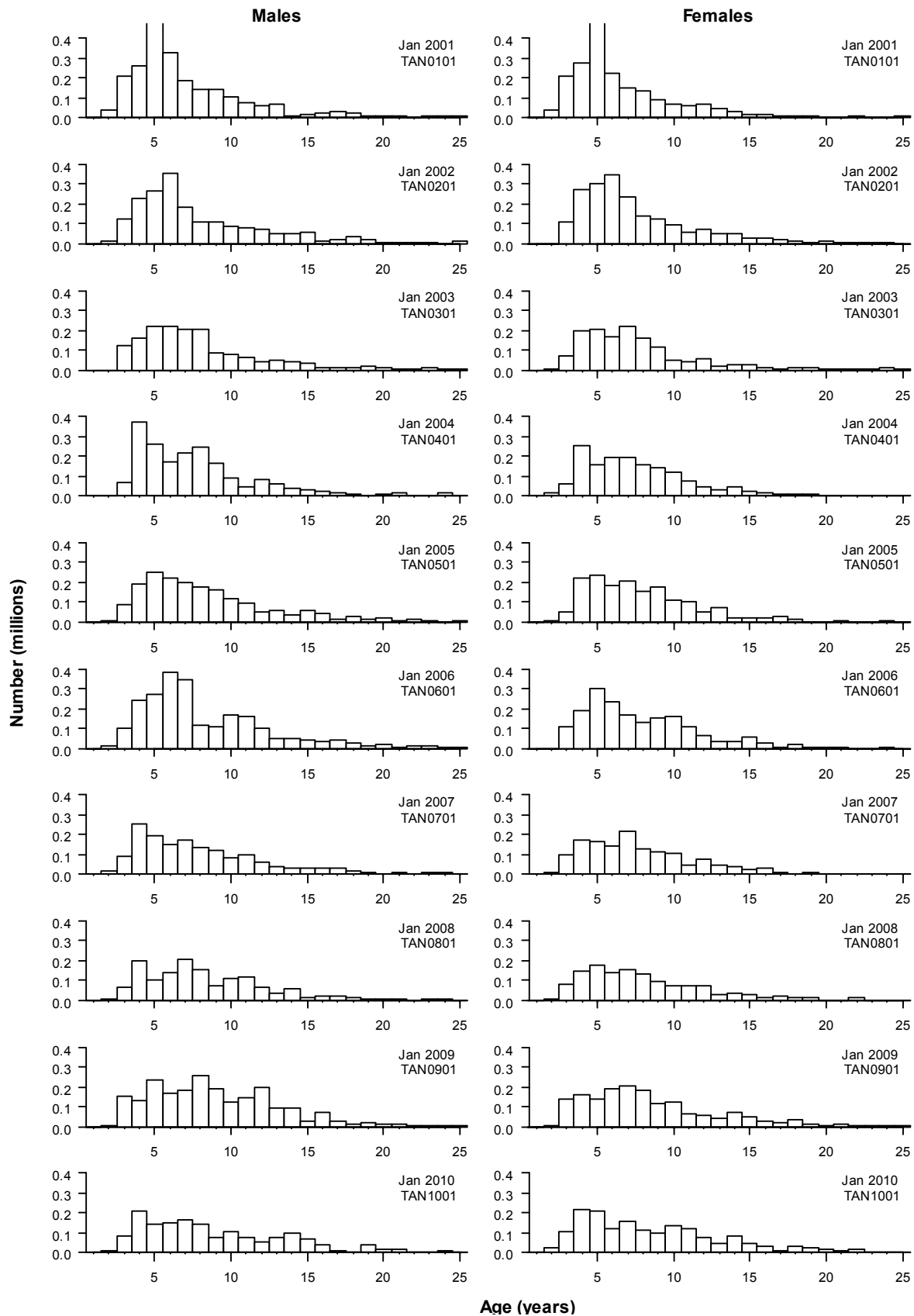


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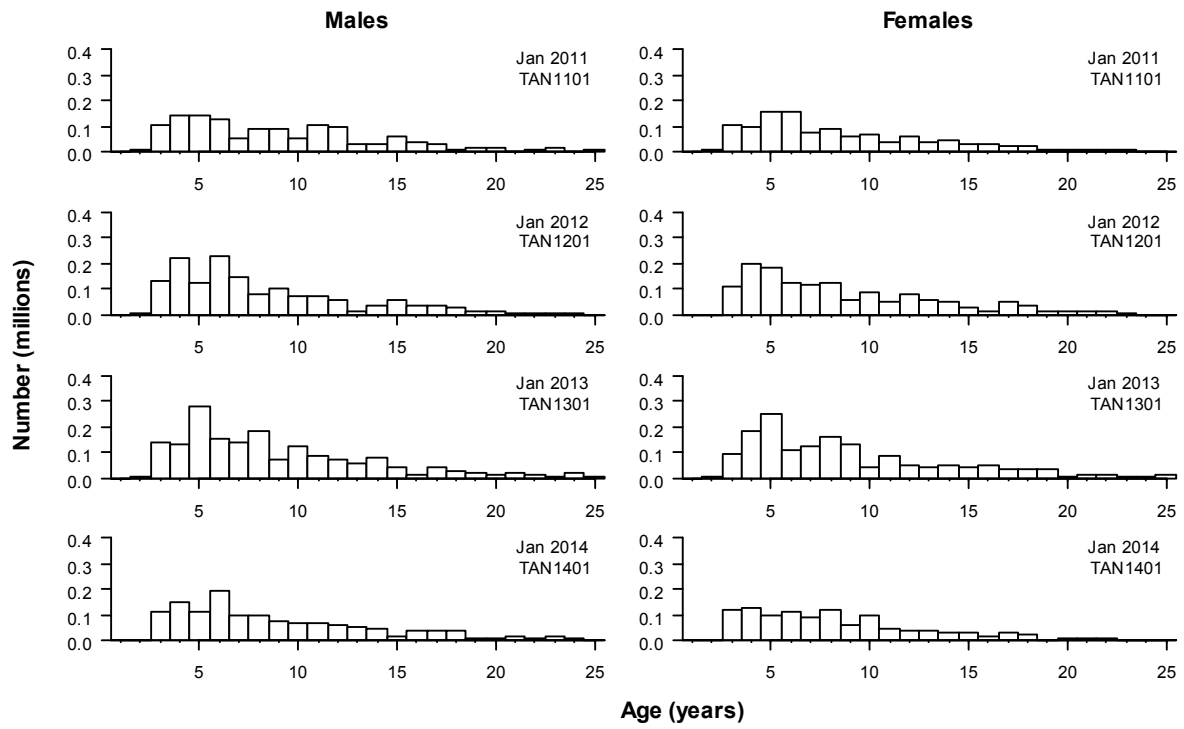


