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Tini a Tangaroa

Catch-at-age for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) in the 2017–18 fishing year and from research trawl surveys in 2018, 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. (2019). Catch-at-age for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) in the 2017–18 fishing year and from research trawl surveys in 2018, 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 2017–18 fishing year using data and otoliths collected at sea by observers, and from research trawl surveys of middle depth species off the west coast South Island in August 2018 (TAN1807) and in the Sub-Antarctic in December 2018 (TAN1811). 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 two commercial fisheries (west coast South Island, and Sub-Antarctic), but there were insufficient data to estimate catch-at-age for either the eastern or western Chatham Rise commercial trawl fishery. Catch-at-age for the August 2018 trawl survey of west coast South Island was also estimated, but the estimated CV (60%) exceeded the target CV. The catch-at-age for the December 2018 trawl survey of the Sub-Antarctic had an estimated CV of 52% which also did not meet the target.

For ling, the target CV was met for the commercial trawl fisheries from west coast South Island, Chatham Rise, and the Sub-Antarctic, and for the December 2018 Sub-Antarctic trawl survey, but not for the August 2018 west coast South Island trawl survey. There were insufficient data collected to estimate catch-at-age for the 2018 Cook Strait commercial trawl fishery. Catch-at-age was also estimated, and the target CVs were met for the ling longline fisheries on Chatham Rise and the Campbell Plateau in 2017–18.

Where target CVs were not met, it was not possible to improve the precision by reading more otoliths (i.e., increasing the sample size), because all available data and otoliths were used in the analyses. We recommend that observer sampling for ling and hake is focused on areas and months needed for existing catch-at-age time-series. Those areas and months are listed in the last paragraph of the Discussion 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.

It is recommended that all future analyses of commercial fishery catch-at-age include an evaluation of the representativeness of the observer sampling (as presented in Appendix C for west coast South Island hake).

1. INTRODUCTION

This work aimed to determine catch-at-age from the main fisheries for hake and ling in the 2017–18 fishing year, and for hake and ling from research trawl surveys conducted in August and December 2018. Catch-at-age data are a vital input for 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 extended existing series of catch-at-age data. It fulfils the reporting requirements for hake and ling in Objective 1 of Project MID201803 “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, east and south of South Island, Sep 2017–May 2018 [650].
HAK 1 — research trawl survey, Sub-Antarctic, December 2018 (project MID2018-01) [650].
HAK 4 — commercial trawl fishery, east Chatham Rise, Oct 2017–Apr 2018 [650].
HAK 7 — commercial trawl fishery, west coast South Island (WCSI), Jun–Sep 2018 [650].
HAK 7 — research trawl survey, WCSI, August 2018 (project MID2018-02) [650].

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 2017 [550].
LIN 3&4 — commercial trawl fishery, Chatham Rise, Oct 2017–May 2018 [600].
LIN 5&6 — commercial longline fishery, spawning, Puysegur, Oct–Dec 2016, and non-spawning, Campbell, Feb–Jul 2017 [500 per fishery].
LIN 5&6 — research trawl survey, Sub-Antarctic, December 2018 (project MID2018-01) [600].
LIN 7 — research trawl survey, WCSI, August 2018 (project MID2018-02) [600].
LIN 7&2 — commercial trawl fishery, Cook Strait, Jun–Sep 2017 [500].

There was insufficient data available from the Chatham Rise (HAK 4) trawl fishery, and insufficient or no observer otoliths available from the ling longline spawning fishery on Sub-Antarctic (LIN 5&6), and the winter 2018 Cook Strait trawl fishery (LIN 7&2), so catch-at-age distributions were 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 either the January 2018 Chatham Rise research trawl survey (LIN 3&4) or the August 2018 WCSI research trawl survey (LIN 7), with the addition of some extra observer-collected otoliths to cover lengths that were not adequately sampled by the trawl surveys.

LIN 3&4 — commercial trawl fishery, Chatham Rise, Oct 2017–May 2018.
LIN 7 — commercial trawl fishery, WCSI, Jun–Sep 2018.

A catch-at-age model describing the age structure of each of the commercial fisheries and surveyed areas was developed as in previous years (most recently by Horn & Sutton 2019) for both species. For each of the samples, otoliths (for each sex separately) from each 1 cm length class were selected roughly 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 distribution (constituting about 2% of that length frequency) were fully sampled. Any clear juvenile length modes were deliberately under-sampled (usually taking only 2–3 otoliths per length class), as these modes could comprise large numbers of similarly aged young fish. This sampling procedure was likely to provide a sample with a mean weighted CV better than that from proportional sampling, particularly for the older age classes. 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).

Commercial 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. Trawl survey catch-at-age distributions were scaled to total estimated relative biomass available to the trawl in the survey area.

In some instances, trawl surveys occurred around the middle of the periods sampled for commercial fishery catch-at-age (e.g., the January Chatham Rise trawl survey occurred in the middle of the October–April hake trawl fishery and the October–May ling trawl fishery). Consequently, where a survey occurred during a fishery, catch-at-age distributions for the fisheries were estimated using age-length keys developed for the relevant survey. It was sometimes necessary, however, to age some additional fish from the trawl fisheries to cover length-sex combinations that were inadequately sampled by the survey. Such additional samples seldom comprised more than 150 otoliths.

The target mean weighted CV for hake from trawl surveys was often not met. To maximise the chances of meeting the target, all hake from the trawl shots used for 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, 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, each with two strata), rather than four fisheries was statistically satisfactory. Consequently, two commercial age frequencies have been developed for each year since the start of this series (whenever sufficient data were available) using a single age-length key and two areas 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.

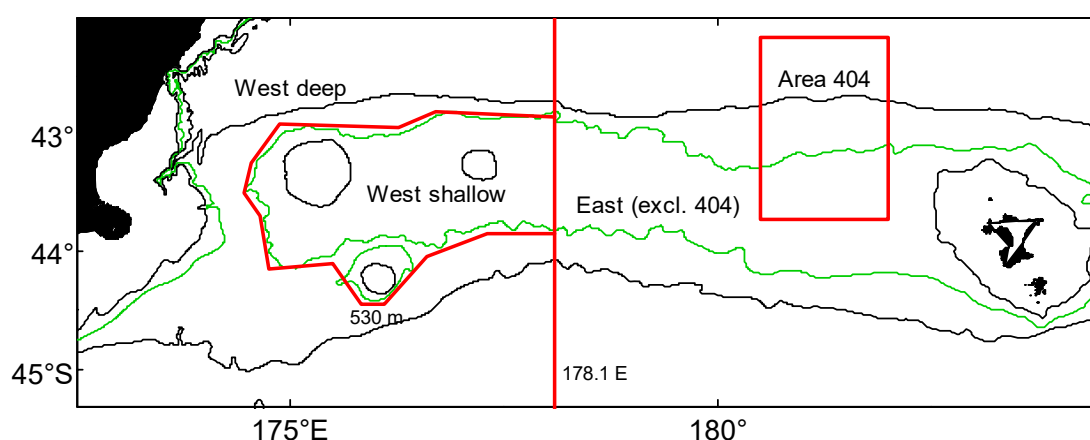


Figure 1: Strata defined for the Chatham Rise hake fishery. The west stratum boundary defined by depth (530 m) is shown only approximately (red). Isobaths at 1000 (black), 500 (green), and 250 m (black) are also shown.

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 2017–18 fishing year, insufficient length data were available from both the western ($n = 143$) and eastern ($n = 183$) strata to calculate catch-at-age distributions, and only 99 otoliths were collected.

Estimated proportion-at-age distributions for all years 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 from 1991–92 to 2017–18. The number of tows sampled by observers and the estimated mean weighted CV (%) by age are also listed. Values in italics (and where Tows and CV columns are blank) indicate that insufficient length-frequency 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	142	199			181	217
1994–95	318	603	69	32.8	234	88	14	43.1	170	191
1995–96	802	917	103	28.2	250	120			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	78	148			290	440
1999–2000	807	901	168	19.0	101	67			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	175	78			455	419
2002–03	176	272	61	25.4	34	24			256	345
2003–04	597	438	101	26.8	378	92	38	26.6	364	304
2004–05	896	437	82	24.2	59	66			391	343
2005–06	234	330	69	39.1	24	20			189	255
2006–07	66	82			409	278	47	27.6	368	388
2007–08	286	270	53	20.6	71	69			350	335
2008–09	257	162	43	24.3	39	25			237	185
2009–10	147	259	38	25.6	23	14			228	244
2010–11	202	249	46	34.3	50	83			199	251
2011–12	6	8			3	3			0	0
2012–13	84	64			99	78			0	0
2013–14	213	221	37	29.5	49	59			150	145
2014–15	106	142			249	273	33	28.6	91	132
2015–16	307	303	36	28.7	41	42			250	209
2016–17	17	53			35	55			0	0
2017–18	66	77			92	91			0	0

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 in assessments of 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 March, 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 there were sufficient otoliths (n about 400) 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 2017–18 fishing year are in Table 3. The mean weighted CV of 22% was lower than the target of 30%.

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

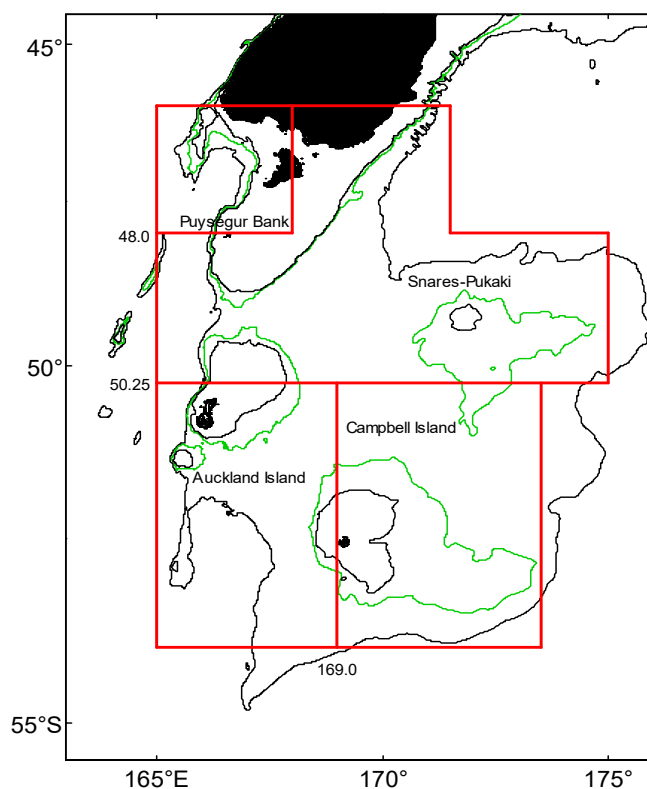


Figure 2: Fishery strata defined for the Sub-Antarctic hake fishery (red lines). Numbers show latitudes and longitudes of fishery boundaries. Isobaths at 1000 (black), 500 (green), and 250 (black) m are also shown.

Table 2: Numbers of measured male and female hake, numbers of fish aged and used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age, for the Sub-Antarctic trawl fishery. – , no data.

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
2015–16	2 125	217	931	166	64	26.4
2016–17	2 409	203	777	143	67	23.2
2017–18	2 067	215	1 090	175	75	22.4

Table 3: Calculated numbers-at-age, separately by sex, with CVs, for hake sampled by observers during commercial trawl operations in the Sub-Antarctic, September 2017 – May 2018. Summary statistics for the samples are also presented. Age in years. –, no data.

Age	Male	CV	Female	CV
2	41	1.176	0	–
3	22	1.182	43	1.387
4	69	1.187	75	0.915
5	127	1.011	38	1.353
6	6 270	0.259	1 029	0.494
7	18 091	0.153	5 549	0.229
8	16 702	0.182	4 800	0.247
9	16 222	0.189	8 205	0.226
10	8 955	0.261	5 251	0.266
11	3 665	0.388	3 170	0.354
12	4 842	0.327	3 667	0.338
13	7 433	0.291	3 524	0.378
14	4 236	0.387	1 632	0.492
15	4 058	0.389	724	0.725
16	2 208	0.476	1 518	0.465
17	2 953	0.544	762	0.680
18	1 399	0.621	1 532	0.671
19	1 518	0.610	761	0.704
20	0	–	496	0.914
21	472	1.058	916	0.634
22	0	–	367	1.181
23	0	–	0	–
24	0	–	1 408	0.696
Measured males			2 067	
Measured females			1 090	
Aged males			215	
Aged females			175	
No. of tows sampled			75	
Mean weighted CV (% , sexes pooled)			22.4	

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 4 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. The HAK 7 stock was assessed in early 2019 and the Deepwater Fisheries Assessment Working Group queried whether the observer sampling was representative of the fishery. Consequently, an analysis was conducted here to establish whether the sampling of hake from WCSI was adequate (Appendix C). Estimated landings of hake from the WCSI stock area were compared with landings sampled for hake by observers; it was concluded that observer sampling of the hake fishery in 2017–18 (and in most previous years) was comprehensive. It is recommended that all future analyses of commercial fishery catch-at-age (for both hake and ling in all areas) include an evaluation of the representativeness of the observer sampling.

Details of the estimated catch-at-age distribution for trawl-caught hake in the 2017–18 fishing year are in Table 5. The mean weighted CV of 14% was much lower than the target of 30%.

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

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
2013–14	8 128	320	7 242	384	360	13.1
2014–15	12 334	329	10 173	363	498	13.6
2015–16	5 304	461	4 589	449	240	13.2
2016–17	9 019	363	6 572	382	362	13.3
2017–18	4 242	419	4 758	434	392	13.6

Table 5: Calculated numbers at age, separately by sex, with CVs, for hake sampled by observers during commercial trawl operations off the WCSI, June–September 2018. Summary statistics for the samples are also presented. Age in years. –, no data.

Age	Male	CV	Female	CV
2	8 066	0.214	5 088	0.266
3	6 468	0.325	5 043	0.272
4	20 393	0.298	3 889	0.374
5	73 395	0.123	16 574	0.225
6	121 868	0.099	43 864	0.138
7	58 545	0.136	56 541	0.122
8	39 804	0.183	62 821	0.115
9	16 848	0.267	35 098	0.155
10	8 839	0.355	20 625	0.194
11	3 774	0.553	15 319	0.209
12	2 174	0.661	11 881	0.271
13	5 132	0.510	4 334	0.404
14	3 975	0.700	5 988	0.457
15	1 631	0.761	3 321	0.552
16	3 268	0.517	448	1.176
17	3 203	0.574	1 149	1.043
18	808	1.248	2 520	0.657
19	1 530	1.026	919	0.848
20	0	–	824	1.051
21	0	–	0	–
22	262	1.424	0	–
Measured males			4 242	
Measured females			4 758	
Aged males			419	
Aged females			434	
No. of tows sampled			392	
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 additional deeper strata (800–1300 m) were 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. The 30% target was met in only one of the 20 surveys (TAN9106, see Table 6). There was no survey of this area conducted in January 2019.

All estimated proportion-at-age distributions from the Chatham Rise trawl surveys are presented in Appendix A (Figure A5).

Table 6: Numbers of measured male and female hake (used to calculate the catch-at-length and catch-at-age), age data used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age, for the Chatham Rise trawl surveys. Number of aged fish exceeds the number measured in some years, because hake caught outside the core trawl survey area were also aged.

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
TAN1801	111	143	107	115	34	49.4

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 area. 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 were derived from the core 300–800 m strata only.

Table 7 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. A catch-at-age distribution was not produced for the survey conducted in December 2016 (TAN1614) as only 33 hake were caught and it was not believed that they adequately represented the population. The details of the estimated catch-at-age distribution for hake caught in the December 2018 trawl survey are given in Table 8. The mean weighted CV of 52% did not meet the target of 30%.

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 7: Numbers of measured male and female hake (used to calculate the catch-at-length and catch-at-age), numbers of fish aged and used in the age-length key, tows sampled, and estimated mean weighted CV (%) by age for the Sub-Antarctic trawl surveys. –, no data.

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
TAN1614	1	0	32	0	15	—
TAN1811	61	64	204	218	31	52.1
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

Table 8: Calculated numbers-at-age in the survey area, separately by sex, with CVs, for hake caught during a trawl survey of the Sub-Antarctic in December 2018 (survey TAN1811). Summary statistics for the samples are also presented. Age in years. –, no data.

Age	Male	CV	Female	CV
2	0	–	1 776	0.982
3	8 563	0.594	22 226	0.457
4	12 720	0.510	23 908	0.625
5	3 092	1.077	16 793	0.724
6	3 589	0.696	6 827	0.671
7	2 670	0.862	32 478	0.331
8	11 894	0.812	27 345	0.433
9	1 790	1.080	25 094	0.485
10	3 650	0.901	17 967	0.569
11	1 172	1.958	22 178	0.574
12	2 875	0.936	2 011	1.052
13	0	0.000	5 370	1.223
14	1 713	1.122	15 185	0.784
15	2 103	1.282	23 304	0.582
16	0	–	1 889	0.938
17	0	–	2 475	1.139
26	0	–	336	1.725
Measured males				61
Measured females				204
Aged males				64
Aged females				218
No. of tows sampled				31
Mean weighted CV (% , sexes pooled)				52.1

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 area. A combined trawl and acoustic survey by *Tangaroa* in winter 2000 (O’Driscoll et al. 2004) was replicated (with some modifications) in 2012 (O’Driscoll et al. 2014), 2013 (O’Driscoll et al. 2015), 2016 (O’Driscoll & Ballara 2018) and 2018 (O’Driscoll & Ballara 2019), so a five year comparable time series is available. The relative biomass estimates from the five 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, referred to as the ‘core’ strata), with stratum areas from the 2012 survey (O’Driscoll & Ballara 2018). Additional strata were sampled in the surveys from 2012 onwards, and the 2019 stock assessment of hake used biomass and catch-at-age series from an area combining the ‘core’ strata plus shallower waters from 200 to 300 m and deeper waters from 650 to 800 m (subsequently referred to as ‘all’ strata) (O’Driscoll et al. 2014).

Table 9 summarises the data used each year to produce the catch-at-age distributions for the ‘core’ and ‘all’ strata areas, 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 to estimate a catch-at-age distribution. The age-length keys for the subsequent surveys were derived using otoliths collected during those surveys. The details of the estimated catch-at-age distribution for hake caught in the August 2018 trawl survey are given in Table 10. The mean weighted CVs of 60% (‘core’ strata) and 33% (‘all’ strata) did not meet the target of 30%.

All estimated proportion-at-age distributions from the WCSI trawl surveys are presented in Appendix A for the ‘core’ strata (Figure A8) and ‘all’ strata (Figure A9).

Table 9: Numbers of measured male and female hake (used to calculate the catch-at-length and catch-at-age), age data used in the age-length key, tows sampled with a hake catch, and estimated mean weighted CV (%) by age for the ‘core’ strata (300–650 m) and ‘all’ strata (m) of the west coast South Island trawl surveys. See Section 2 for an explanation of why number aged is often larger than number measured.

Survey	Males		Females		Tows	Mean CV
	Measured	Aged	Measured	Aged		
‘Core’ strata						
TAN0007	331	230	407	255	36	26.4
TAN1210	211	330	228	332	36	26.6
TAN1308	94	255	213	371	34	33.7
TAN1609	43	168	71	210	17	59.3
TAN1807	27	356	42	277	15	60.0
‘All’ strata						
TAN1210	371	330	335	332	41	23.8
TAN1308	212	255	302	371	39	30.0
TAN1609	176	168	169	210	25	34.4
TAN1807	174	356	158	277	22	33.0

Table 10: Calculated numbers-at-age in the survey area, separately by sex, with CVs, for hake caught in the ‘core’ and ‘all’ strata during a trawl survey of WCSI in August 2018 (survey TAN1807). Summary statistics for the samples are also presented. Age in years. –, no data.

Age	‘Core’ strata				‘All’ strata			
	Male	CV	Female	CV	Male	CV	Female	CV
2	2 716	0.855	3 883	0.974	9 037	0.332	8 428	0.594
3	582	1.528	784	1.329	5 344	0.451	1 176	0.922
4	741	0.971	385	1.735	1 771	0.735	1 132	0.938
5	1 567	0.821	1 855	0.814	8 050	0.375	3 985	0.474
6	4 766	0.481	5 343	0.458	16 286	0.264	11 219	0.312
7	4 602	0.563	4 108	0.525	11 663	0.325	11 517	0.285
8	4 476	0.665	4 979	0.483	10 149	0.370	12 742	0.248
9	1 095	0.869	3 251	0.523	3 566	0.446	7 593	0.299
10	975	0.825	1 577	0.580	2 731	0.482	4 385	0.398
11	372	1.137	1 710	0.909	993	0.737	3 848	0.461
12	24	2.107	1 114	1.124	790	1.072	2 185	0.661
13	245	1.568	222	2.019	1 695	0.757	928	0.899
14	260	1.657	1 933	0.897	812	0.803	2 228	0.765
15	308	1.507	0	–	464	1.233	760	1.077
16	1 049	1.079	0	–	2 245	0.694	0	–
17	977	1.292	86	2.249	1 447	0.948	163	1.415
18	0	–	0	–	0	3.342	180	1.849
19	0	–	452	1.740	296	1.327	452	1.453
20	0	–	173	1.681	0	–	349	1.284
21	0	–	0	–	0	–	0	–
22	0	–	0	–	172	1.961	0	–
Measured males			27				174	
Measured females			42				158	
Aged males			356				356	
Aged females			277				277	
No. of tows sampled with hake			15				22	
Mean weighted CV (% , sexes pooled)			60.0				33.0	

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 2010–2012. Four trips were observed in 2018, and the details of the estimated catch-at-age distribution are given in Table 12. The mean weighted CV of 26% met the target of 30%.

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
2015	598	179	778	256	3	116	25.1
2016	799	396	722	368	3	152	21.5
2017	959	230	768	250	5	120	27.0
2018	1 192	273	903	216	4	196	26.3

Table 12: Calculated numbers-at-age, separately by sex, with CVs, for ling sampled by observers during commercial longline operations on Chatham Rise (LIN3&4) in June–October 2018. Summary statistics for the samples are also presented. Age in years. –, no data.