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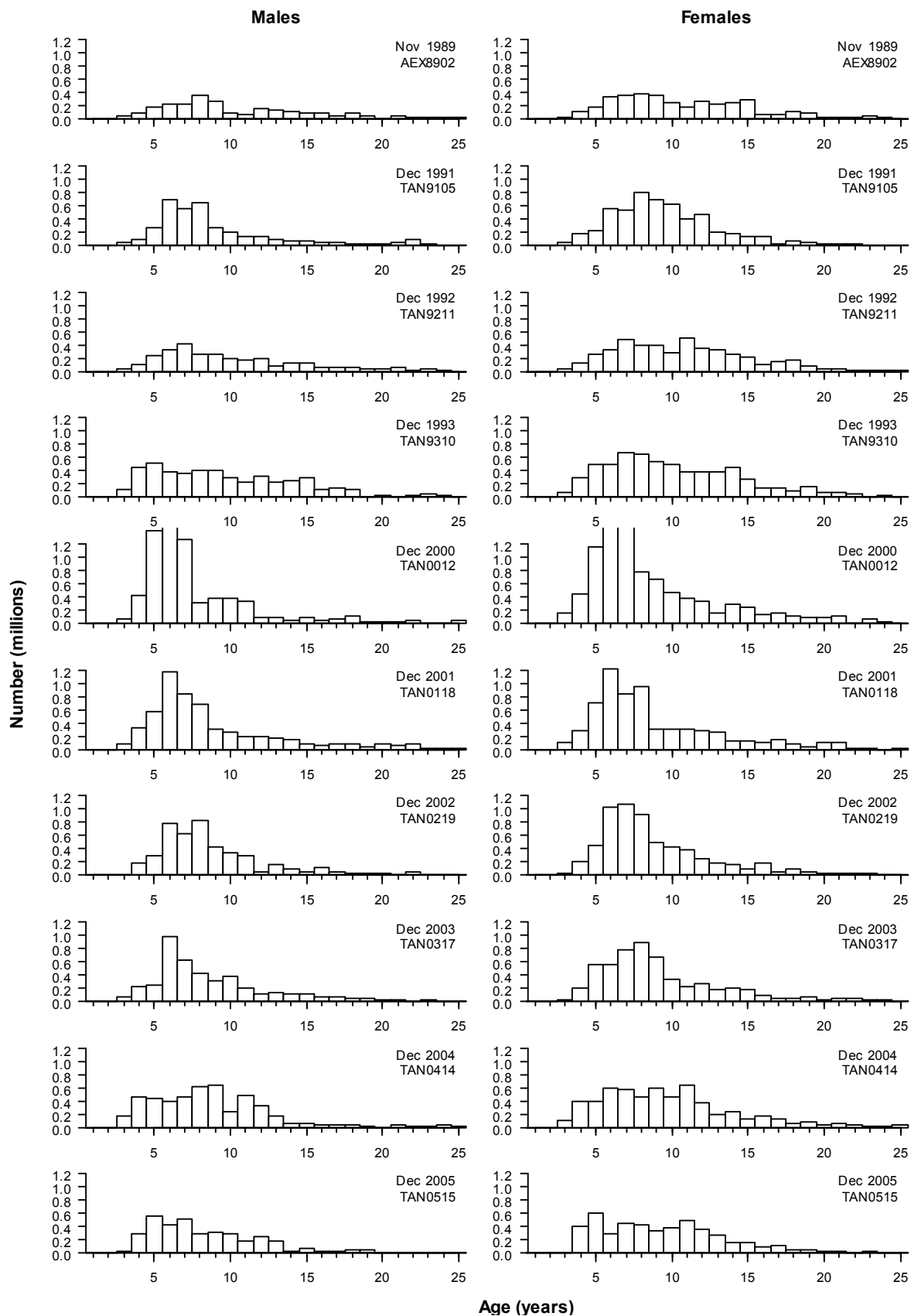


Figure B12: Available age frequencies of ling (ages 1 to 25) from summer resource surveys in the Sub-Antarctic, 1989 to 2013.

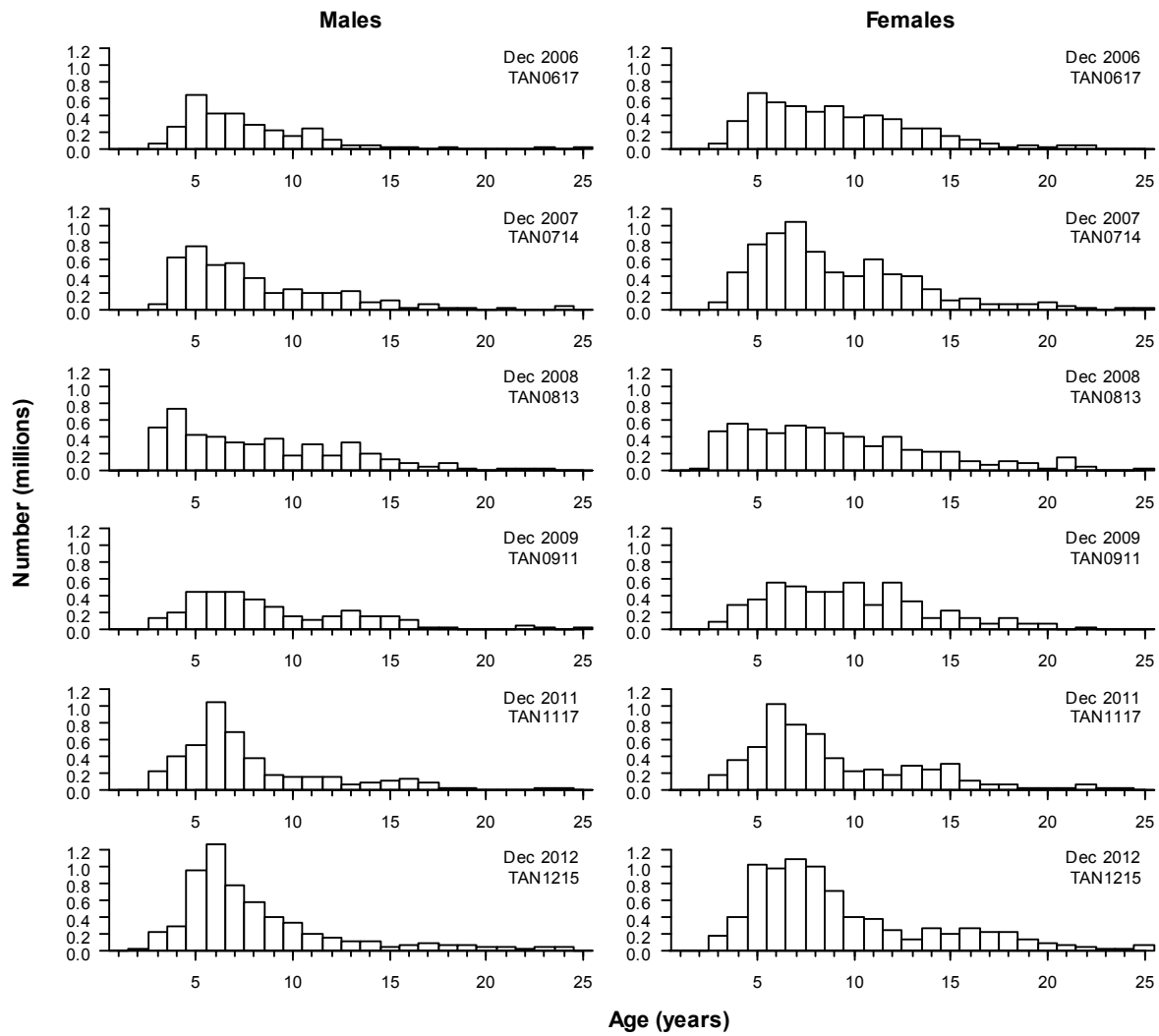


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