Age	Male	CV	Female	CV
3	16	1.686	0	–
4	33	1.950	38	1.952
5	109	0.802	125	1.467
6	779	0.423	139	0.754
7	588	0.554	465	0.542
8	1 655	0.300	1 274	0.414
9	2 671	0.225	1 031	0.414
10	2 491	0.225	1 936	0.311
11	2 791	0.242	1 271	0.351
12	1 744	0.286	1 686	0.338
13	2 019	0.343	2 174	0.315
14	1 897	0.269	1 446	0.311
15	1 509	0.337	1 981	0.277
16	1 475	0.313	1 650	0.280
17	1 587	0.351	1 219	0.345
18	1 466	0.325	1 979	0.320
19	956	0.398	372	0.561
20	1 297	0.418	848	0.585
21	868	0.389	708	0.551
22	1 547	0.309	251	0.679
23	1 333	0.343	891	0.497
24	648	0.437	287	0.653
25	567	0.598	672	0.574
26	275	0.745	8	1.881
27	154	1.197	53	0.916
28	732	0.470	0	–
29	124	0.855	51	1.212
30	0	–	0	–
31	167	0.953	0	–
32	0	–	40	1.387
33	0	–	52	0.994
34	0	–	0	–
35	43	1.324	0	–
36	28	1.177	0	–
37	0	–	88	1.143
Measured males				1 192
Measured females				903
Aged males				273
Aged females				216
No. of sets sampled				196
Mean weighted CV (% , sexes pooled)				26.3

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 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. Sufficient observer samples were available from the non-spawning fishery in the 2017–18 fishing year to produce a catch-at-age distribution (Table 14). The mean weighted CV of 21% was better than the target of 30%.

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, 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							
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
2017	305	144	365	160	2	42	32.1
Non-spawning							
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
2018	383	136	1 256	531	1	82	21.2

Table 14: Calculated numbers-at-age, by sex, with CVs, for ling sampled by observers during commercial longline operations on non-spawning Sub-Antarctic (LIN 5&6) ling in February–July 2018, i.e., 2017–18 fishing year. Summary statistics for the samples are also presented. Age in years. –, no data.

Age	Male	CV	Female	CV
5	93	0.931	124	0.934
6	360	0.554	264	0.575
7	317	0.591	757	0.369
8	1 097	0.365	2 104	0.244
9	918	0.423	2 584	0.204
10	589	0.395	2 733	0.178
11	618	0.476	3 539	0.163
12	951	0.342	4 546	0.130
13	805	0.359	2 045	0.209
14	701	0.430	2 360	0.168
15	340	0.526	2 976	0.161
16	529	0.526	2 251	0.178
17	176	0.639	1 999	0.201
18	297	0.615	1 734	0.215
19	512	0.463	1 668	0.227
20	54	1.207	1 659	0.233
21	252	0.753	1 396	0.236
22	231	0.710	1 003	0.283
23	260	0.637	527	0.413
24	479	0.500	629	0.395
25	332	0.490	675	0.407
26	154	1.007	227	0.690
27	121	0.901	33	1.463
28	177	0.691	57	1.228
29	0	–	52	1.020
30	25	1.569	124	0.738
31	59	1.397	0	–
32	67	1.077	62	1.108
33	0	–	0	–
34	154	1.029	0	–
Measured males				383
Measured females				1 256
Aged males				136
Aged females				531
No. of sets sampled				82
Mean weighted CV (% , sexes pooled)				21.2

3.3.3 West coast South Island

Longline 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 15 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. No longline trips targeting ling off WCSI were sampled in the 2017–18 fishing year. All estimated proportion-at-age distributions from the WCSI longline fishery are presented in Appendix B (Figure B4).

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 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

3.3.4 Cook Strait

The longline 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 16 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 2017–18 fishing year. All estimated proportion-at-age distributions from the Cook Strait longline fishery are presented in Appendix B (Figure B5).

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 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 17 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 2017–18 fishing year. All estimated proportion-at-age distributions from the Bounty Plateau longline fishery are presented in Appendix B (Figure B6).

Table 17: 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 were analysed as a separate stratum because the gear used in this fishery usually retains ling of a smaller average size than the trawls used to target finfish.

Table 18 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 2017–18 fishing year is given in Table 19. The observer sampling in 2017–18 was at a relatively low level, similar to the previous year but with more otoliths available. The mean weighted CV of 25% 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 18: 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
2015–16	371	287	423	292	47	32.8
2016–17	853	220	719	171	76	28.9
2017–18	745	357	773	343	75	24.9

Table 19: Calculated numbers-at-age, separately by sex, with CVs, for ling sampled by observers during commercial trawl operations on the Chatham Rise during October 2017–May 2018. Summary statistics for the samples are also presented. Age in years. –, no data.

Age	Male	CV	Female	CV
3	2 310	0.675	4 839	0.559
4	6 862	0.513	8 844	0.512
5	9 148	0.390	10 075	0.344
6	15 520	0.271	17 593	0.278
7	19 865	0.226	15 030	0.289
8	18 129	0.250	14 137	0.244
9	17 520	0.259	14 397	0.250
10	17 790	0.224	13 572	0.248
11	14 078	0.242	11 617	0.254
12	5 031	0.358	6 949	0.367
13	5 481	0.381	6 243	0.355
14	6 002	0.365	6 471	0.339
15	7 625	0.308	4 488	0.373
16	6 495	0.428	5 181	0.394
17	4 651	0.427	3 098	0.530
18	4 022	0.490	1 324	0.616
19	2 964	0.509	1 438	0.705
20	1 104	0.788	335	1.684
21	2 946	0.466	1 213	0.972
22	1 561	0.738	1 559	0.923
23	4 268	0.441	237	1.045
24	1 517	0.565	829	1.111
25	561	1.121	277	1.798
26	520	1.108	374	1.066
27	1 212	0.791	365	1.292
28	690	1.079	0	–
29	107	1.684	0	–
30	0	–	0	–
31	520	1.437	495	1.860
38	0	–	377	1.655
46	221	1.634	0	–
Measured males				745
Measured females				773
Aged males				357
Aged females				343
No. of tows sampled				75
Mean weighted CV (% , sexes pooled)				24.9

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 ≤ 450 m, and target not scampi).
3. Deep (bottom depth > 450 m, and target not scampi).

Table 20 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 2017–18 fishing year is given in Table 21. The mean weighted CV of 17% was lower 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 20: 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
2015–16	5 419	307	3 637	306	198	18.0
2016–17	4 207	344	3 190	404	218	16.7
2017–18	6 509	316	7 639	358	325	17.3

Table 21: Calculated numbers-at-age, separately by sex, with CVs, for ling sampled by observers during commercial trawl operations in the Sub-Antarctic during September 2017–April 2018. Summary statistics for the samples are also presented. Age in years. –, no data.

Age	Male	CV	Female	CV
2	376	1.347	425	0.974
3	951	0.615	3 121	0.373
4	26 128	0.285	33 995	0.272
5	61 229	0.214	25 837	0.339
6	81 044	0.208	43 378	0.275
7	145 440	0.166	86 605	0.170
8	152 094	0.158	166 866	0.156
9	91 475	0.215	125 706	0.170
10	146 661	0.157	76 034	0.260
11	81 491	0.216	125 986	0.173
12	67 272	0.222	83 641	0.210
13	45 417	0.282	76 657	0.223
14	53 179	0.244	58 256	0.255
15	19 968	0.397	60 909	0.230
16	27 950	0.348	20 620	0.420
17	3 784	0.896	39 088	0.263
18	28 404	0.322	23 030	0.370
19	10 770	0.514	12 326	0.529
20	8 823	0.570	19 487	0.389
21	3 784	0.793	12 405	0.472
22	8 558	0.605	9 933	0.555
23	9 330	0.577	12 206	0.507
24	10 184	0.515	15 721	0.422
25	11 191	0.531	5 389	0.599
26	3 655	1.178	5 445	0.597
27	6 110	0.732	0	–
28	2 295	0.960	1 349	0.921
29	0	–	0	–
30	55	1.749	0	–
Measured males			6 509	
Measured females			7 639	
Aged males			316	
Aged females			358	
No. of tows sampled			325	
Mean weighted CV (% , sexes pooled)			17.3	

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 22 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 2009 to 2011. The details of the estimated catch-at-age distribution for trawl-caught ling in 2018 are given in Table 23. The amount of length data and otoliths available from that year was maintained at a relatively high level, as it has been since 2015. The mean weighted CV of 23% was lower 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 22: 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
2016	2 220	336	2 374	367	267	20.1
2017	1 722	296	1 862	319	195	23.6
2018	2 029	363	2 059	390	231	22.5

Table 23: Calculated numbers at age, separately by sex, with CVs, for ling sampled by observers during commercial trawl operations off WCSI during June–September 2018. Summary statistics for the samples are also presented. Age in years. –, no data.

Age	Male	CV	Female	CV
2	459	1.017	822	0.846
3	3 071	0.520	2 935	0.506
4	5 748	0.287	4 753	0.338
5	9 221	0.335	6 255	0.269
6	8 043	0.374	4 682	0.326
7	9 540	0.340	6 417	0.327
8	13 570	0.292	8 047	0.304
9	11 883	0.307	6 957	0.312
10	14 323	0.277	8 093	0.295
11	17 375	0.204	11 798	0.240
12	21 718	0.184	16 857	0.212
13	10 772	0.267	14 539	0.189
14	14 307	0.258	16 997	0.176
15	12 505	0.238	11 595	0.230
16	4 801	0.358	6 878	0.386
17	3 465	0.450	2 412	0.404
18	3 298	0.418	5 530	0.308
19	1 572	0.603	2 607	0.439
20	477	1.180	2 483	0.553
21	532	0.953	583	0.895
22	1 547	0.955	3 469	0.578
23	0	–	888	0.808
24	719	0.905	389	0.980
25	696	1.393	1 553	0.675
26	0	–	525	0.884
27	486	1.258	616	0.861
28	700	1.466	223	1.023
29	136	1.464	0	–
30	0	–	259	1.422
Measured males			2 029	
Measured females			2 059	
Aged males			363	
Aged females			390	
No. of tows sampled			231	
Mean weighted CV (% , sexes pooled)			22.5	

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 24 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 2018 (350 length measurements, 162 otoliths).

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

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 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 additional deeper strata (800–1300 m) were surveyed. However, to ensure comparability, the distributions presented here are for the core strata only, i.e., 200–800 m.

Table 25 summarises the data used each year to produce the catch-at-age distributions, and also lists the resulting mean weighted CVs. There was no trawl survey of the Chatham Rise in January 2019.

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

Table 25: 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
TAN1801	568	296	576	291	73	26.3

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 area. 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. The details of the estimated catch-at-age distribution for ling caught in the December 2018 trawl survey are given in Table 27. The mean weighted CV of 25% was lower than the target of 30%.

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
TAN1614	767	225	829	367	55	22.7
TAN1811	1 011	260	870	360	65	24.6
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

Table 27: Calculated numbers at age in the survey area, separately by sex, with CVs, for ling caught during a trawl survey of the Sub-Antarctic in December 2018 (survey TAN1811). Summary statistics for the samples are also presented. Age in years. –, no data.

Age	Male	CV	Female	CV
2	19 330	1.035	8 977	1.581
3	36 400	0.722	102 311	0.575
4	515 821	0.300	444 864	0.220
5	432 756	0.376	562 619	0.235
6	356 415	0.339	431 659	0.302
7	145 993	0.374	282 450	0.335
8	206 383	0.329	254 714	0.280
9	269 178	0.242	318 456	0.264
10	356 374	0.228	358 820	0.227
11	196 953	0.292	277 908	0.242
12	313 224	0.252	309 820	0.235
13	171 688	0.319	215 558	0.285
14	156 259	0.327	167 751	0.305
15	118 417	0.362	112 741	0.395
16	63 847	0.461	146 628	0.347
17	72 889	0.493	153 895	0.335
18	36 876	0.633	92 892	0.411
19	30 244	0.632	81 777	0.465
20	42 660	0.552	102 533	0.453
21	0	–	89 757	0.450
22	25 526	0.740	62 402	0.679
23	7 932	1.258	47 000	0.601
24	39 419	0.639	55 785	0.557
25	0	–	42 895	0.655
26	9 639	1.303	504	2.264
27	8 238	1.365	7 625	1.556
37	0	–	1 319	2.138
Measured males				1 011
Measured females				870
Aged males				260
Aged females				360
No. of tows sampled				65
Mean weighted CV (% , sexes pooled)				24.6

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 area. A combined trawl and acoustic survey by *Tangaroa* in winter 2000 (O’Driscoll et al. 2004) was replicated (with some modifications) in 2012 (O’Driscoll et al. 2014), 2013 (O’Driscoll et al. 2015), 2016 (O’Driscoll & Ballara 2018) and 2018 (O’Driscoll & Ballara 2019), so a five year comparable time series is available. The biomass estimates from the five 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, the ‘core’ strata), with stratum areas from the 2012 survey (O’Driscoll & Ballara 2018).

Table 28 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 to estimate a survey catch-at-age distribution. The age-length keys for the subsequent surveys were derived using otoliths collected during each survey. The details of the estimated catch-at-age distribution

for ling caught in the August 2018 trawl survey are given in Table 29. The mean weighted CV of 34% did not meet 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 28: 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 trawl 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
TAN1609	694	267	429	200	32	30.8
TAN1807	810	261	466	226	35	33.7

Table 29: Calculated numbers at age in the survey area, separately by sex, with CVs, for ling caught in the ‘core’ strata during a trawl survey of west coast South Island in August 2018 (survey TAN1807). Summary statistics for the samples are also presented. Age in years. –, no data.

Age	Male	CV	Female	CV
2	1 687	0.927	1 533	0.772
3	10 655	0.682	5 711	0.555
4	5 658	0.748	5 227	0.356
5	4 420	0.549	5 660	0.515
6	9 234	0.367	4 517	0.544
7	5 227	0.466	4 930	0.508
8	11 590	0.338	3 321	0.575
9	9 713	0.375	3 297	0.492
10	14 839	0.338	4 833	0.421
11	26 032	0.301	5 580	0.459
12	23 971	0.291	12 567	0.306
13	13 501	0.371	13 328	0.291
14	18 672	0.313	10 985	0.308
15	17 862	0.308	10 261	0.334
16	8 278	0.405	5 808	0.528
17	4 696	0.519	1 510	0.749
18	5 616	0.502	6 495	0.415
19	2 535	0.570	1 605	0.729
20	1 188	0.920	2 347	0.580
21	391	1.233	1 201	0.868
22	1 163	0.884	2 077	0.661
23	0	–	874	0.852
24	1 885	0.647	1 181	0.929
25	0	–	1 074	0.886
26	0	–	939	0.773
27	1 029	0.857	1 909	0.722
28	1 894	0.853	1 106	1.022
29	1 004	1.161	0	–
30	0	–	340	1.329
Measured males			810	
Measured females			466	
Aged males			261	
Aged females			226	
No. of tows sampled			35	
Mean weighted CV (% , sexes pooled)			33.7	

4. DISCUSSION

4.1 Hake

In 2017–18 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 (WCSI, CV 14%) and the HAK 1 (Sub-Antarctic, CV 22%) fisheries. The target CV was met in most previous years for samples from the WCSI fishery (see Table 4). The sampling intensity in the WCSI commercial trawl fishery was relatively high in 2017–18, as it was in the previous five years (see Table 4). Sampling intensity in the Sub-Antarctic varied considerably between years, with consequent wide variation in the mean weighted CVs (see Table 2) but sampling for length-frequency data was moderate to high in all years since 2008–09. Sampling for otoliths was less intense than is desirable from 2013–14 to 2017–18 with only about 400 otoliths per year collected from the September–March fishery; a sample approximately twice this size would be desirable. Hake on Chatham Rise were analysed as two separate fisheries (see Table 1), but sampling intensity in both fisheries was low in 2017–18 and there were insufficient data to produce catch-at-age distributions. 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 two distributions were produced. Sampling of the east Chatham Rise fishery was sporadic since 1991–92, and only one distribution was produced since 2006–07.

The WCSI research trawl survey in August 2018 produced fewer measured hake from the core strata than in any other survey in the series (see Table 9); the 2018 sample size was only one-tenth that of the first survey in 2000. The mean weighted CV of 60% was much worse than the target of 30%; the target was met only in the first two surveys. The area surveyed by this series has increased over time (see O’Driscoll & Ballara 2019), but only the catch-at-age from the ‘core’ and ‘all’ strata areas are presented above. Catch-at-age data for the ‘core’ strata (300–650 m) in all surveys, for ‘all’ strata (200–800 m) in surveys since 2012, and for ‘deep’ strata (200–1000 m) since 2016 are presented by O’Driscoll & Ballara (2019) in a single comparison plot.

The Sub-Antarctic trawl survey in December 2018 produced a relatively low number of hake — only four surveys in the series had fewer numbers of hake measured from the core plus Puysegur strata (see Table 7). Consequently, the CV (52%) was much worse than the target of 30%. Females were markedly more abundant in the catch than males, as has occurred in most surveys in this series. The 2018 age distribution was similar in shape to the 2014 survey (see Figure A6).

On the Chatham Rise, younger hake tended 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) tended 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) appeared relatively strong, and was tracked in some subsequent distributions through to about 2003. There was a clear year class progression 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) progressed through to age 9+ years in 2011, for both males and females.

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 appeared to be less abundant in the catch than in most previous years. The catch in most years since 2011 was dominated by males aged 5–7 years and

females aged 6–8 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 the commercial longline fishery on the Chatham Rise in 2017–18, and the CV (26%) was below the 30% target. A distribution produced for the Sub-Antarctic longline non-spawning fishery in 2017–18 also met the CV target (21%).

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 primarily from a trawl survey, i.e., Chatham Rise length data collected from October 2017 to May 2018 were applied to an age-length key comprised primarily of data from the January 2018 (TAN1801) trawl survey of Chatham Rise, but augmented with some observer-collected otoliths to cover lengths in the fishery data that were not sufficiently represented in the trawl survey samples. The estimated CV (25%) was better than the target value. Most samples in this series had CVs between 23 and 33%, and the level of observer sampling was reasonable in most years (see Table 18). The 2018 WCSI catch-at-age distribution was produced using commercial fishery length data applied to an age-length key derived primarily from the trawl survey conducted in the same area in August 2018 (TAN1807), but augmented with some observer-collected otoliths. The estimated CV (23%) was better than the target value. The 2017–18 Sub-Antarctic distribution used only observer length data and otoliths and had a mean weighted CV (17%) much better than the target of 30%. The CVs for this series in the last decade were all below 22%. The Sub-Antarctic and WCSI commercial fisheries were comprehensively sampled in 2017–18; sampling on the Chatham Rise was less intensive. An estimate of catch-at-age for the ling bycatch from the Cook Strait hoki spawning fisheries was not able to be produced for 2018 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 Sub-Antarctic (December 2018) to meet the mean weighted CV target (25%). The target was met in all of the previous surveys of this area (see Table 26). All available ling otoliths collected during the WCSI trawl survey in August 2018 were aged, but the mean weighted CV (34%) was still below the target of 30%. This is the worst result for this survey series (see Table 28); more intensive sampling for ling otoliths is recommended for future surveys.

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). Clear year class progressions were not observed in any of the longline series.

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 observed 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 were 12 years old. Ling in the Sub-Antarctic aged 6 and 8 in 2002 were 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 were also observed, as would be expected given that the same age-length key was applied to trawl fisheries and trawl surveys from a particular area. In the Cook Strait trawl fishery, female ling exhibited 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 2017). 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. 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 was rectified since 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, and are summarised below (Table 30).

Table 30: List of hake and ling fisheries, showing the annual data sampling time periods that were used to produce the catch-at-age series presented above.

Fishstock(s)	Area	Fishing method	Time period
HAK 1	Sub-Antarctic	Trawl	September–May
HAK 4 & HAK 1	Chatham Rise	Trawl	October–April
HAK 7	WCSI	Trawl	June–September
LIN 3 & LIN 4	Chatham Rise	Longline	June–October
LIN 5 & LIN 6	Sub-Antarctic	Longline spawning	October–December
LIN 5 & LIN 6	Sub-Antarctic	Longline non-spawning	February–July
LIN 6	Bounty Plateau	Longline	November–March
LIN 7	WCSI	Longline	May–August
LIN 2 & LIN 7	Cook Strait	Longline	June–September
LIN 3 & LIN 4	Chatham Rise	Trawl	October–May
LIN 5 & LIN 6	Sub-Antarctic	Trawl	September–April
LIN 7	WCSI	Trawl	June–September
LIN 2 & LIN 7	Cook Strait	Trawl	June–September

There are several important fisheries exhibiting current issues with the intensity of observer sampling. Issues were: 1) otolith sampling of ling and (particularly) hake in the Chatham Rise trawl fishery and hake from the WCSI trawl fishery was often inadequate to produce collections of otoliths that could be used to generate a comprehensive age-length key; and 2) negligible observer sampling of the WCSI ling line fishery which produces about 40% of the total WCSI ling catch but is seldom sampled by observers because the fishing trips tend to be of relatively short duration on small vessels. Our recommendations are as follows:

- Hake, Chatham Rise trawl: markedly increase the sampling of both lengths and otoliths (at least a four-fold increase is likely to be necessary).
- Hake, WCSI trawl: increase (e.g., double) the number of otoliths collected per sampled tow.
- Ling, Chatham Rise trawl: increase (e.g., by about 30%) the number of otoliths collected per sampled tow.
- Ling, WCSI longline: formulate an observer plan for this fishery that intensively samples both lengths and otoliths on any observed trips.