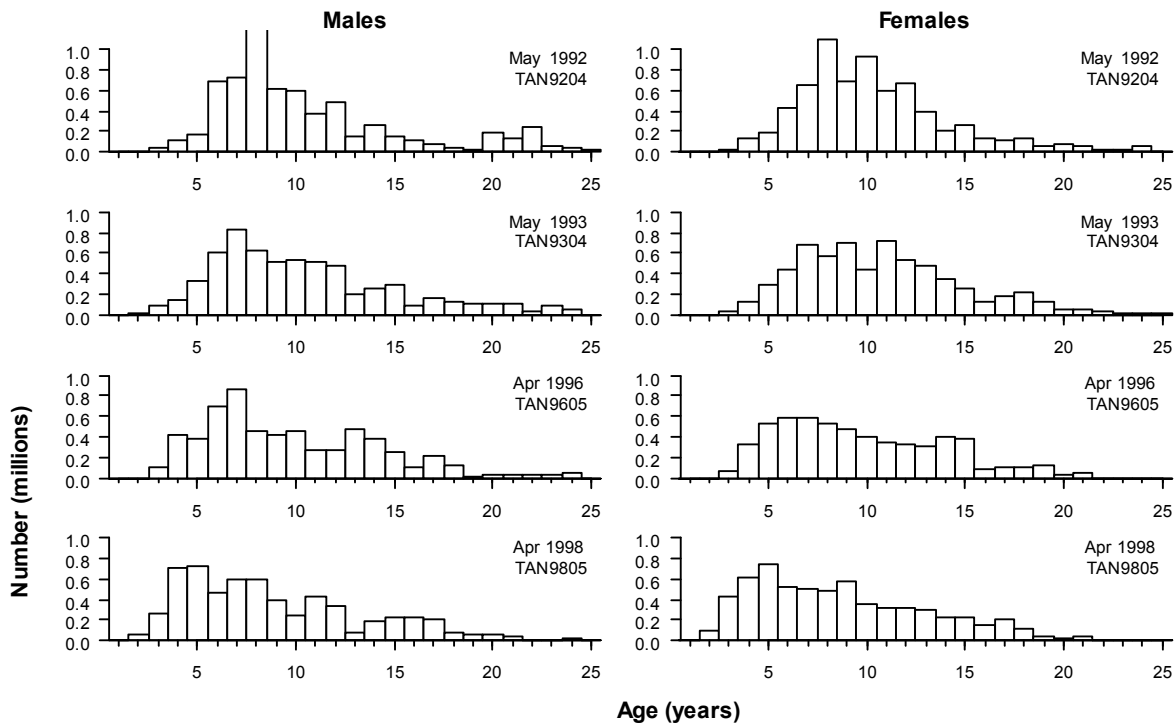


Figure B13: Available age frequencies of ling (ages 1 to 25) from autumn resource surveys in the Sub-Antarctic, 1992 to 1998.