5. ACKNOWLEDGMENTS

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

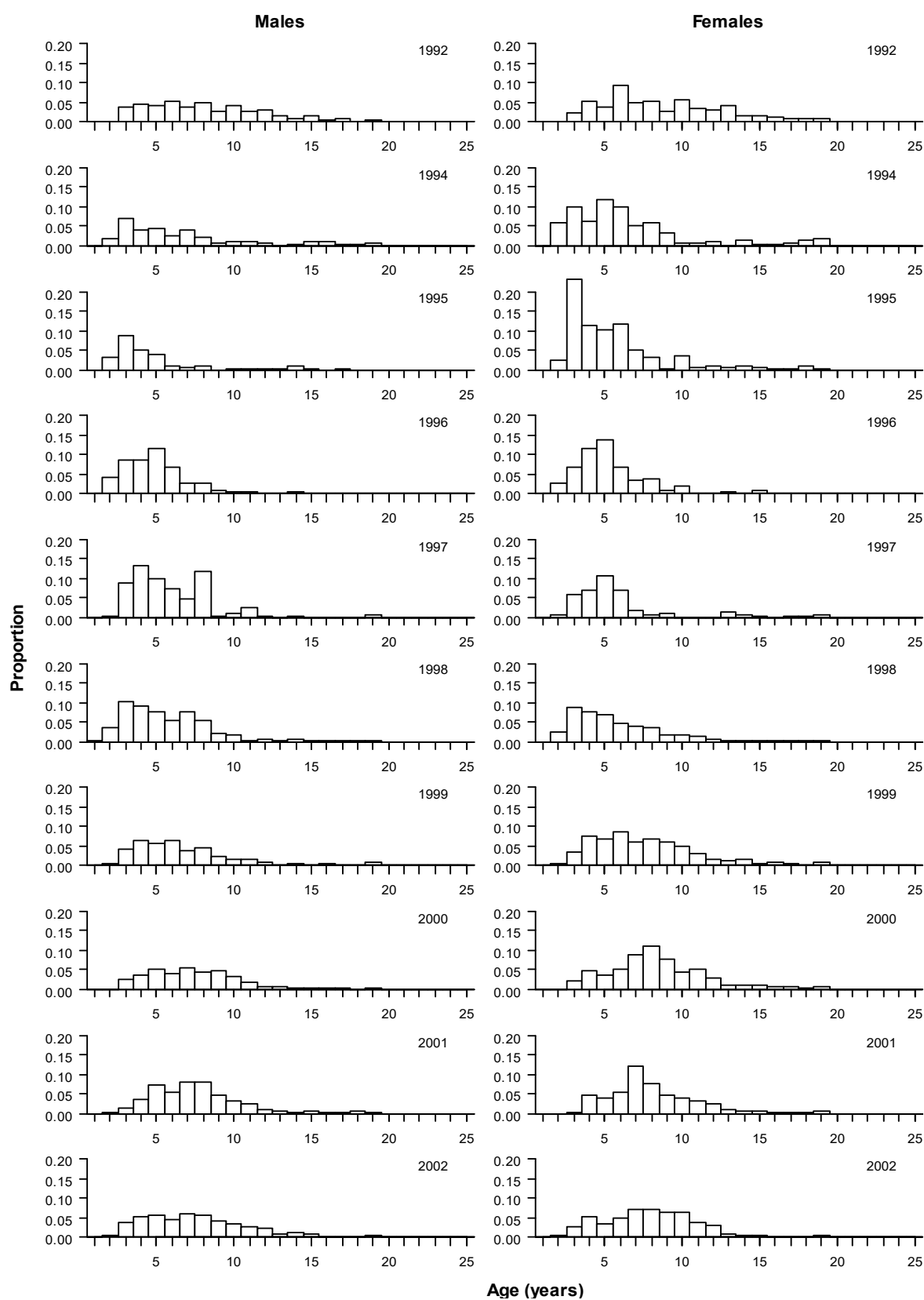


Figure A1: Age frequency distributions of hake from commercial catch-at-age data in the Chatham Rise (west) trawl fishery, 1992 to 2018 (where sufficient data are available). Year labels relate to the latter year when sampling occurs over two calendar years, e.g., “2002” denotes the October 2001–April 2002 sample.

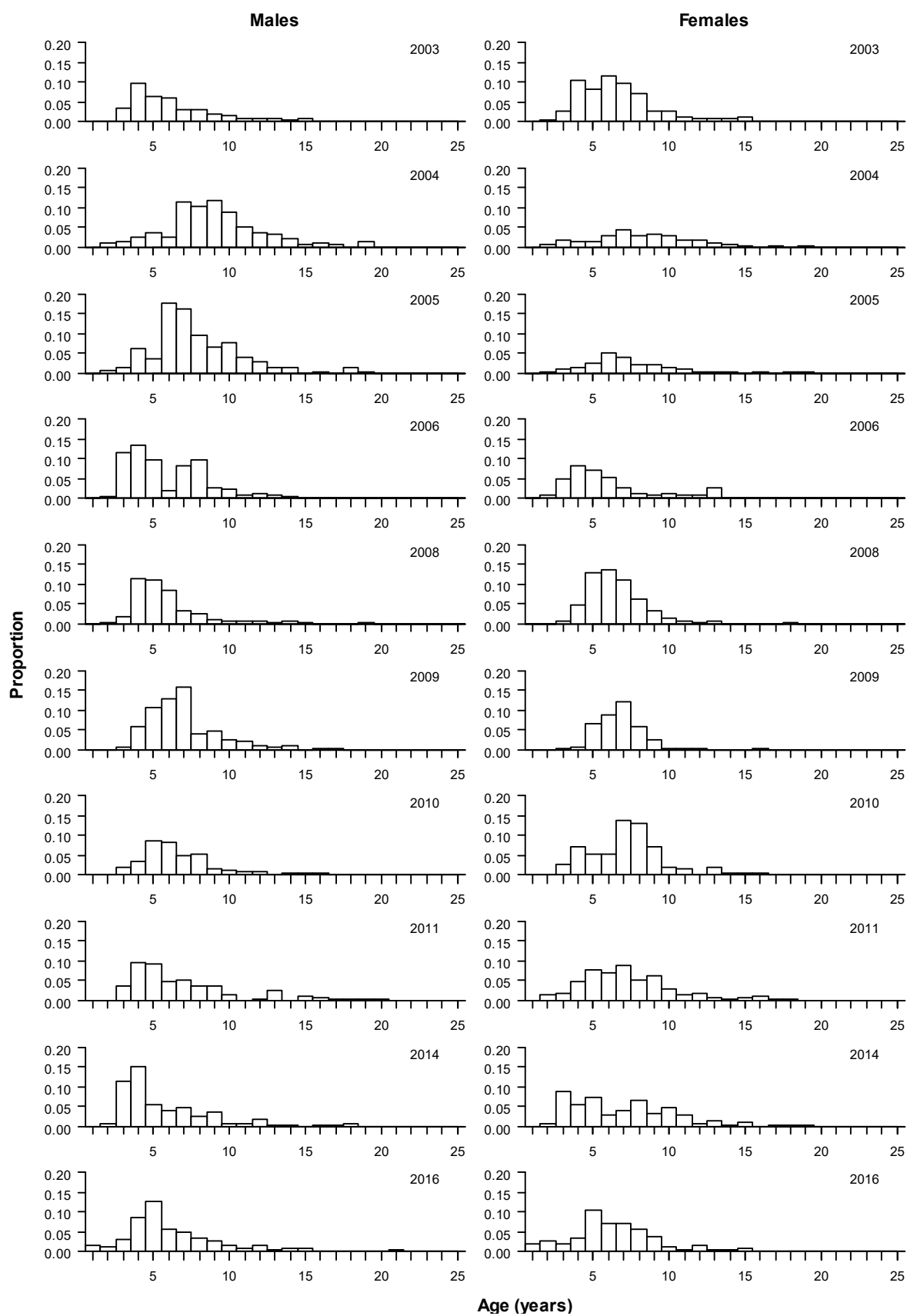


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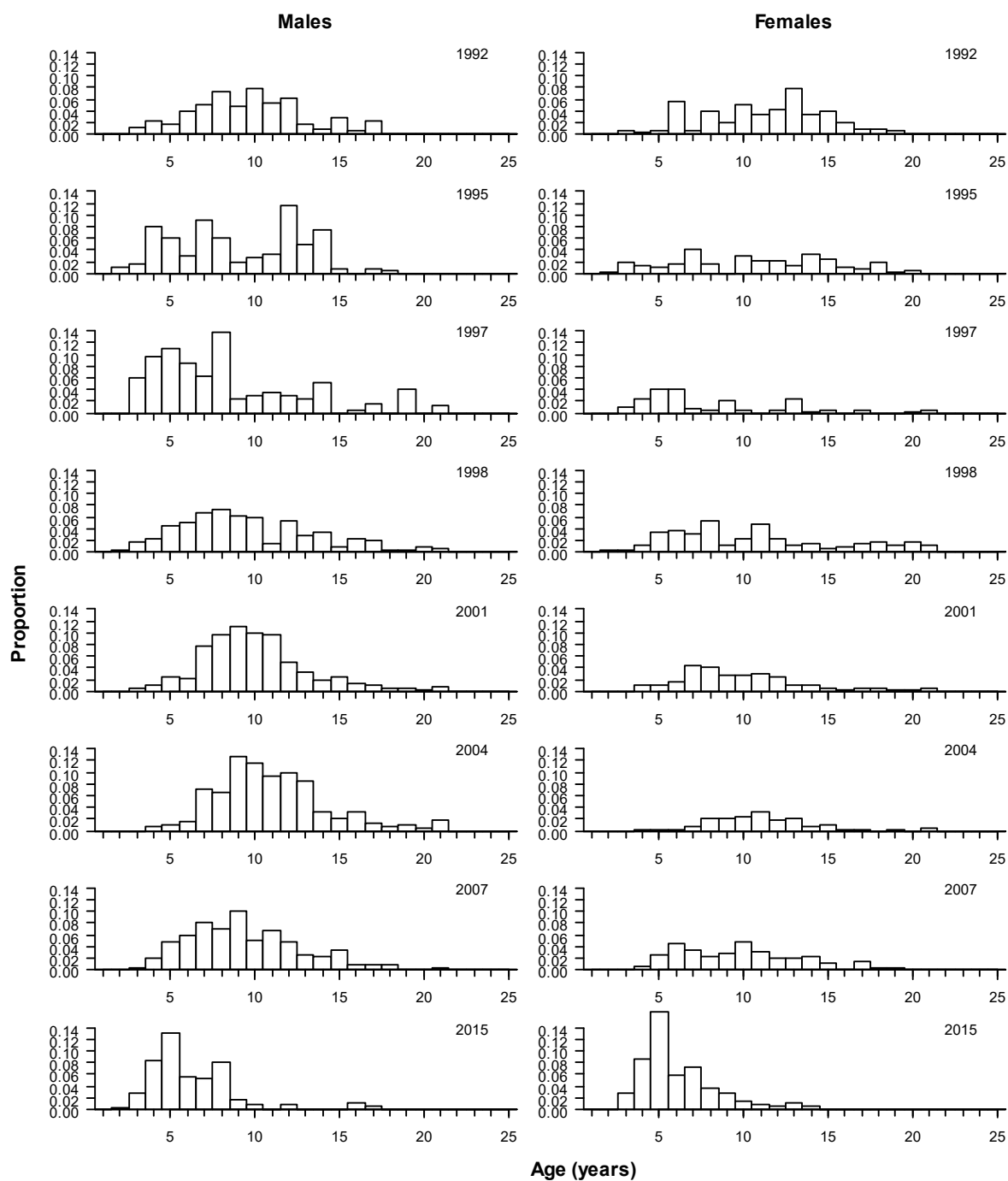


Figure A2: Age frequency distributions of hake from commercial catch-at-age data in the Chatham Rise (east) trawl fishery, 1992 to 2018 (where sufficient data are available).

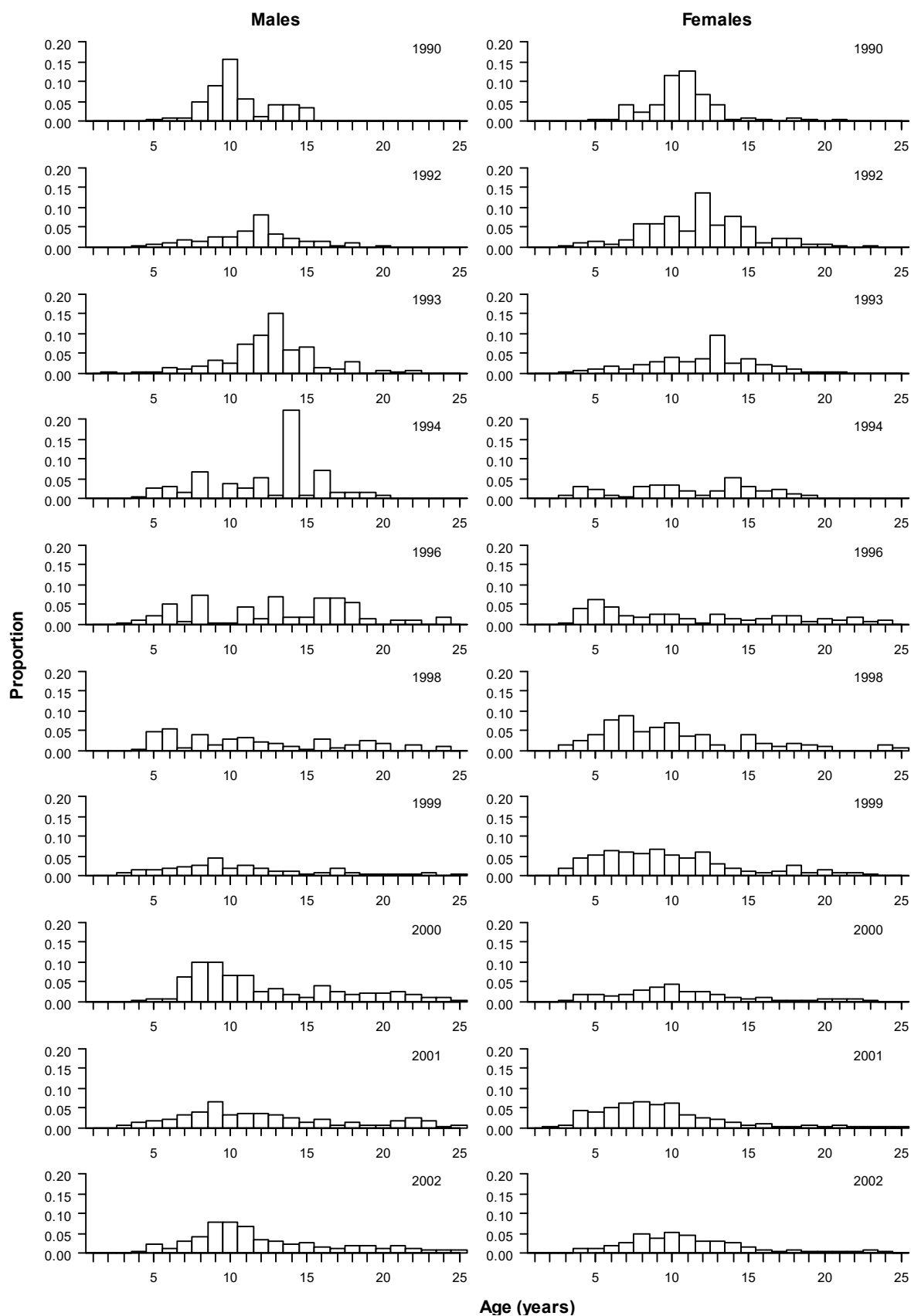


Figure A3: Age frequency distributions of hake from commercial catch-at-age data in the Sub-Antarctic trawl fishery, 1990 to 2018 (where sufficient data are available).

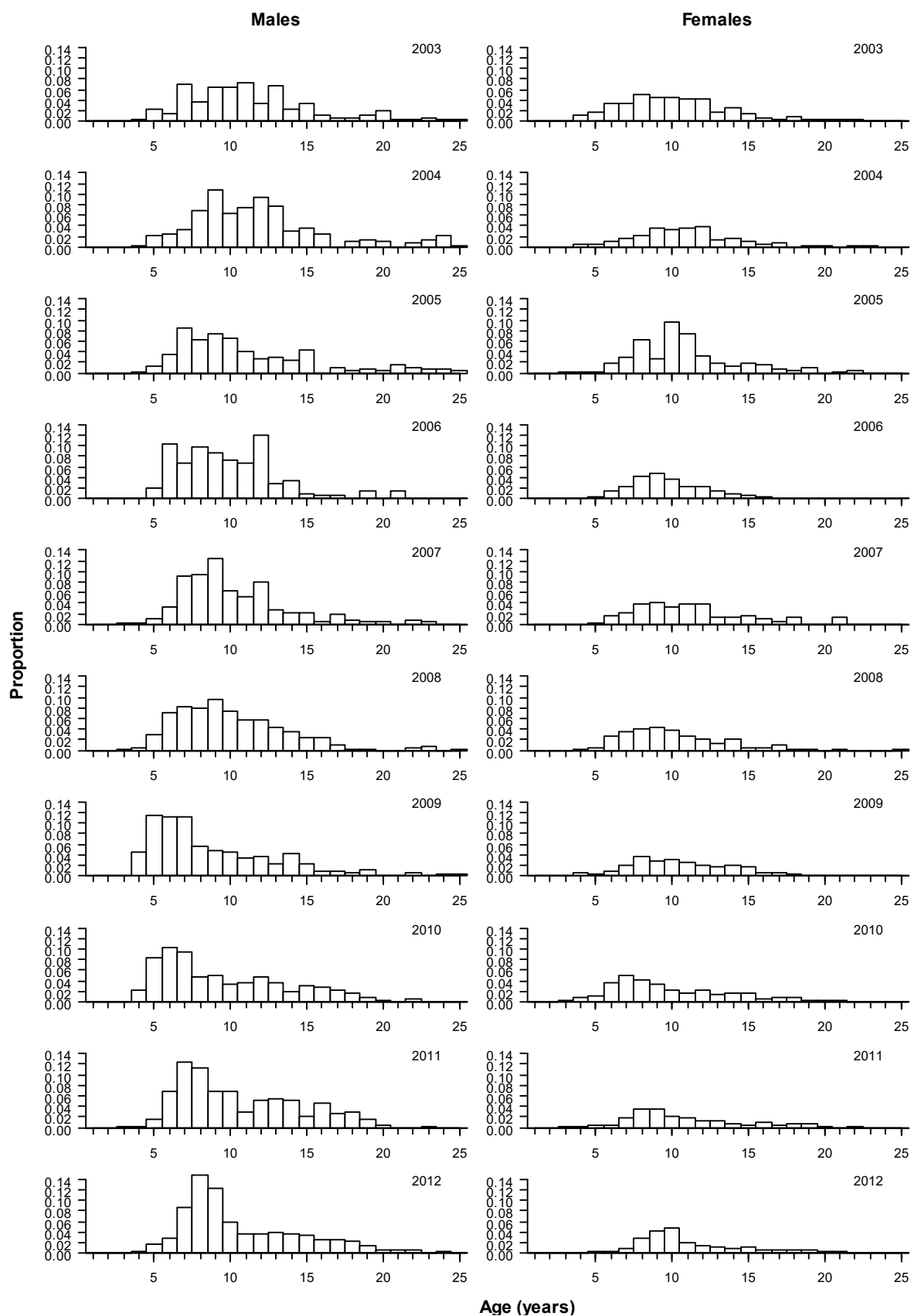


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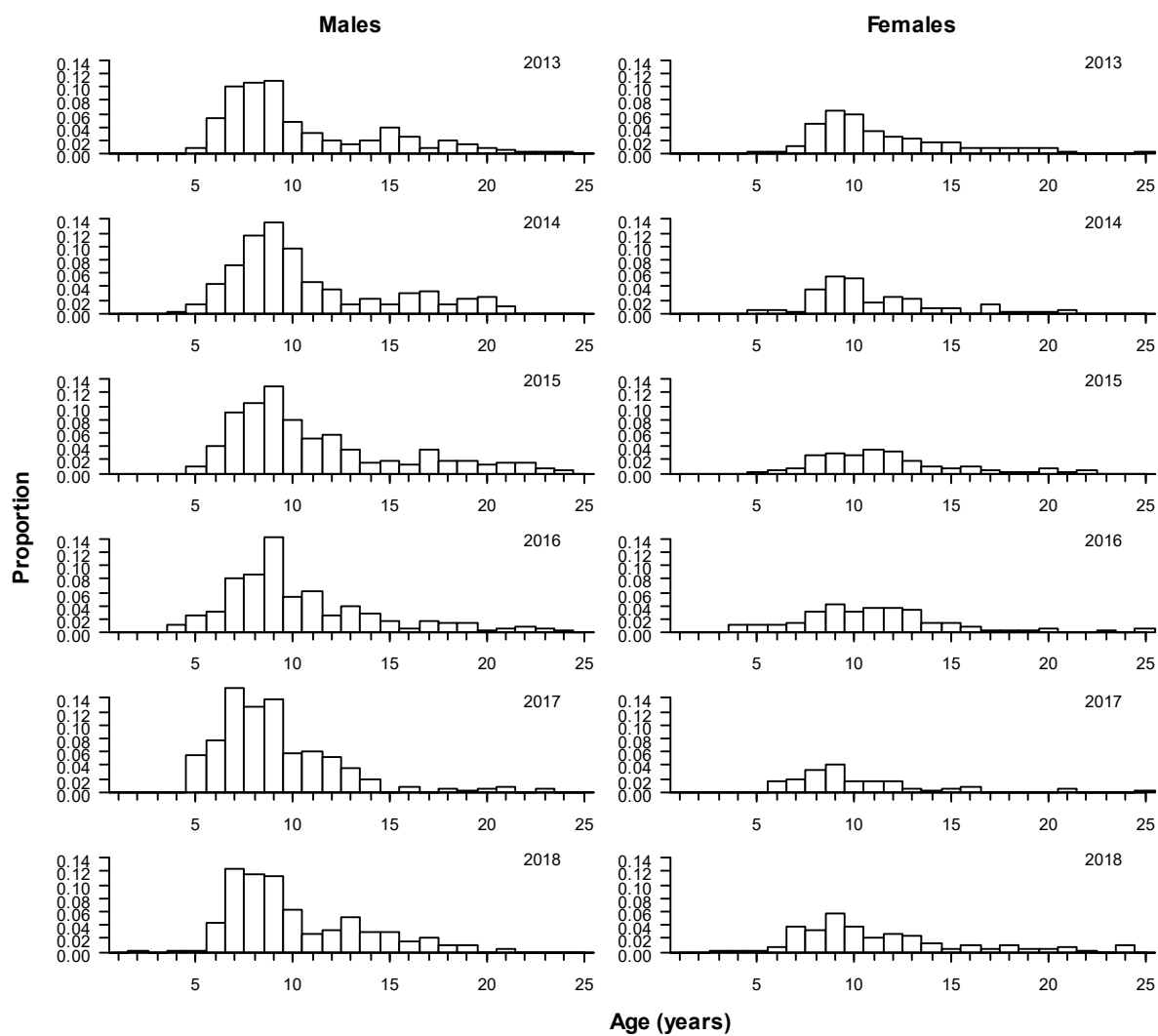


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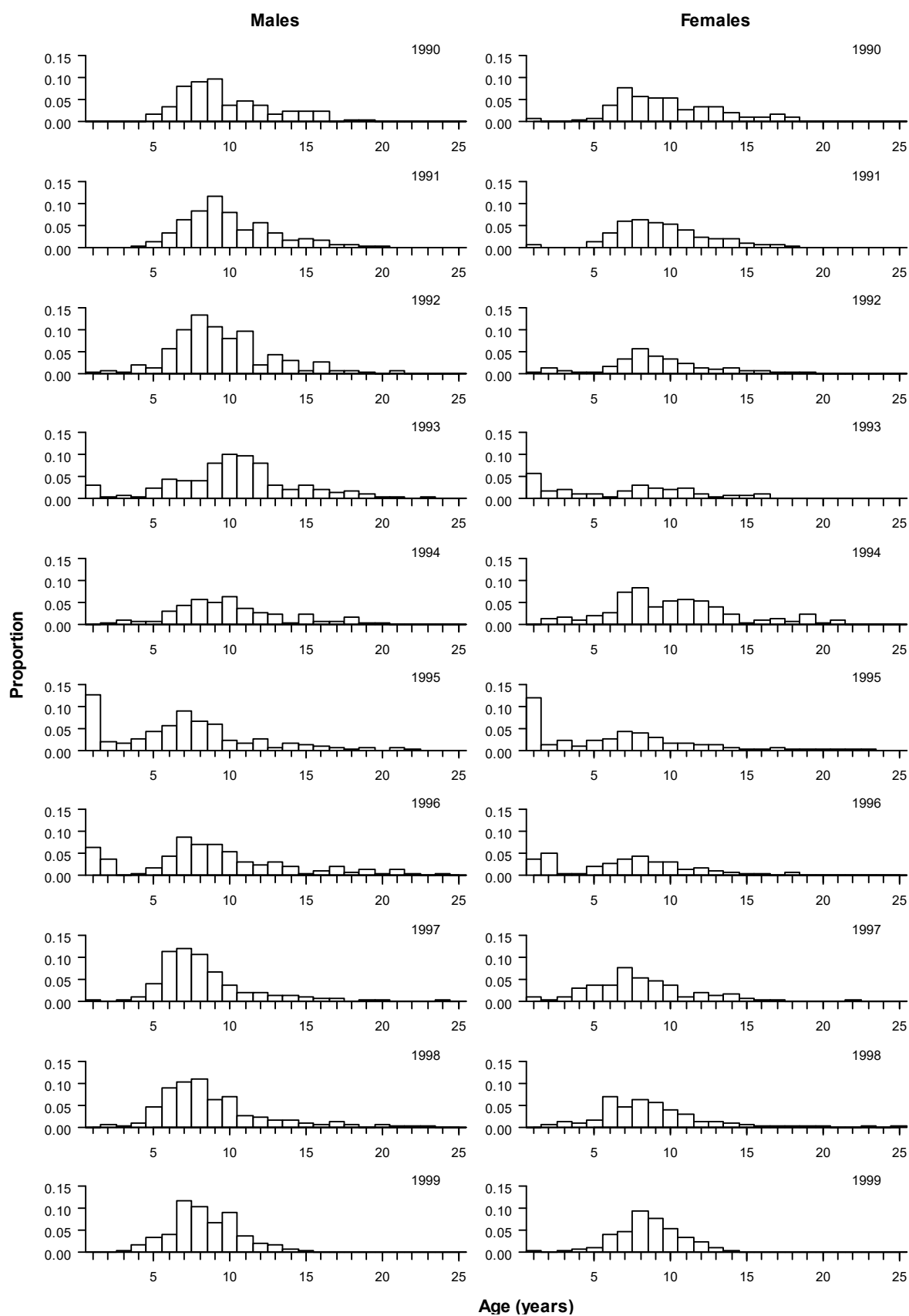


Figure A4: Age frequency distributions of hake from commercial catch-at-age data in the WCSI trawl fishery, 1990 to 2018 (where sufficient data are available).

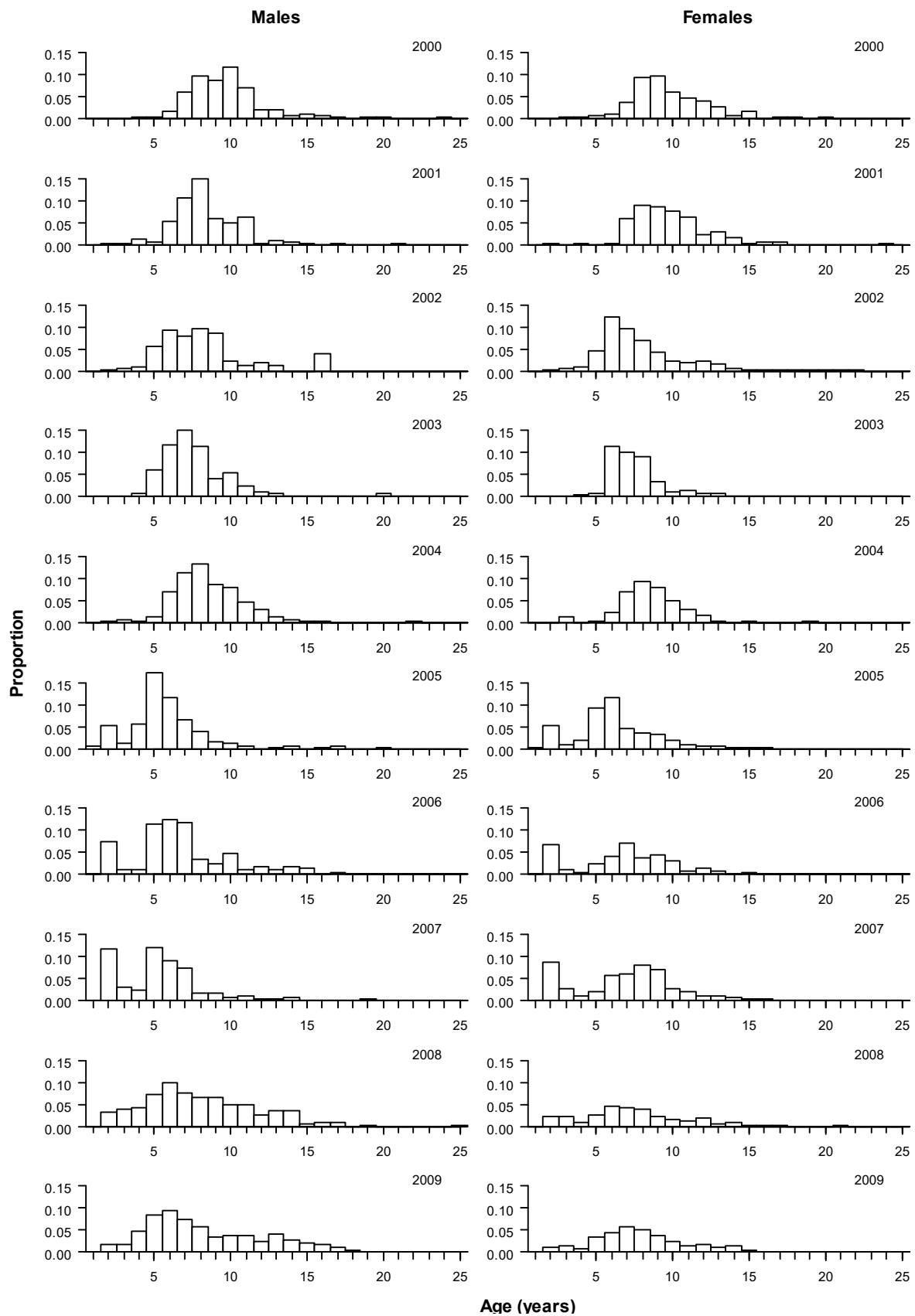


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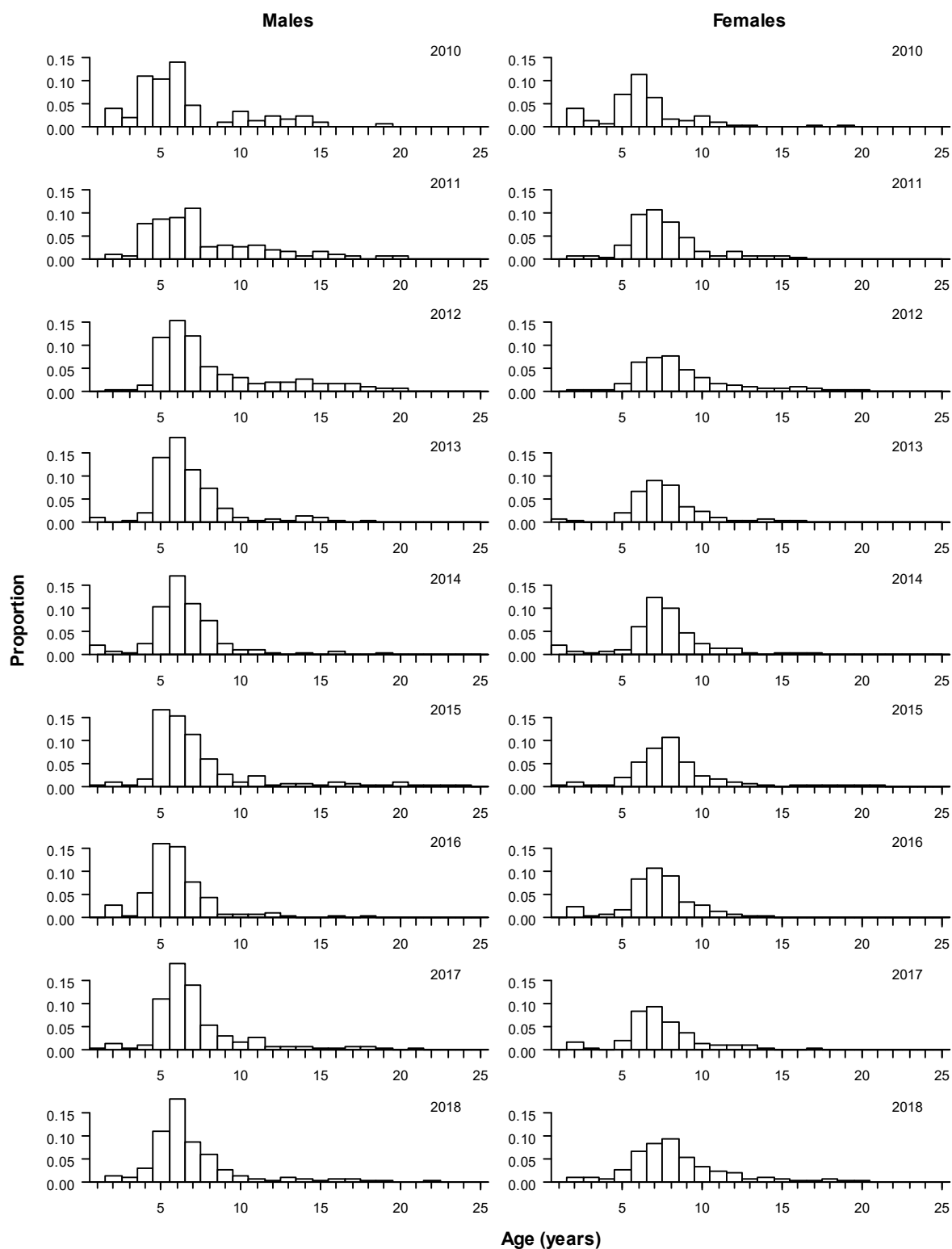


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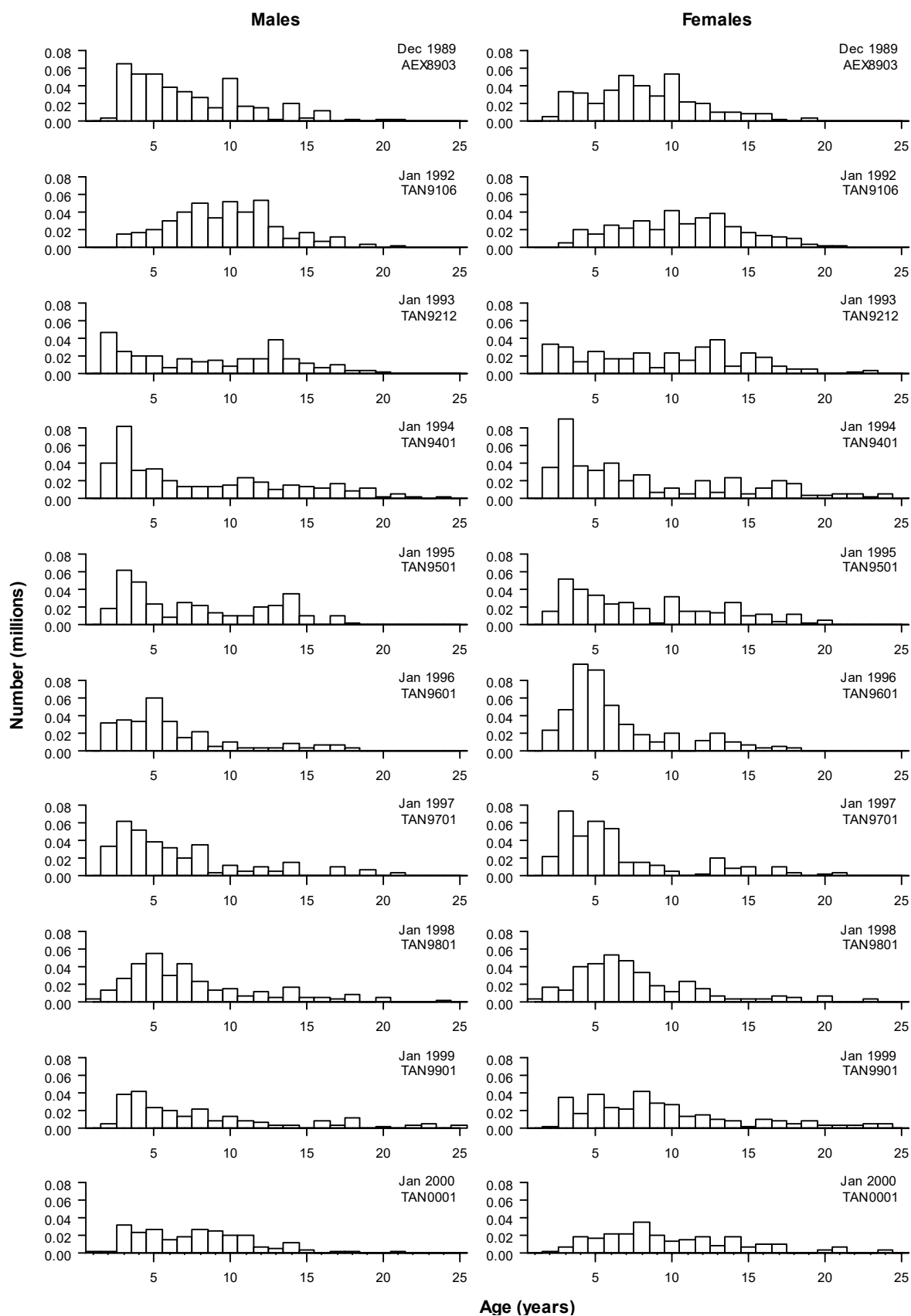


Figure A5: Age frequency distributions of hake (scaled numbers-at-age, ages 1 to 25) from trawl surveys of the Chatham Rise, 1989–90 to 2017–18.

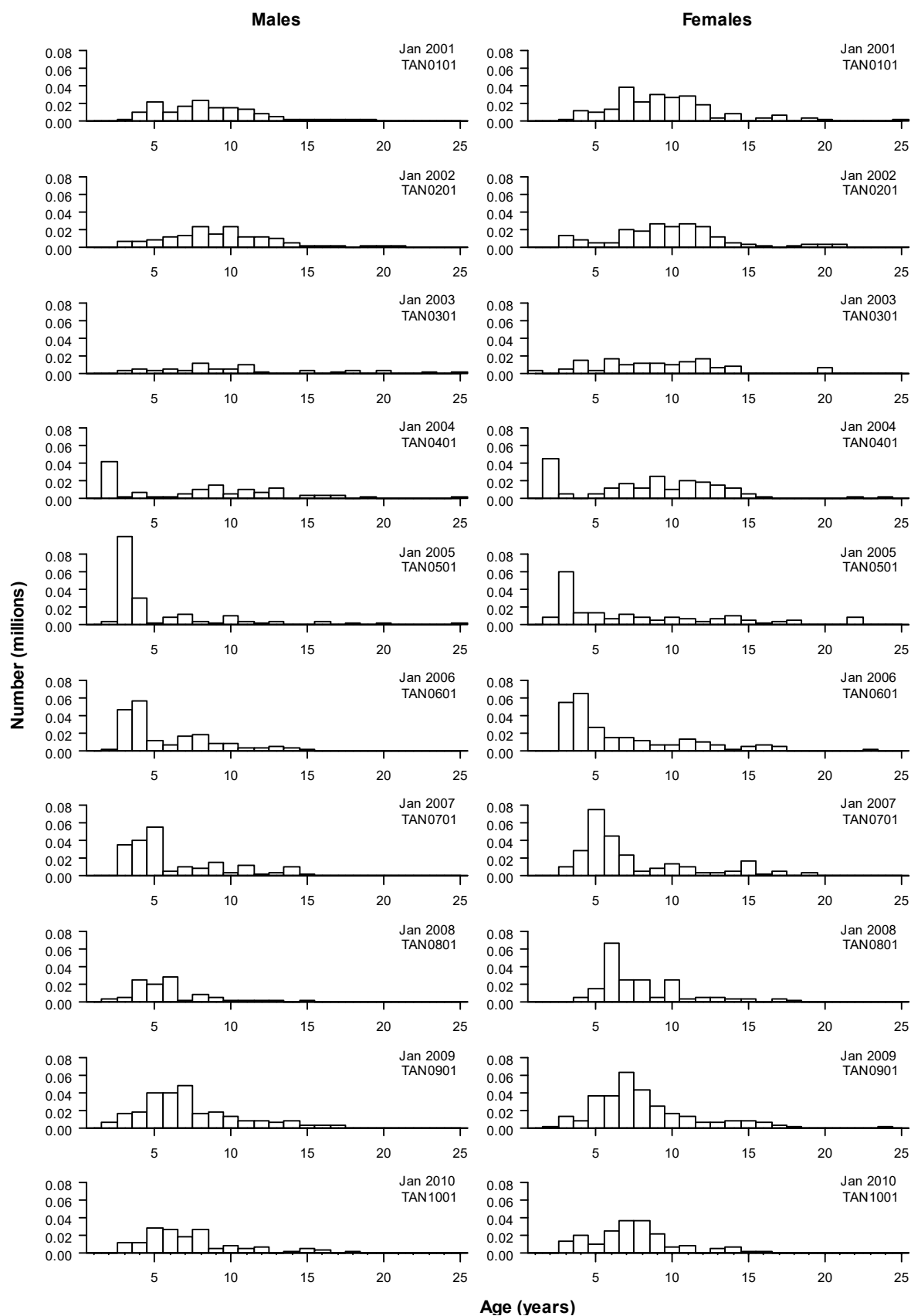


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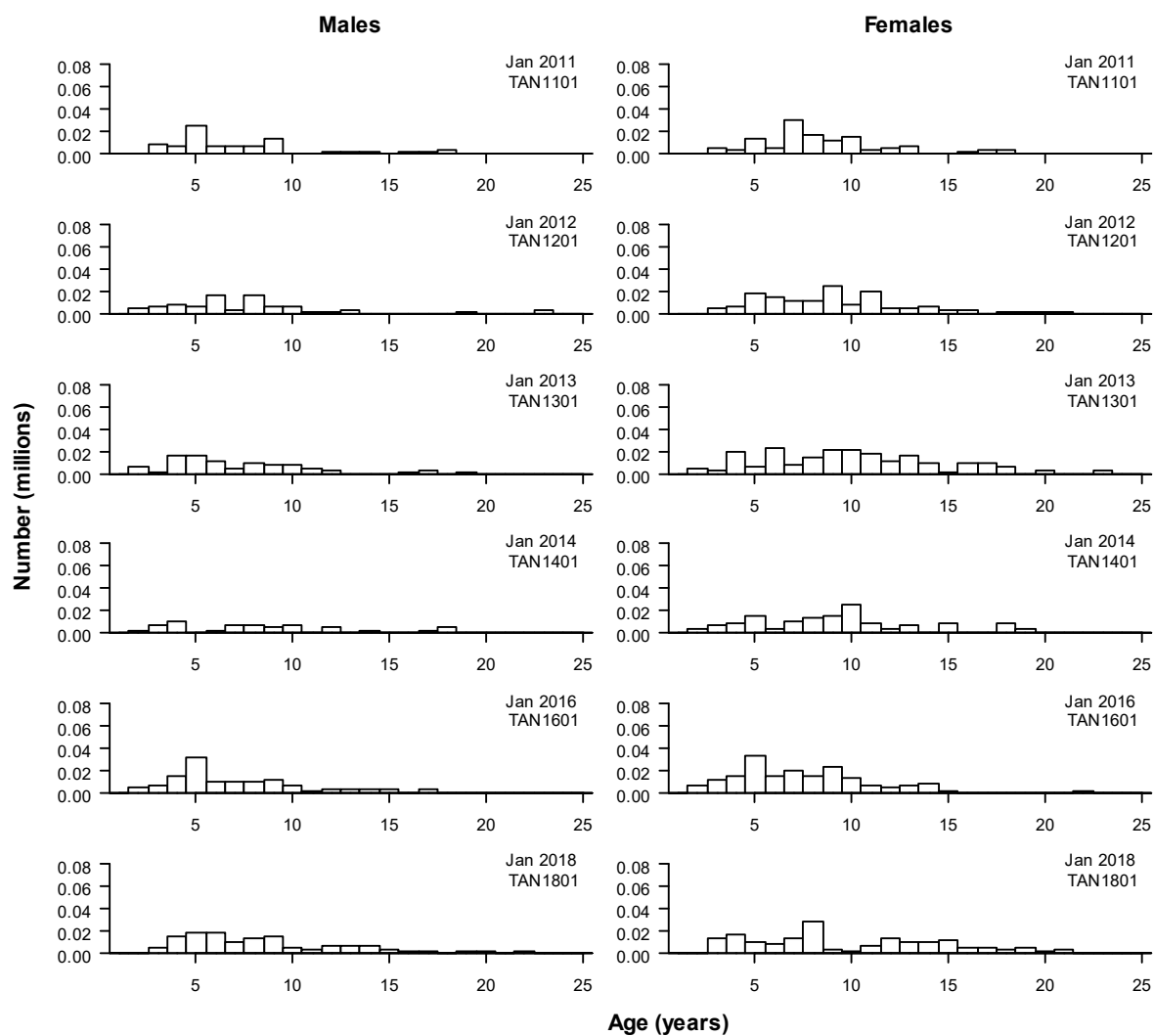