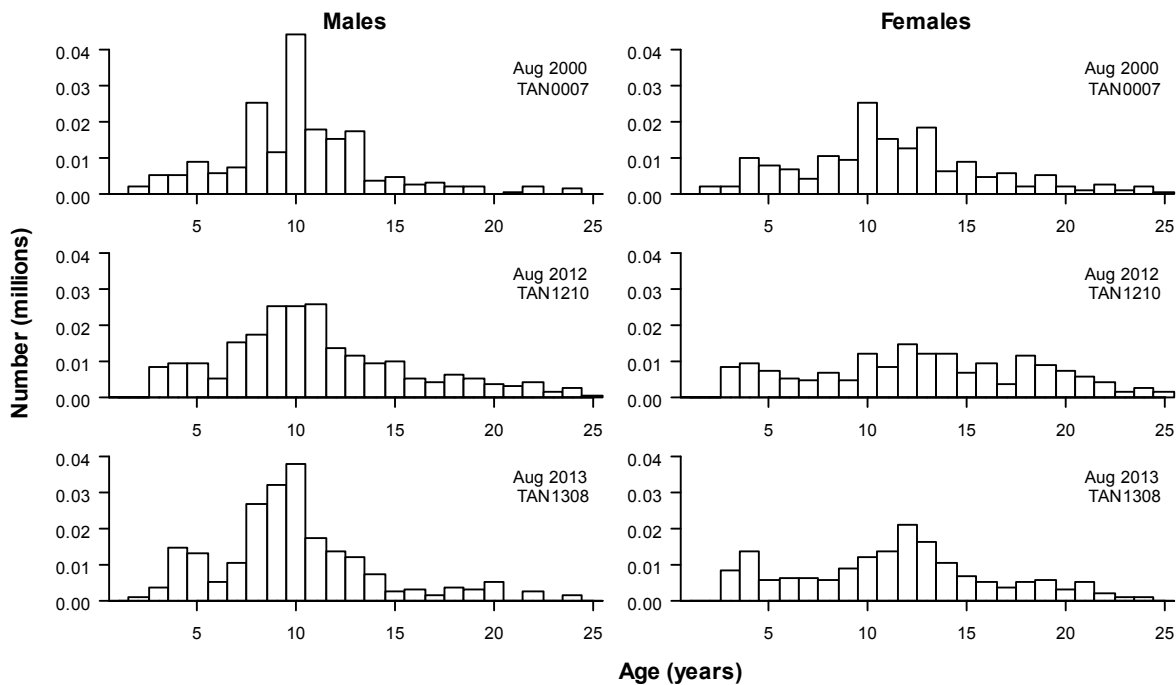


Figure B14: Available age frequencies of ling (ages 1 to 25) from winter resource surveys off WCSI, 2000 to 2013.