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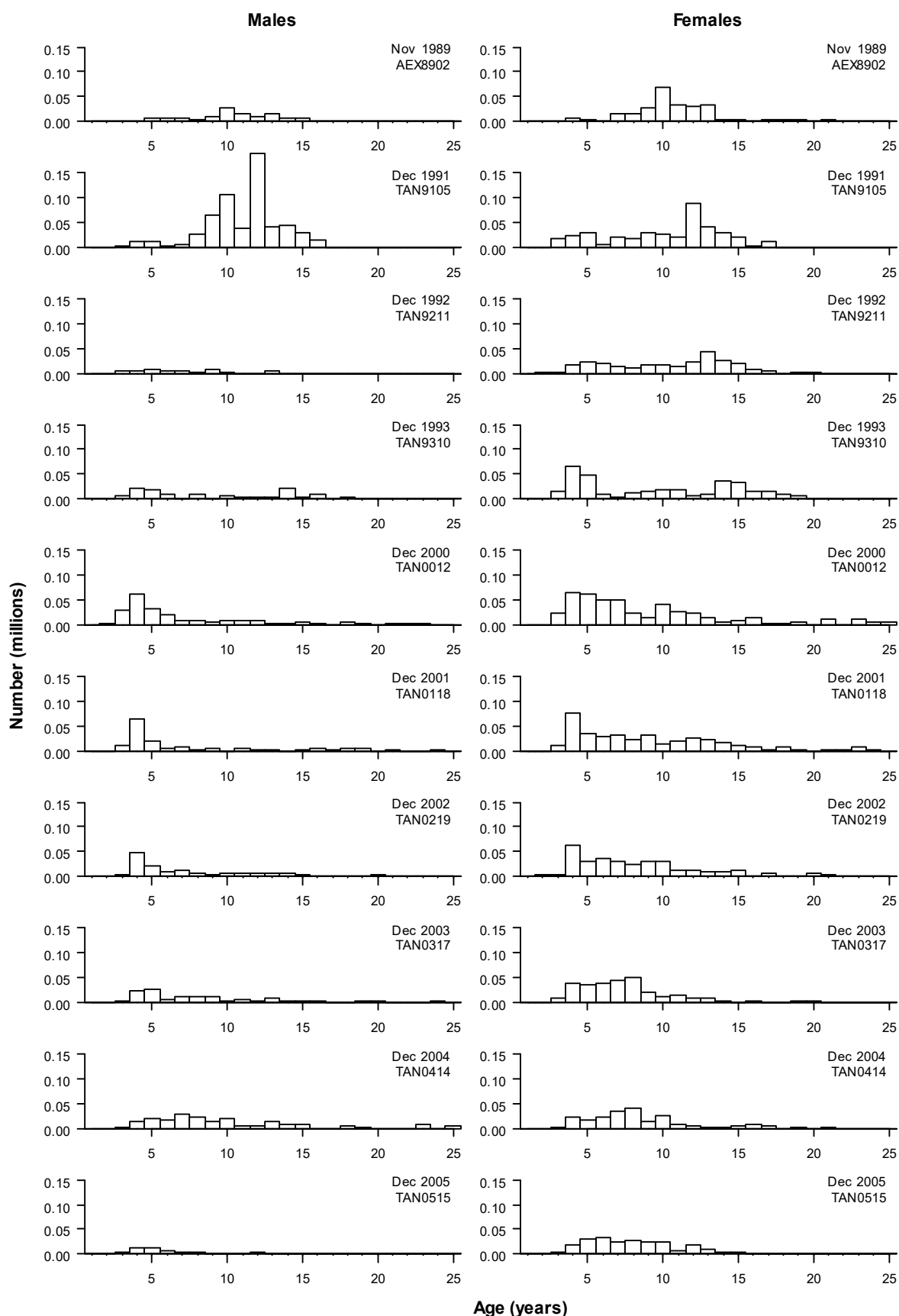


Figure A6: Age frequency distributions of hake (scaled numbers-at-age, ages 1 to 25) from summer trawl surveys of the Sub-Antarctic, 1989 to 2018. The sample from TAN1614 was too small to be aged.

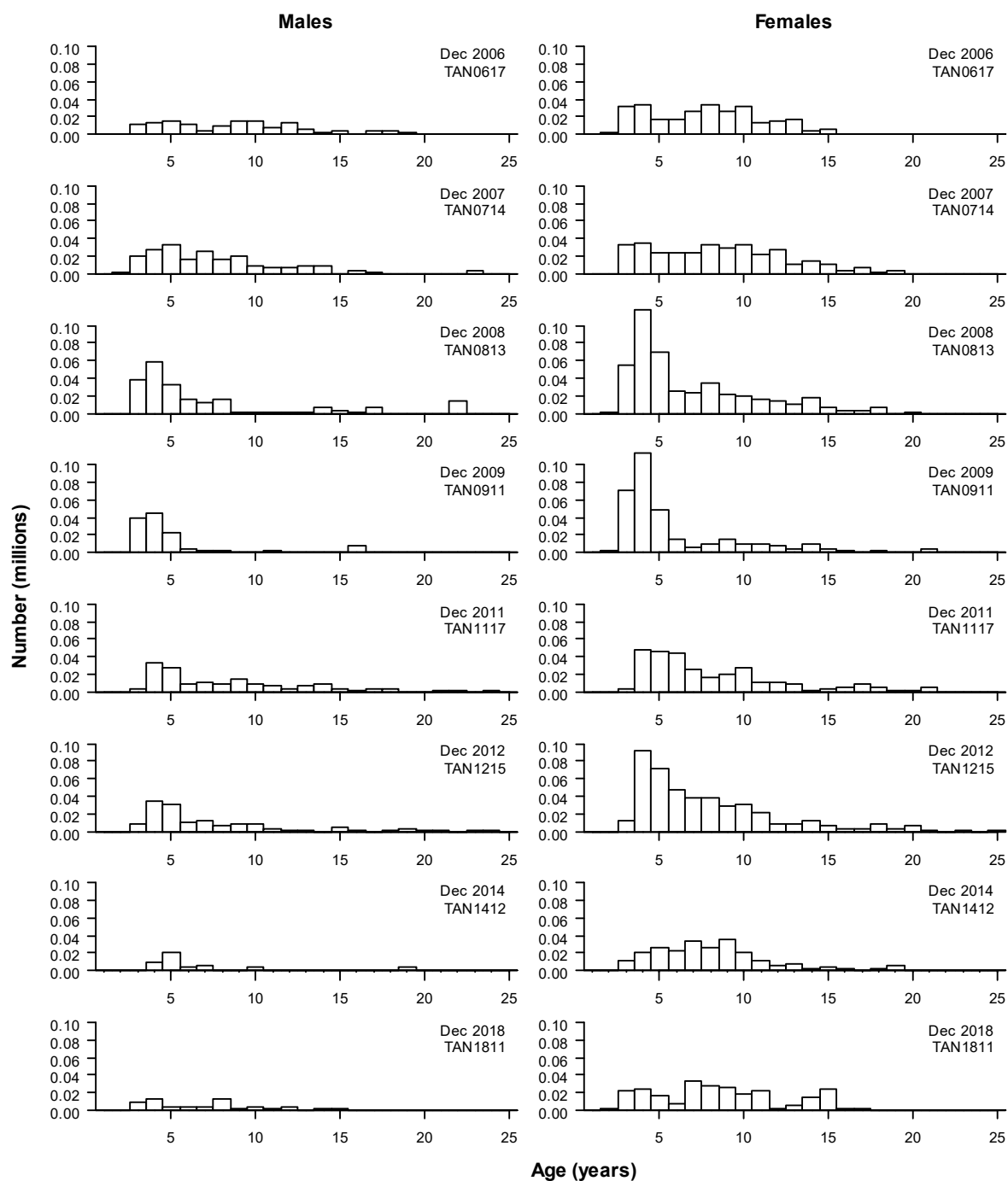


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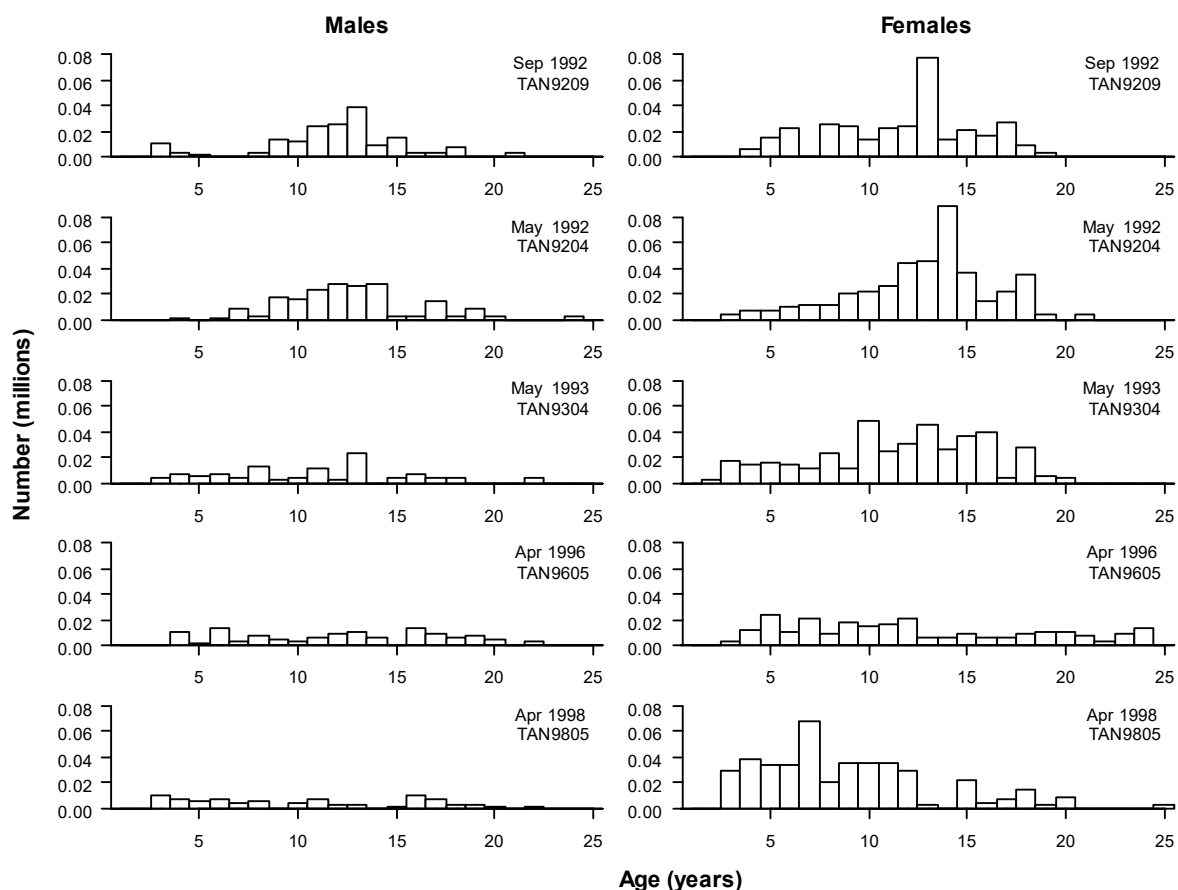


Figure A7: Age frequency distributions of hake (scaled numbers-at-age, ages 1 to 25) from spring and autumn trawl surveys of the Sub-Antarctic, 1992 to 1998.

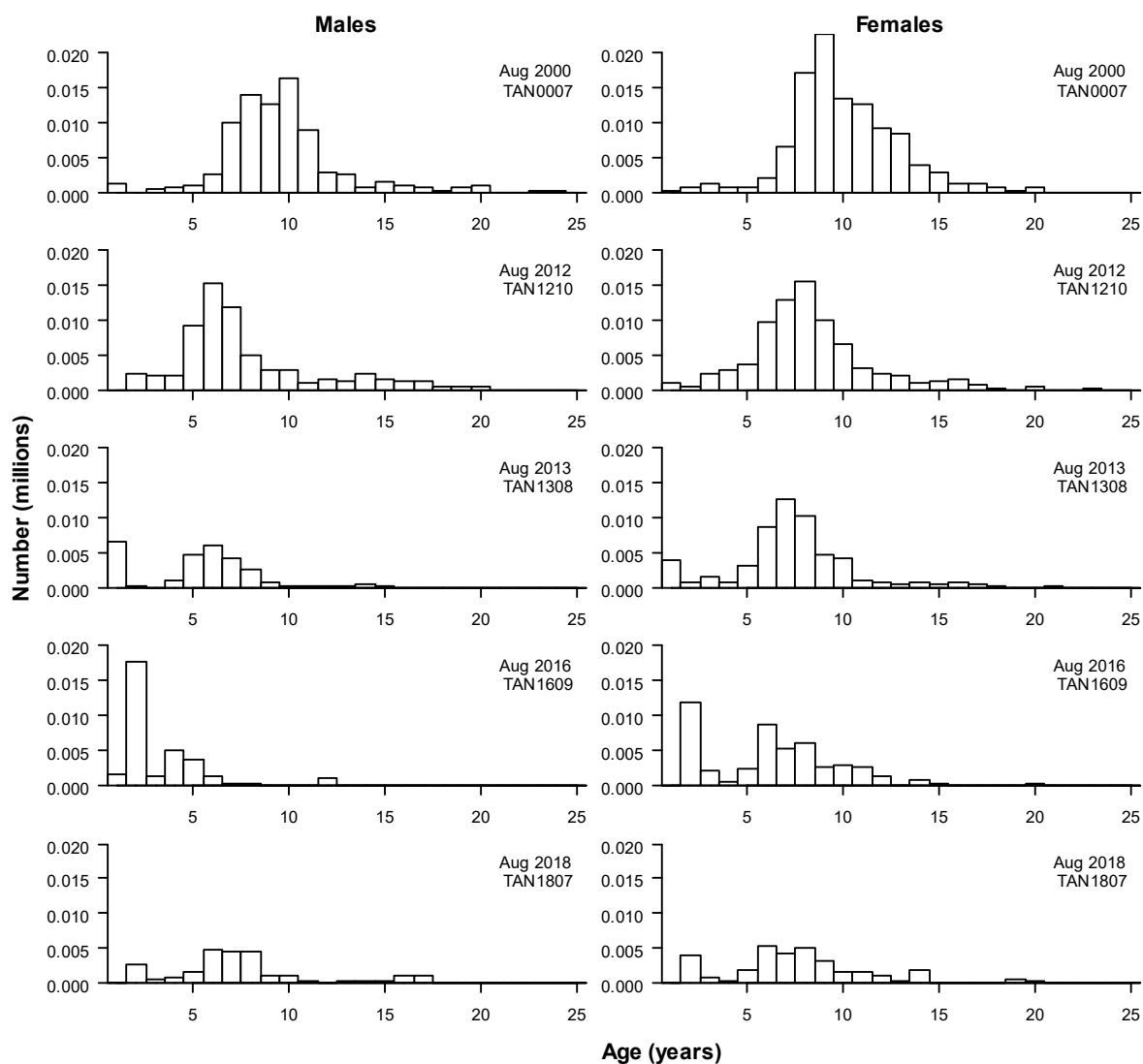


Figure A8: Age frequency distributions of hake (scaled numbers-at-age, ages 1 to 25) from trawl surveys of the WCSI ('core' strata only), from 2000 to 2018.

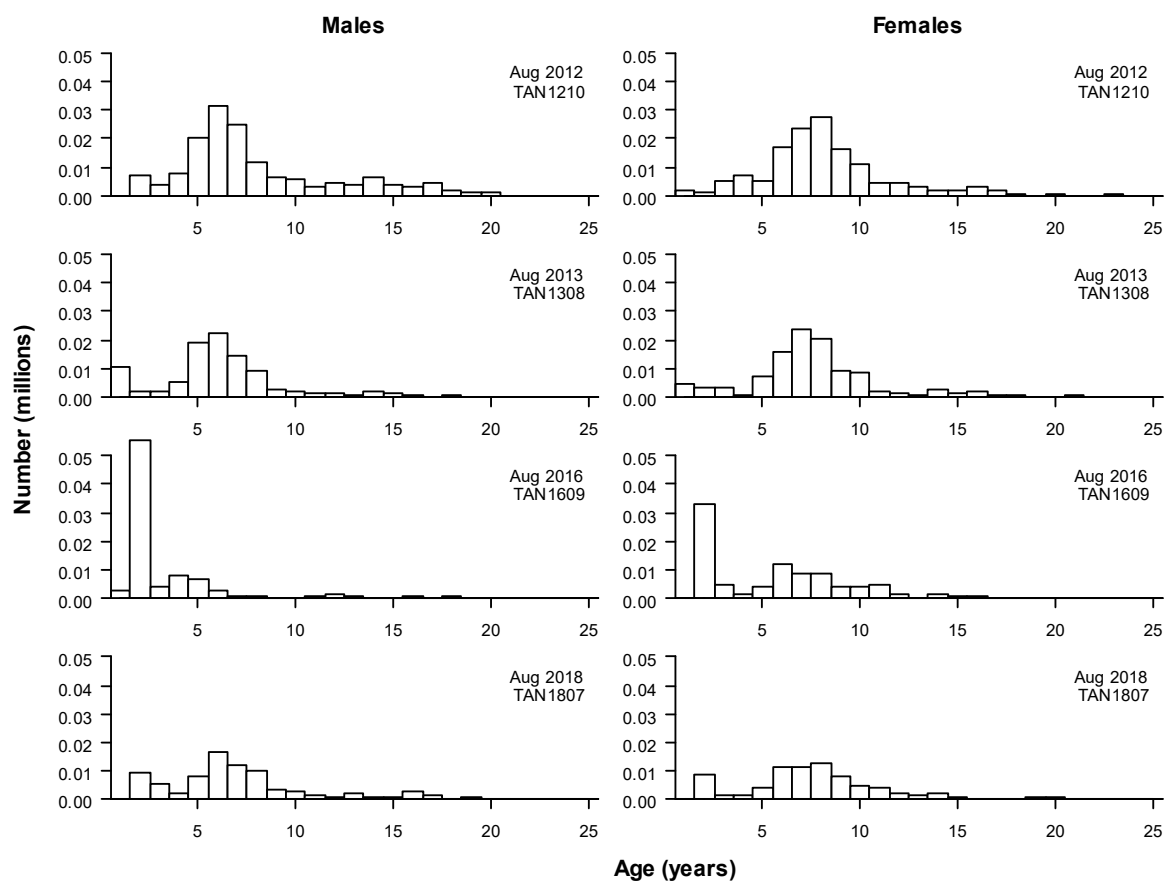


Figure A9: Age frequency distributions of hake (scaled numbers-at-age, ages 1 to 25) from trawl surveys of the WCSI ('all' strata), from 2012 to 2018.

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

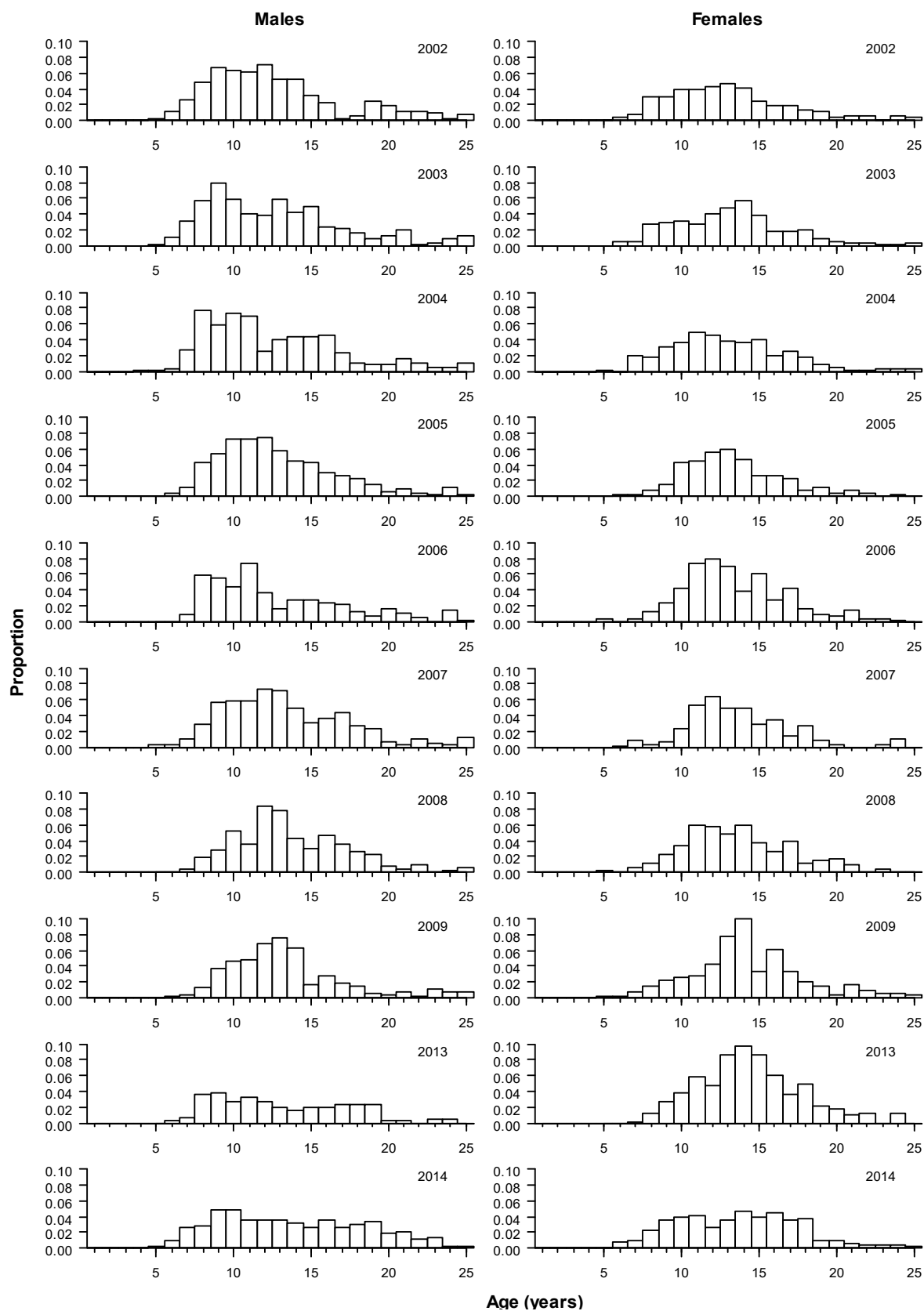


Figure B1: Age frequency distributions of ling from commercial catch-at-age data in the Chatham Rise longline fishery, 2002 to 2018 (where sufficient data are available).

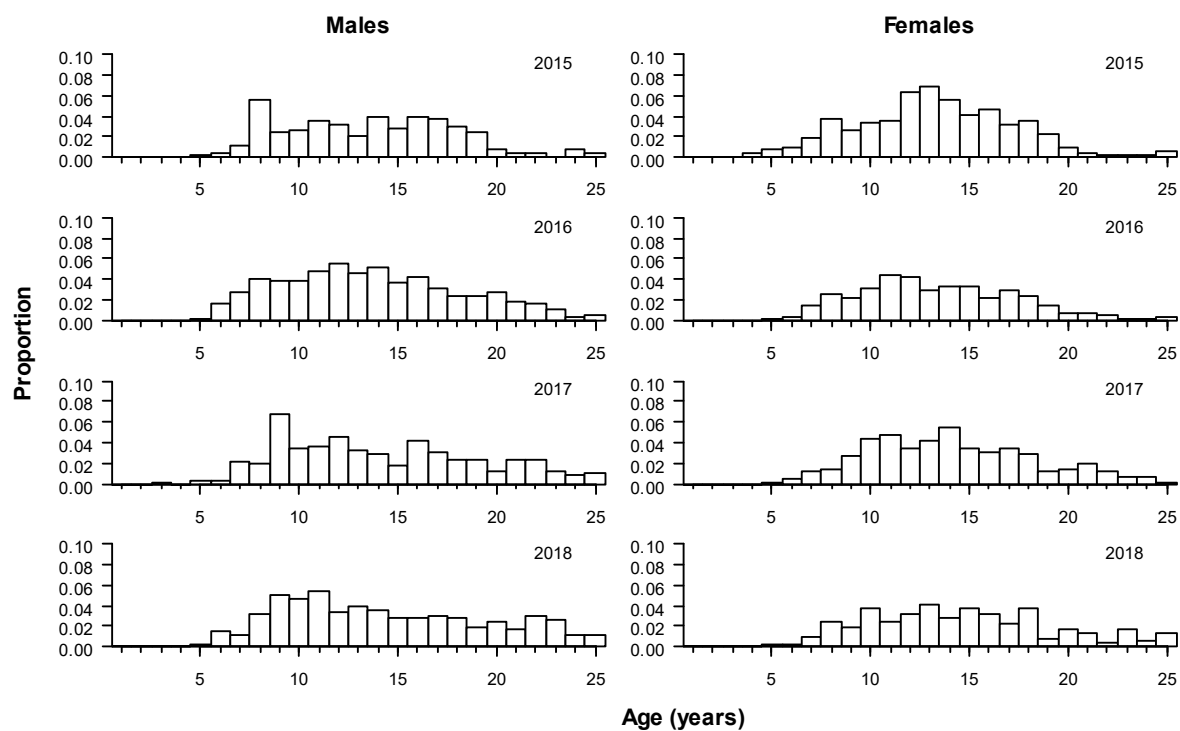


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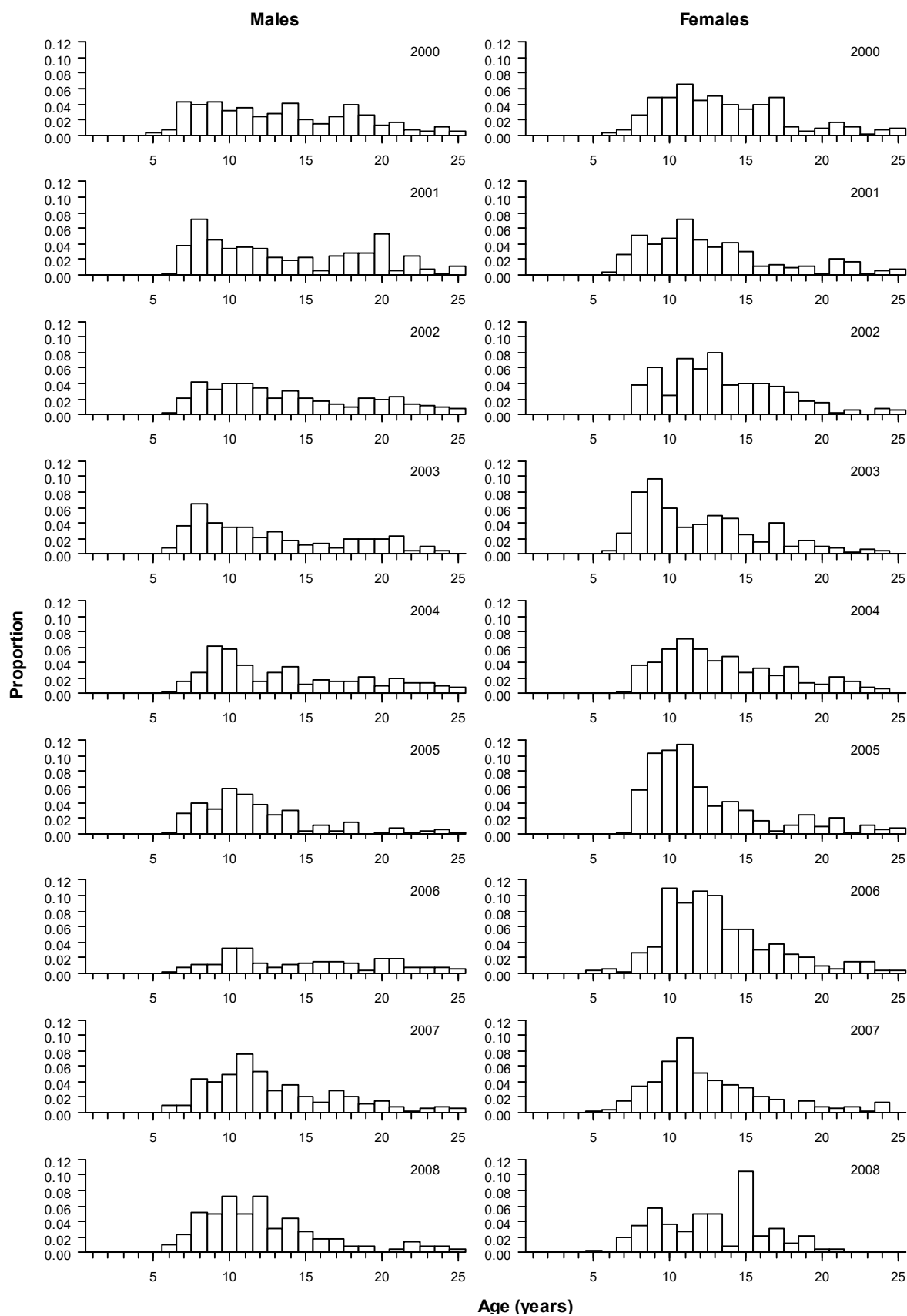


Figure B2: Age frequency distributions of ling from commercial catch-at-age data in the Sub-Antarctic (spawning season) longline fishery, 2000 to 2018 (where sufficient data are available).

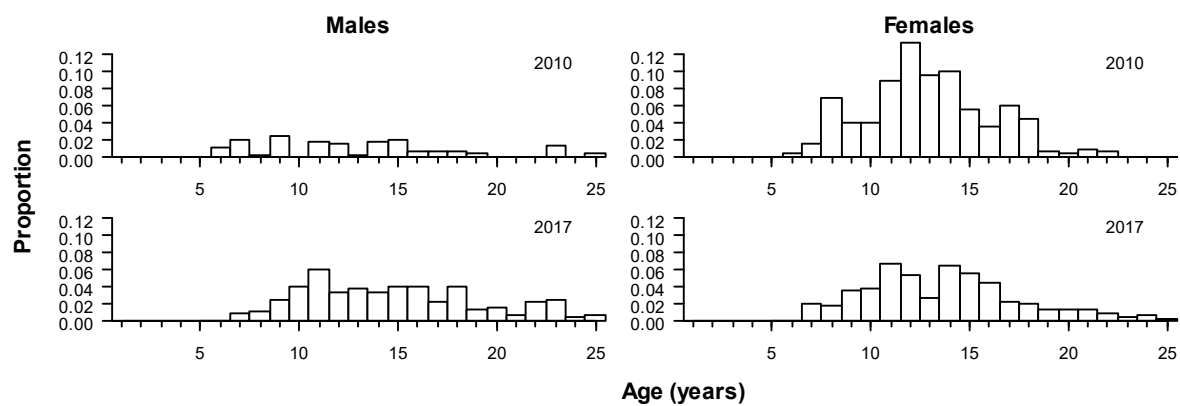


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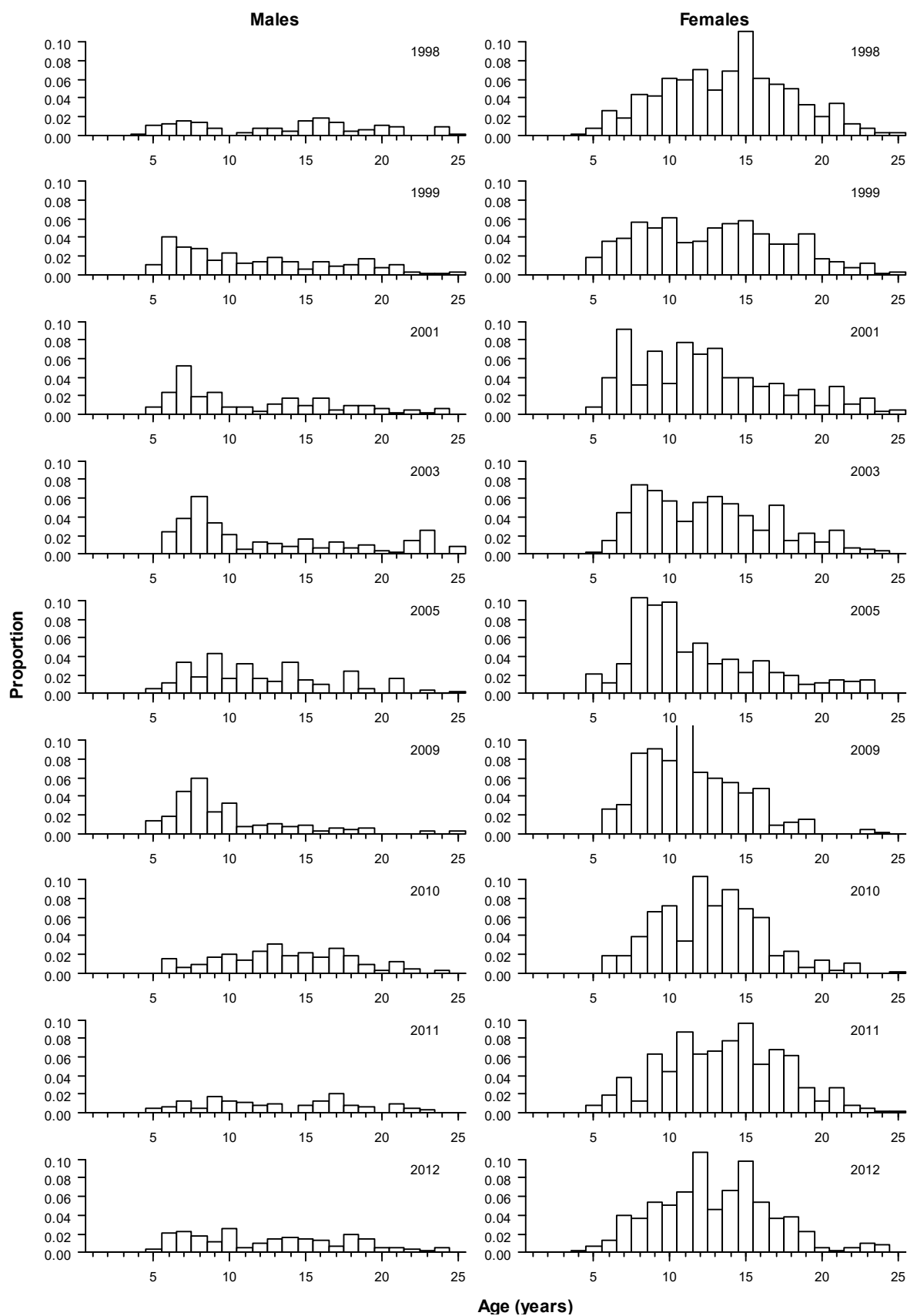


Figure B3: Age frequency distributions of ling from commercial catch-at-age data in the Sub-Antarctic (non-spawning season) longline fishery, 1998 to 2018 (where sufficient data are available).

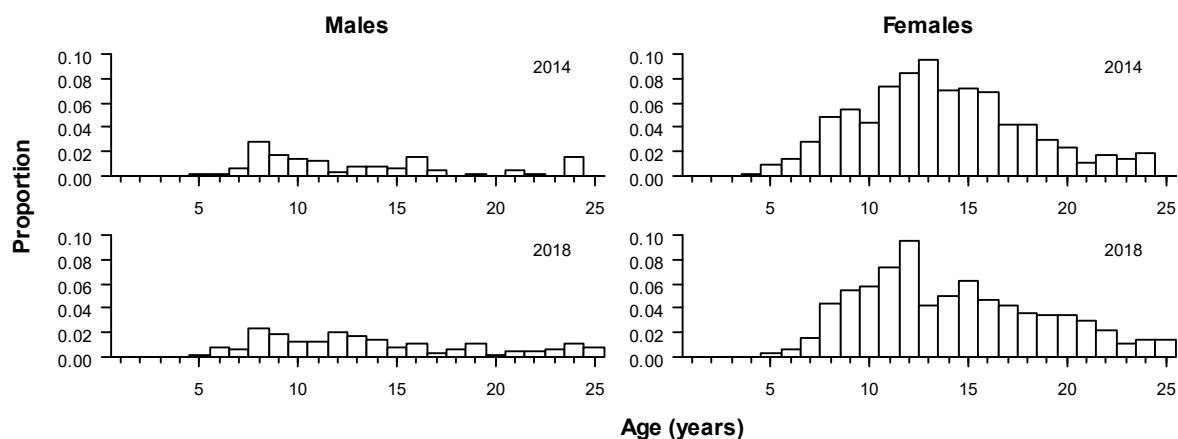


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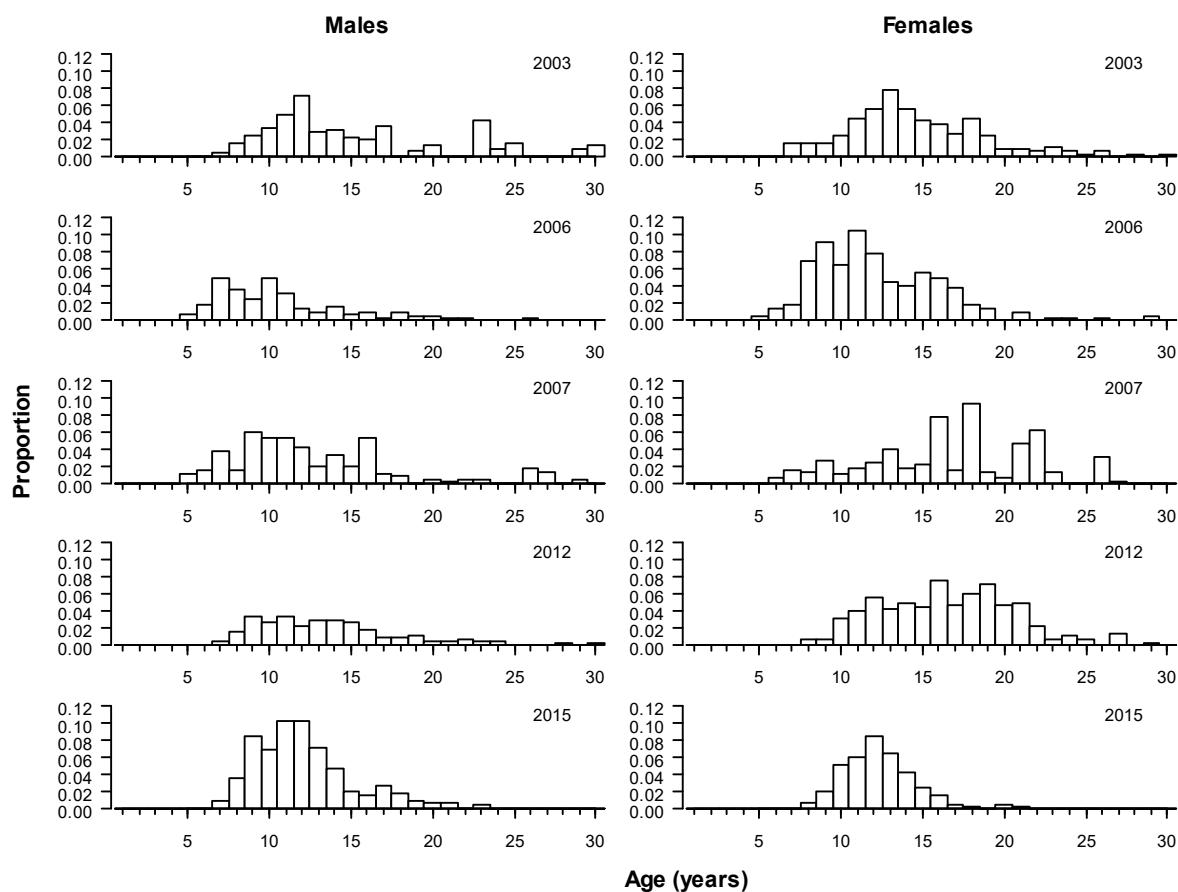


Figure B4: Age frequency distributions of ling from commercial catch-at-age data in the west coast South Island longline fishery, 2003 to 2018 (where sufficient data are available).

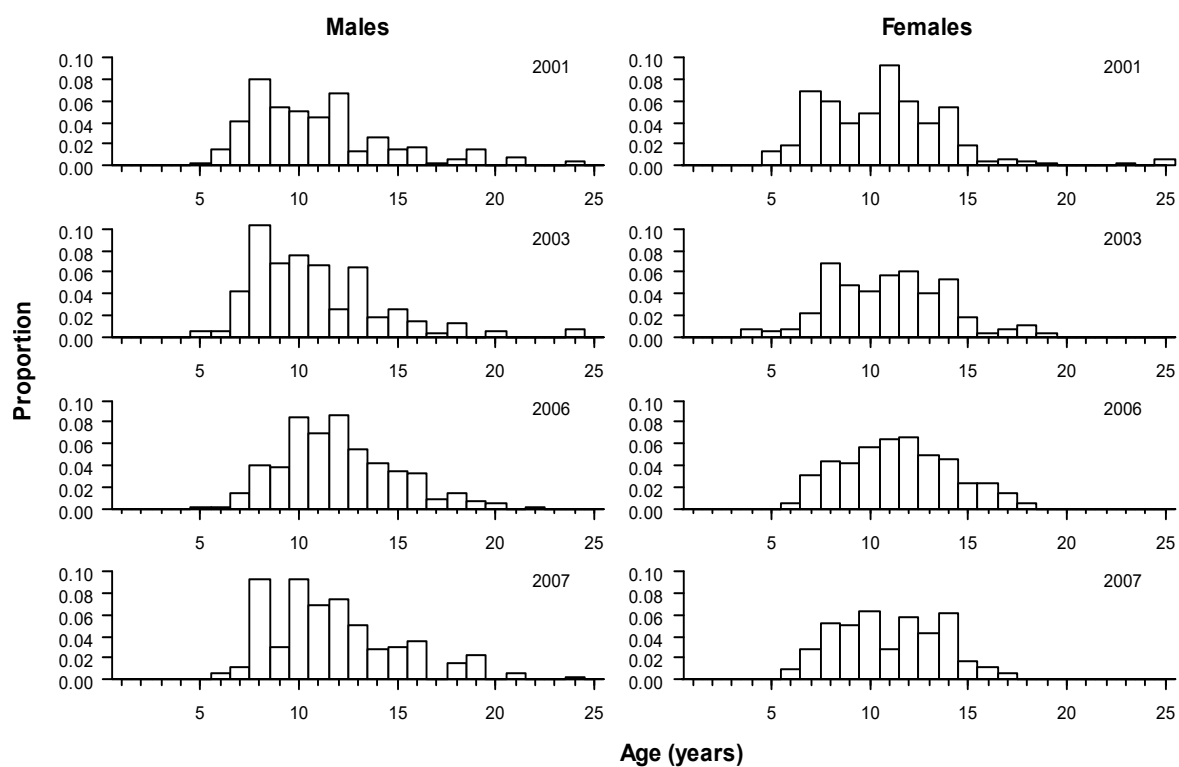


Figure B5: Age frequency distributions of ling from commercial catch-at-age data in the Cook Strait longline fishery, 2001 to 2018 (where sufficient data are available).

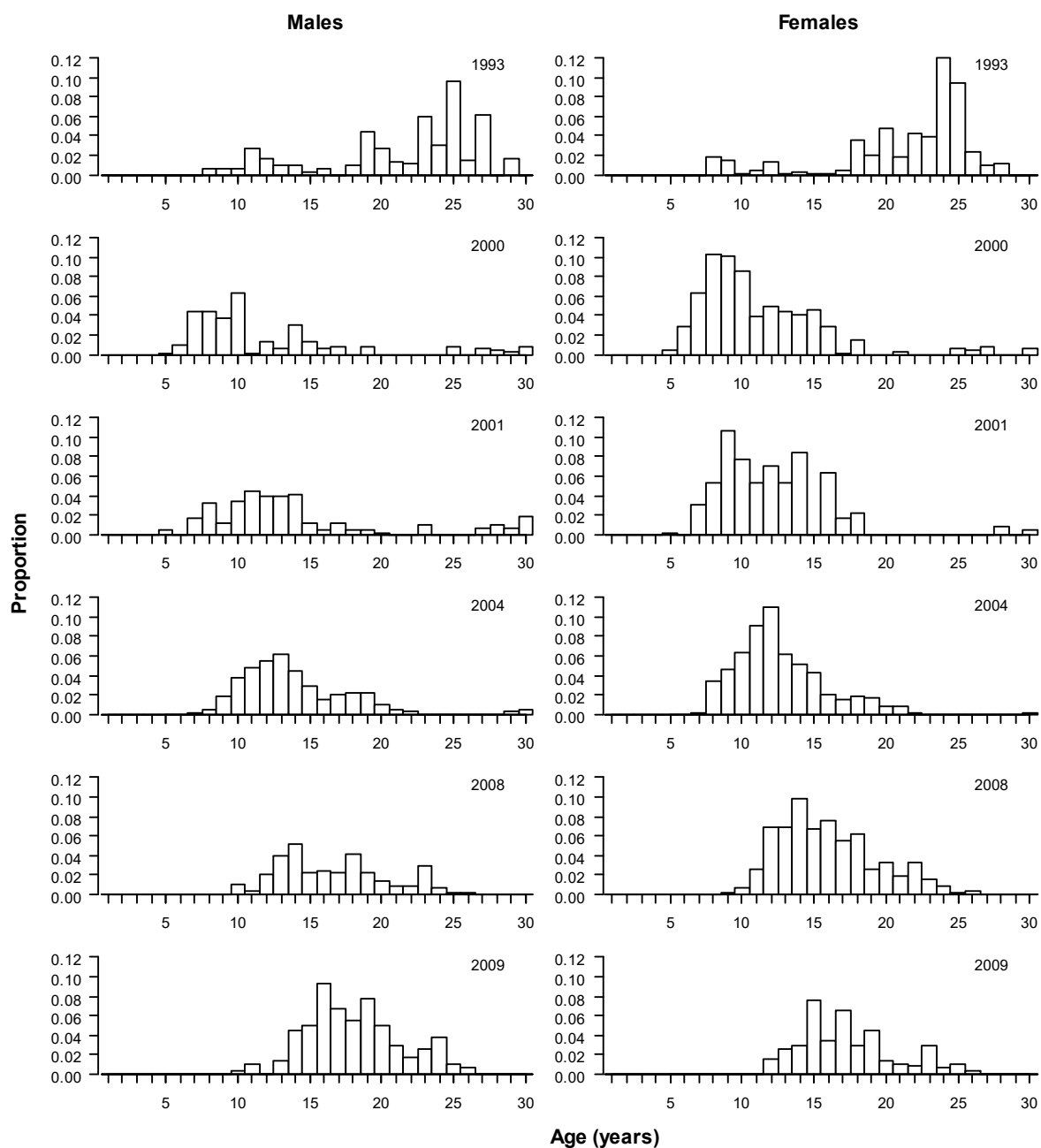


Figure B6: Age frequency distributions of ling from commercial catch-at-age data in the Bounty Plateau longline fishery, 1993 to 2018 (where sufficient data are available).

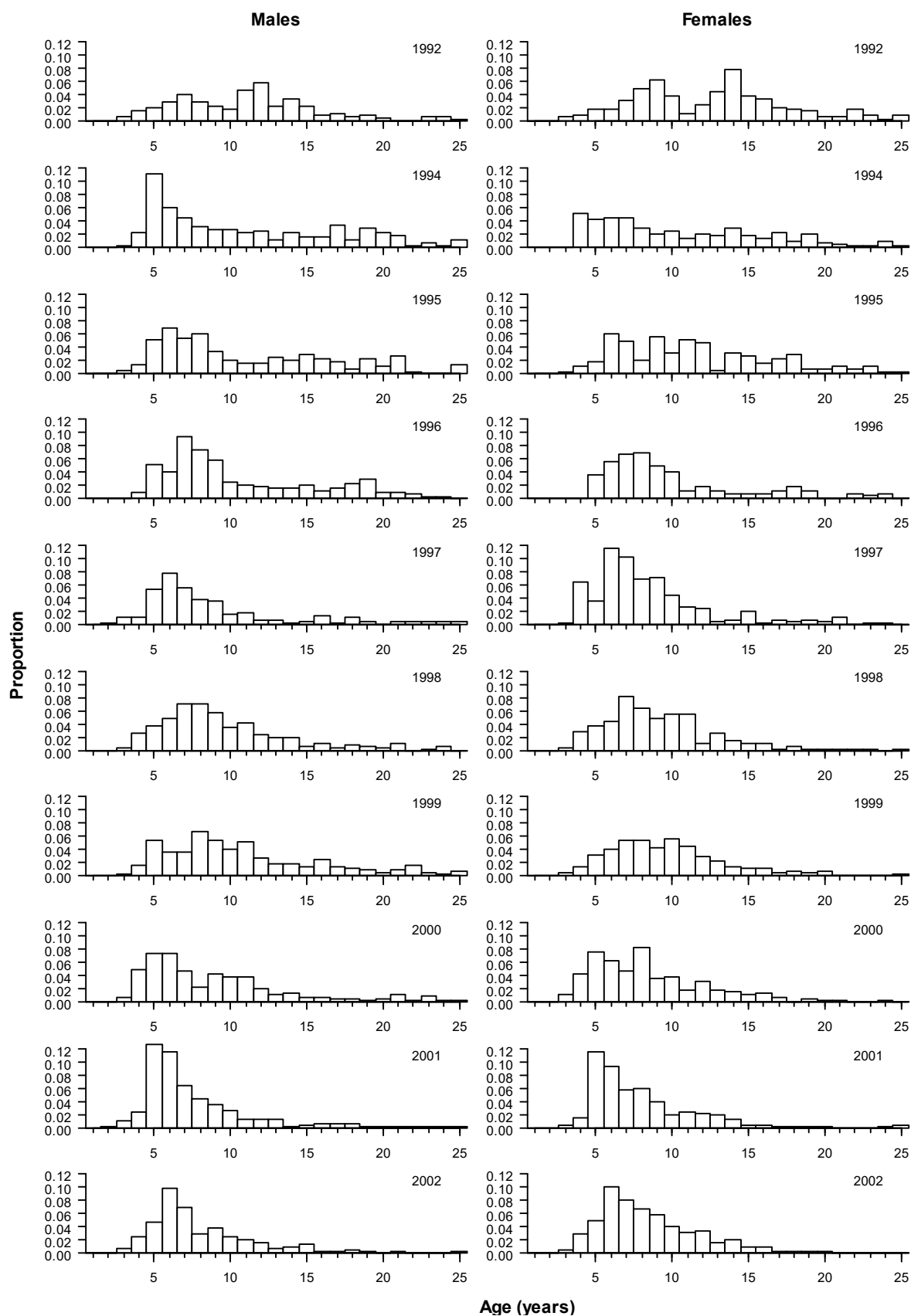


Figure B7: Age frequency distributions of ling from commercial catch-at-age data in the Chatham Rise trawl fishery, 1992 to 2018 (where sufficient data are available).

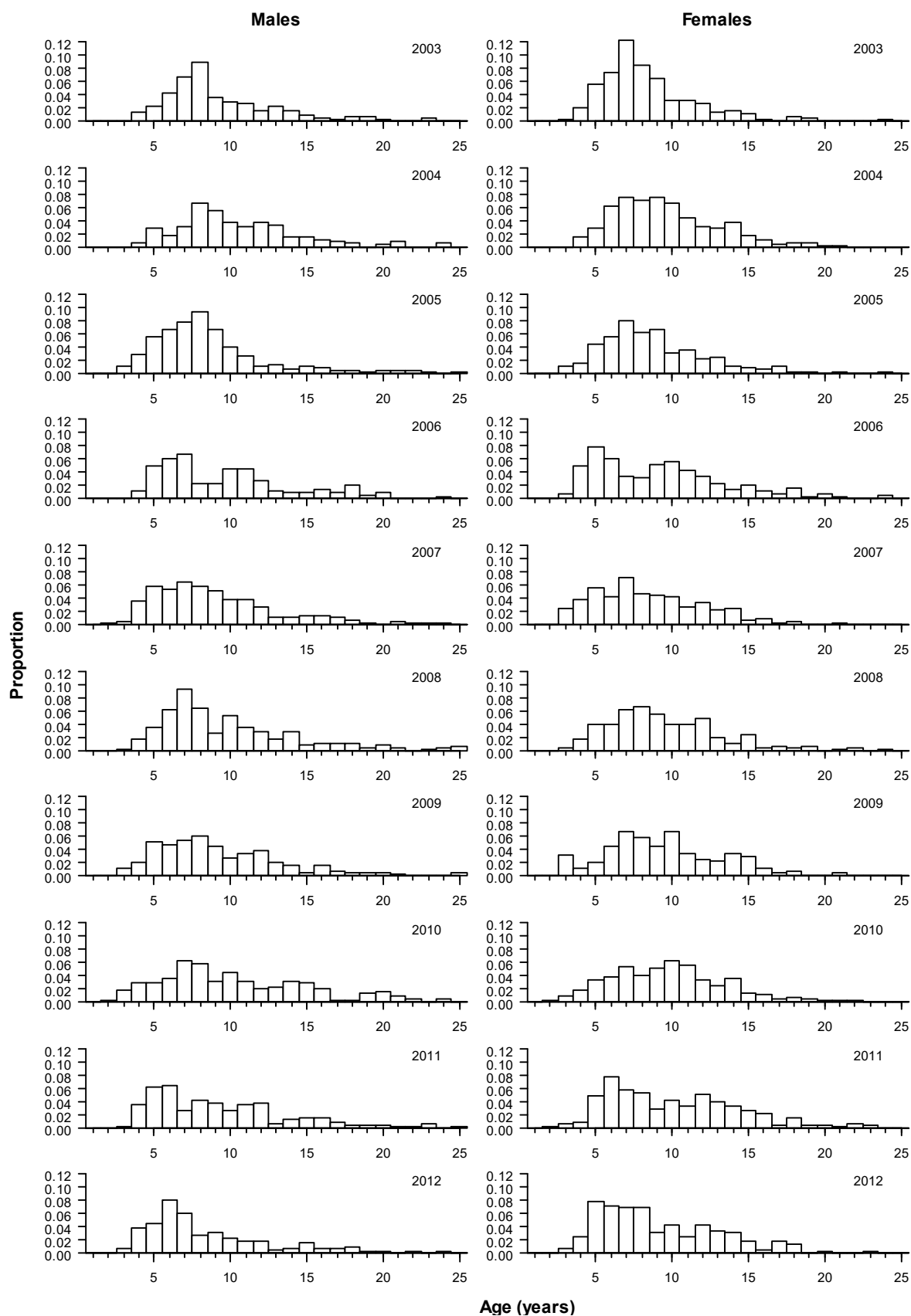


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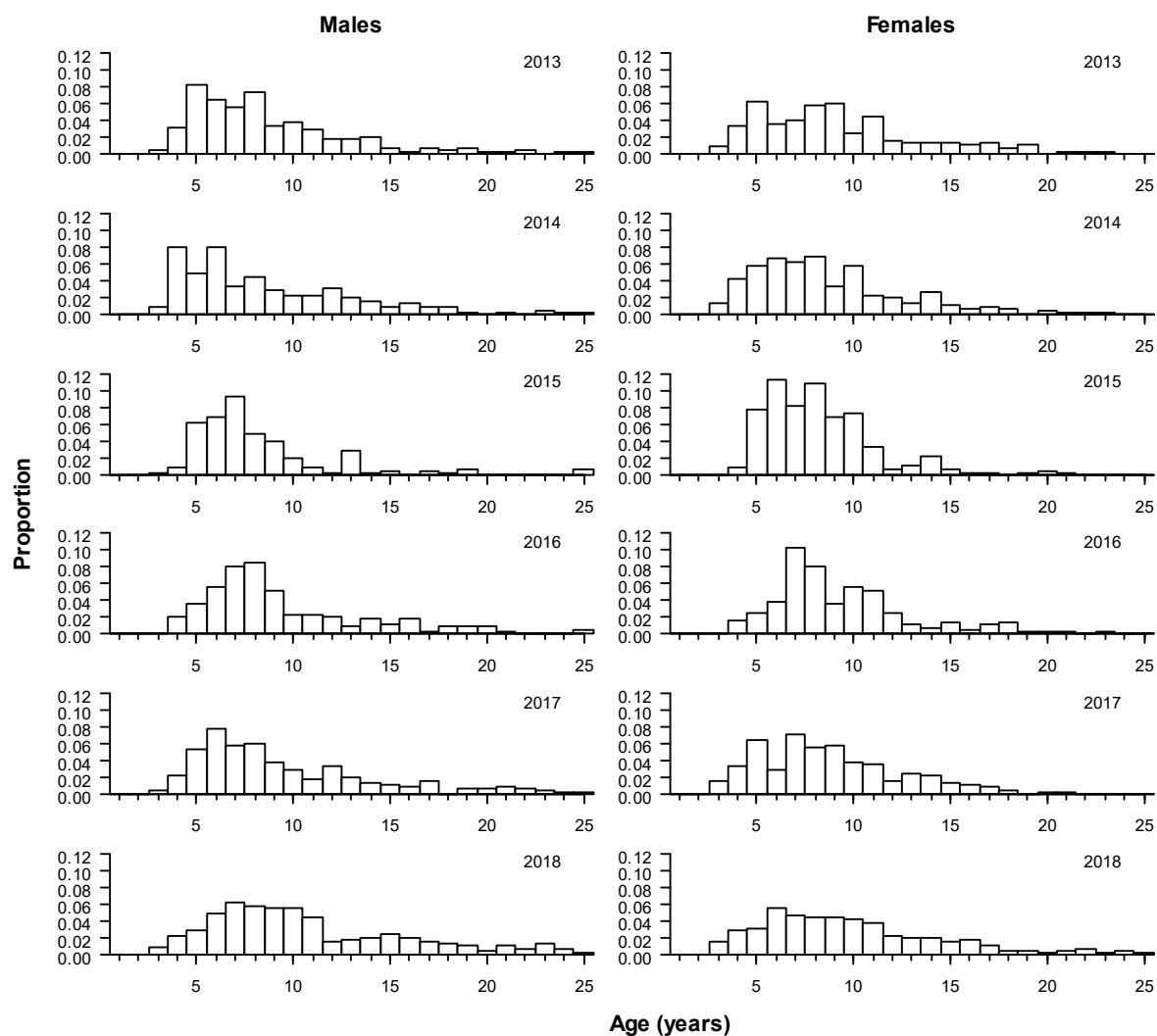


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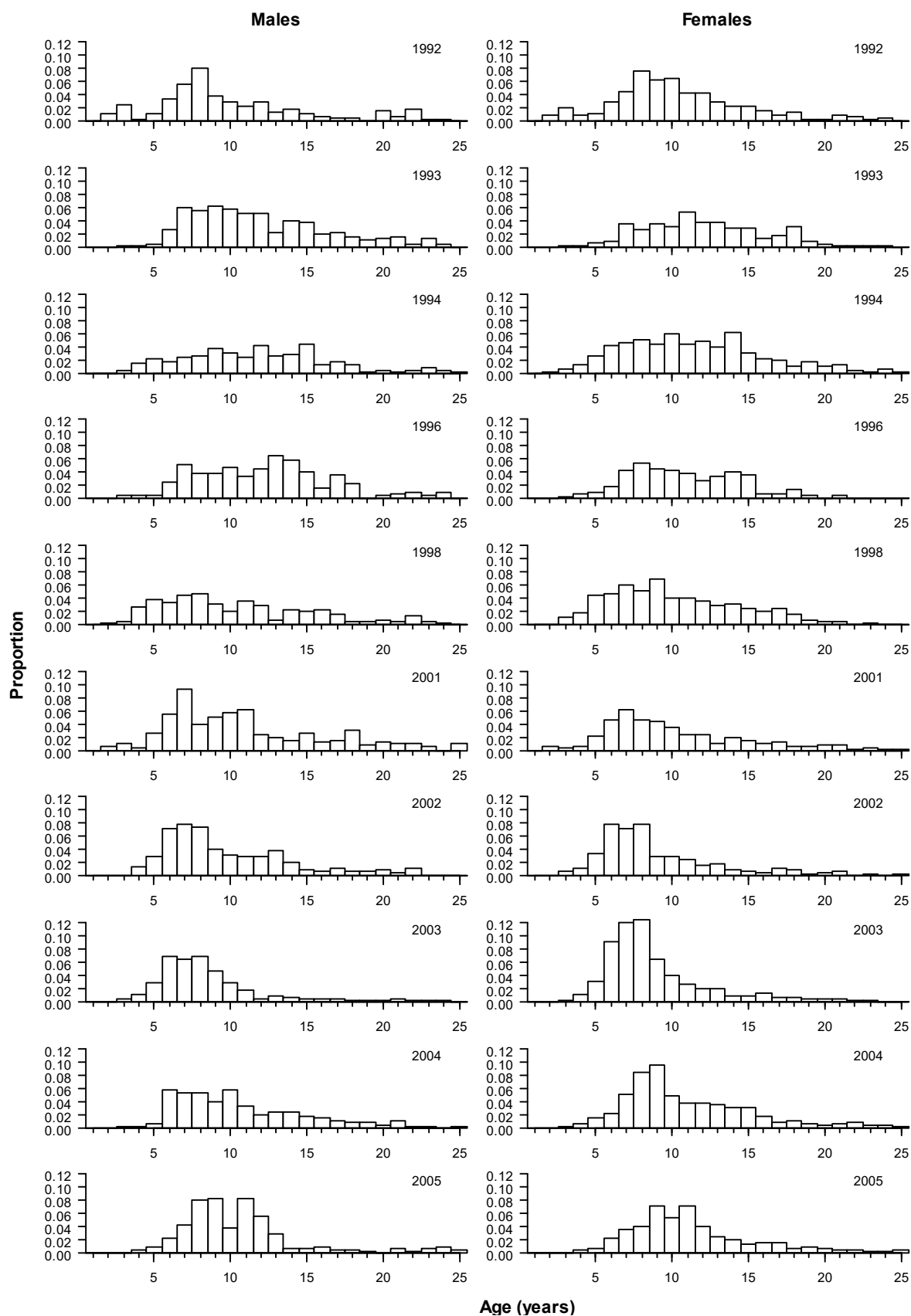


Figure B8: Age frequency distributions of ling from commercial catch-at-age data in the Sub-Antarctic trawl fishery, 1992 to 2018 (where sufficient data are available).

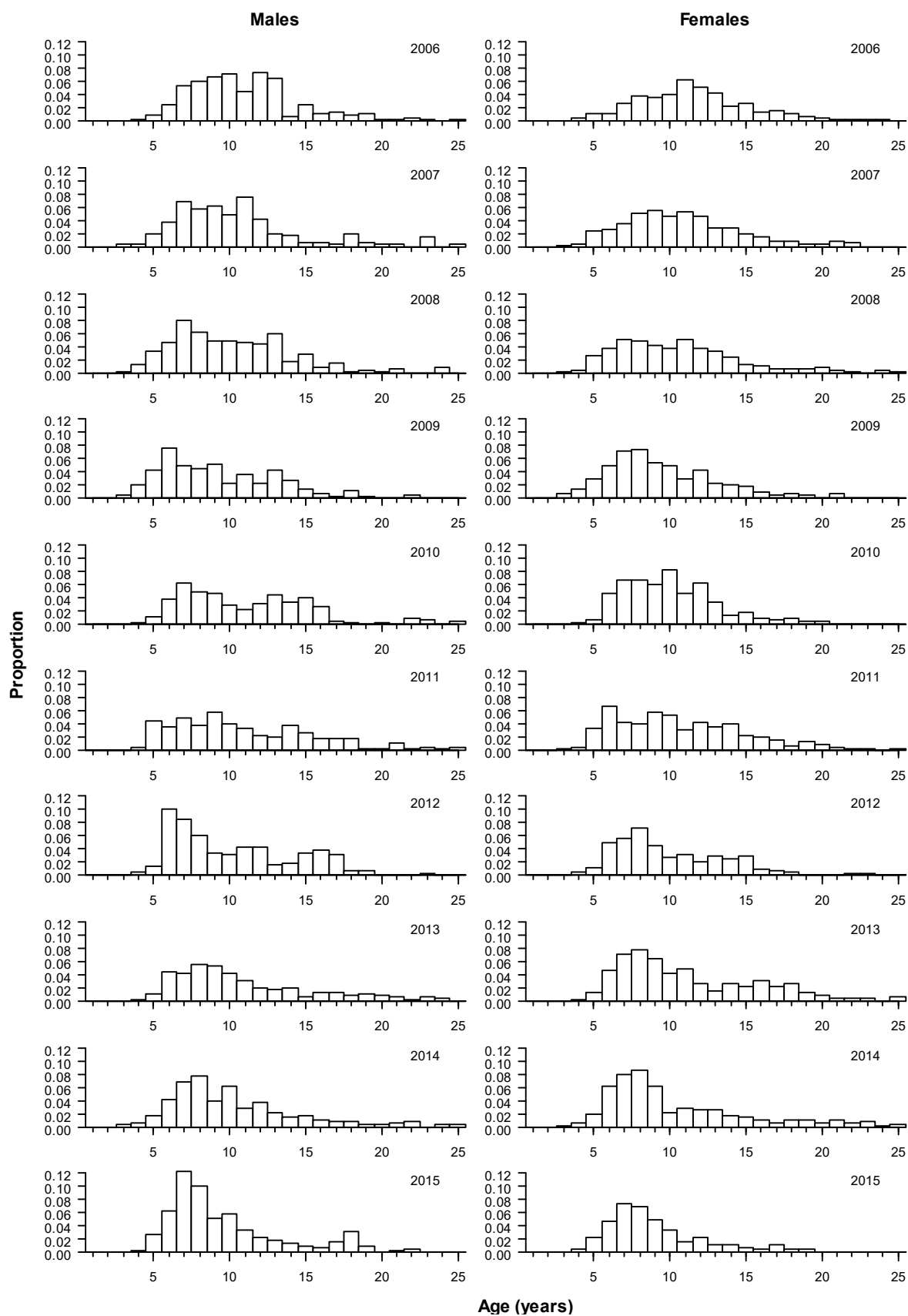


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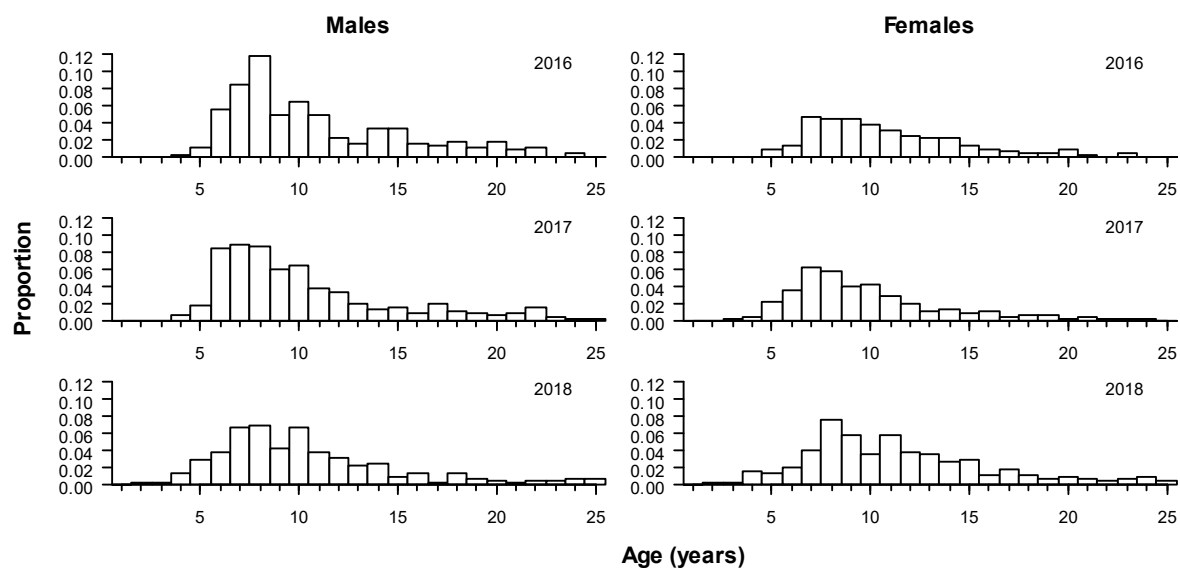


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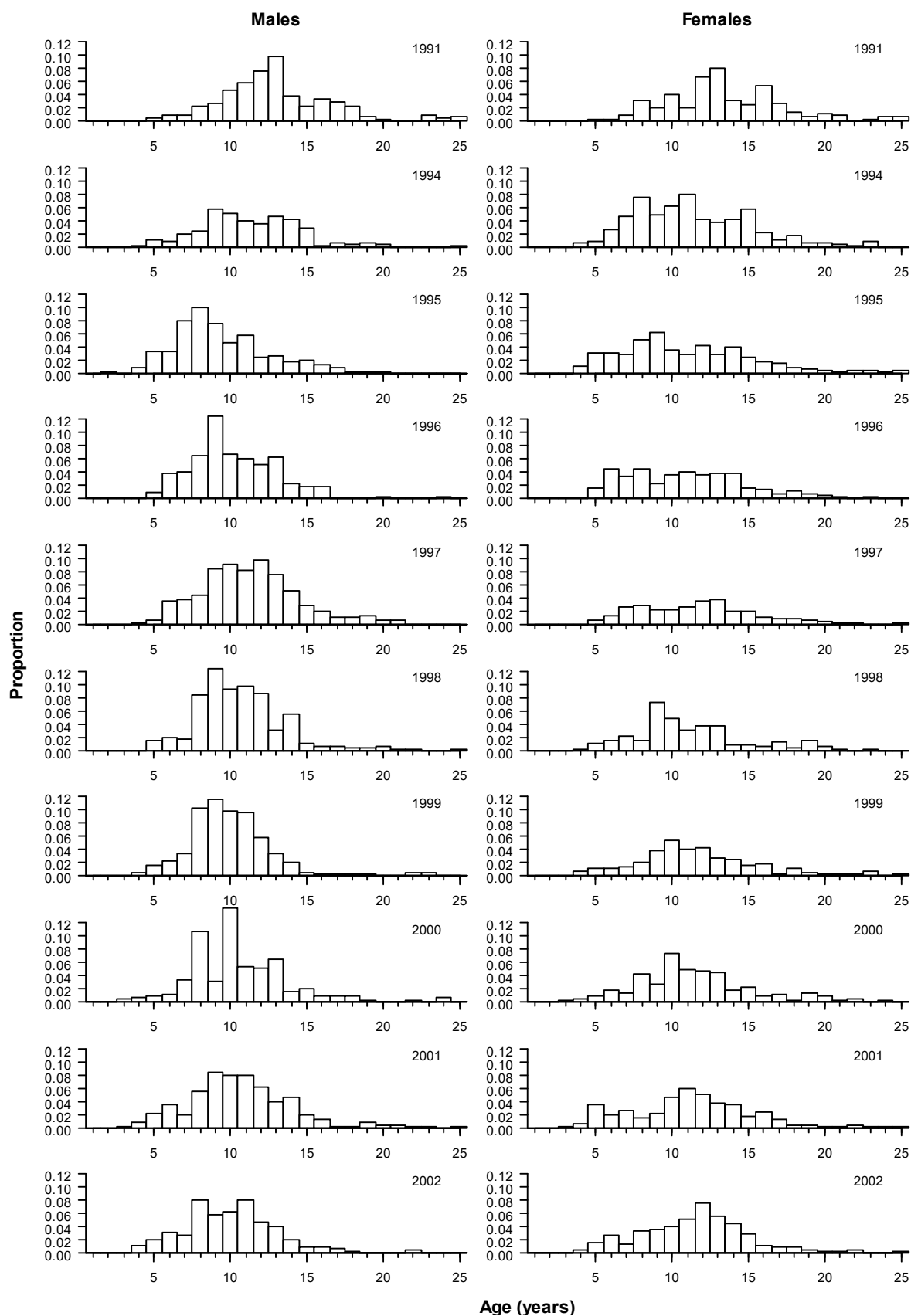


Figure B9: Age frequency distributions of ling from commercial catch-at-age data in the WCSI trawl fishery, 1991 to 2018 (where sufficient data are available).

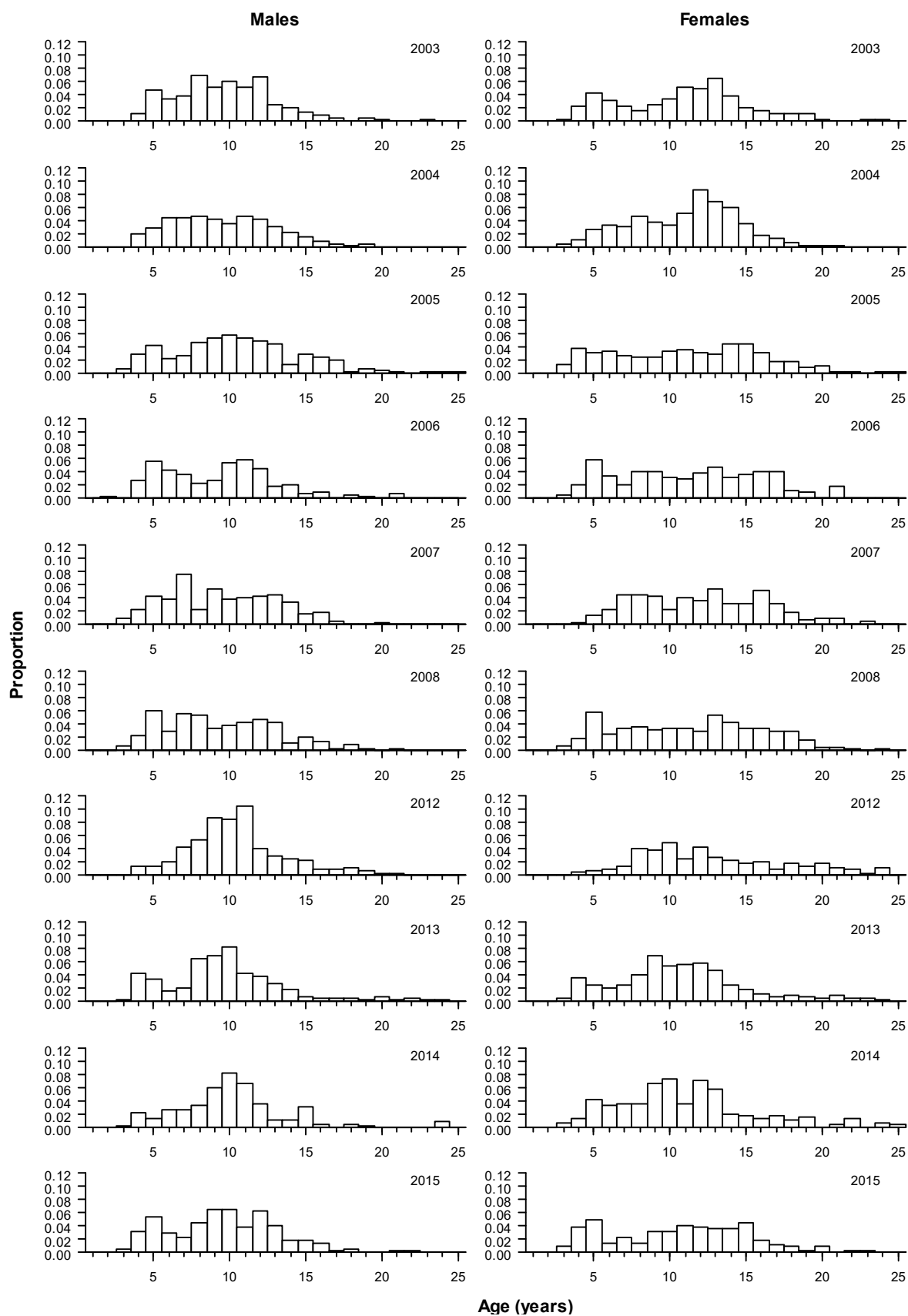


Figure B9 ctd.

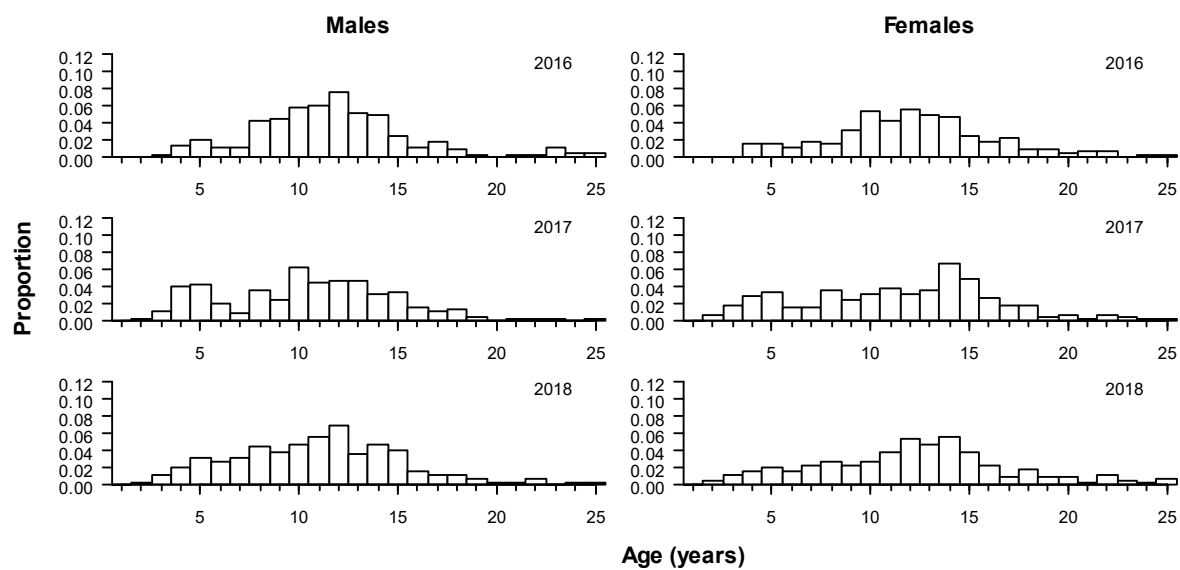


Figure B9 ctd.

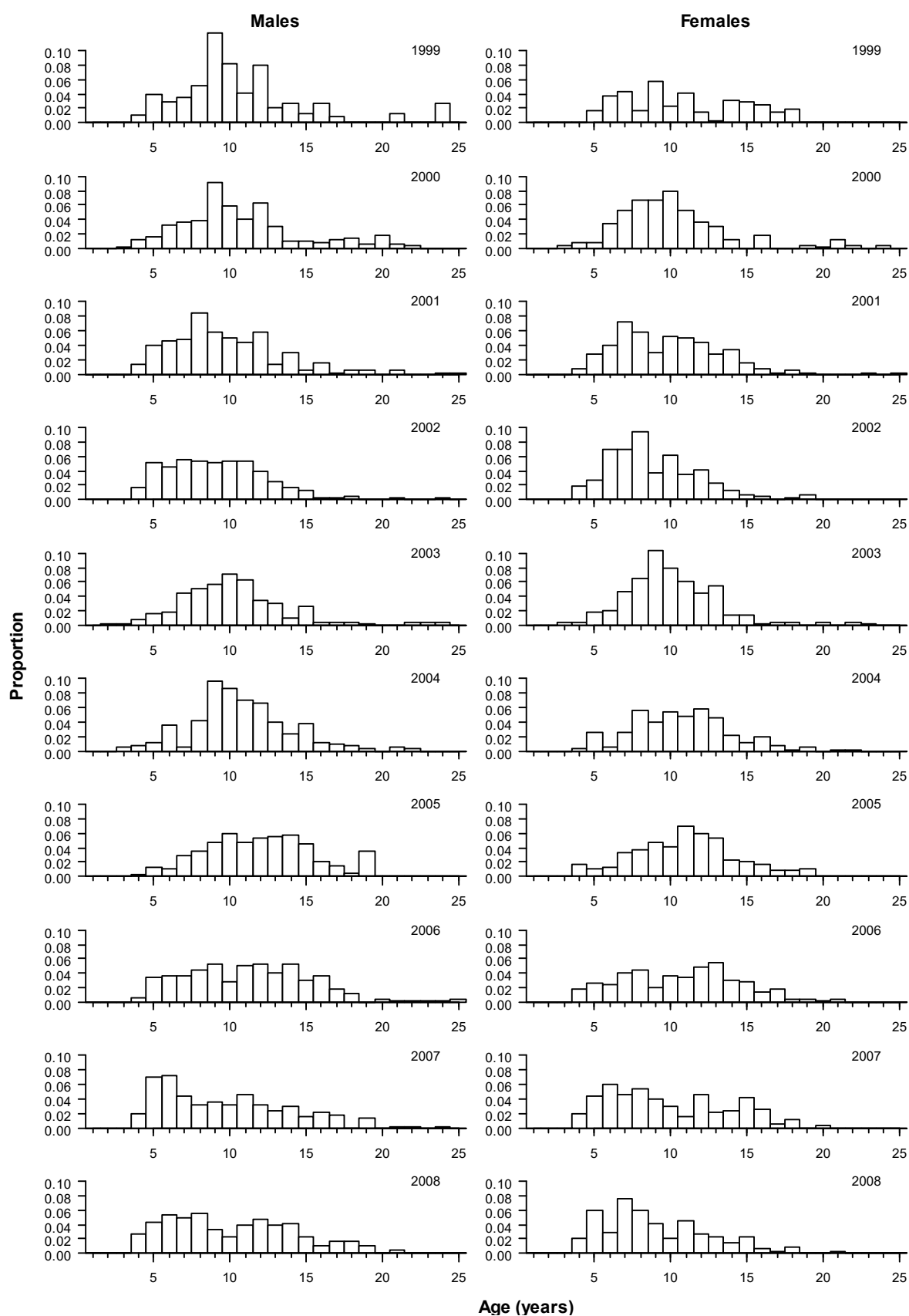


Figure B10: Age frequency distributions of ling from commercial catch-at-age data in the Cook Strait trawl fishery, 1999 to 2018 (where sufficient data are available).

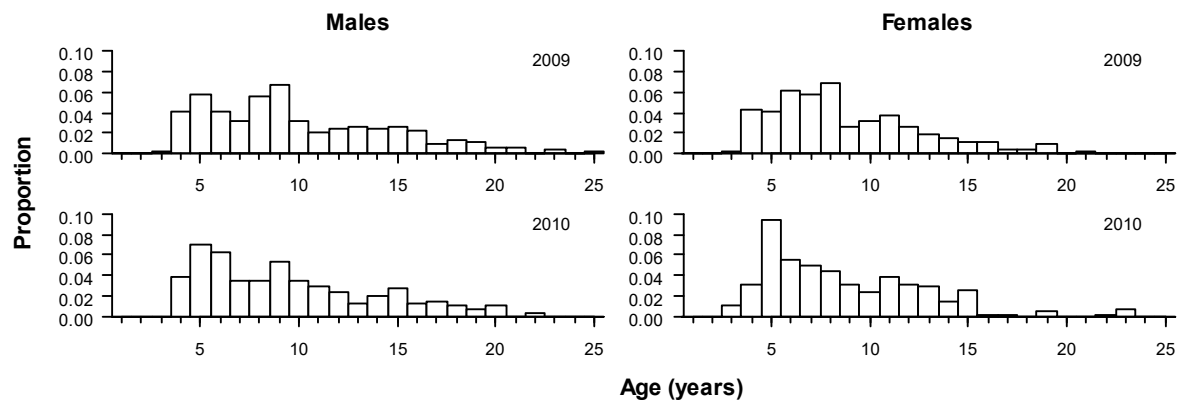


Figure B10 ctd.

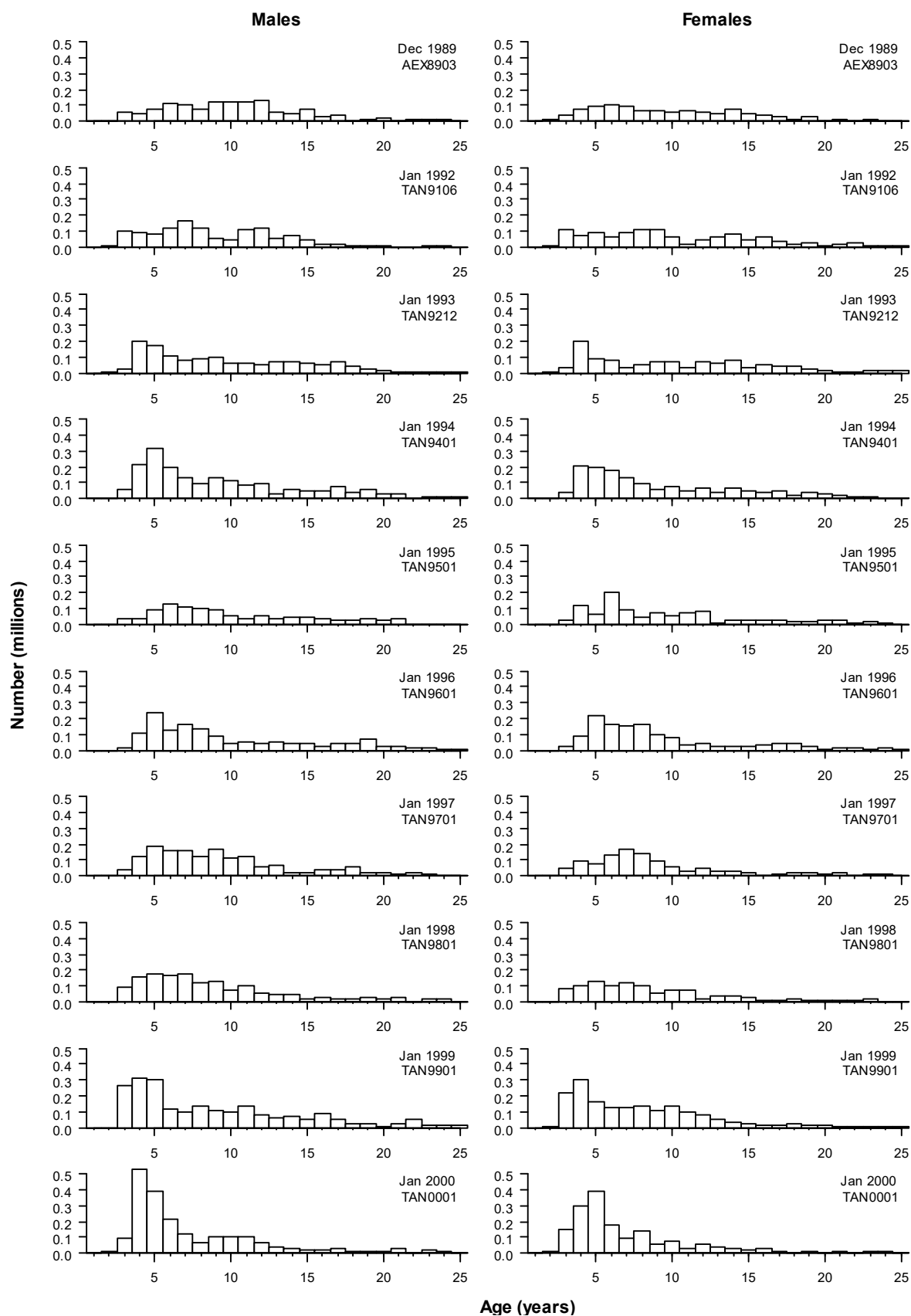


Figure B11: Age frequency distributions of ling (scaled numbers-at-age, ages 1 to 25) from trawl surveys of the Chatham Rise, 1989–90 to 2017–18.

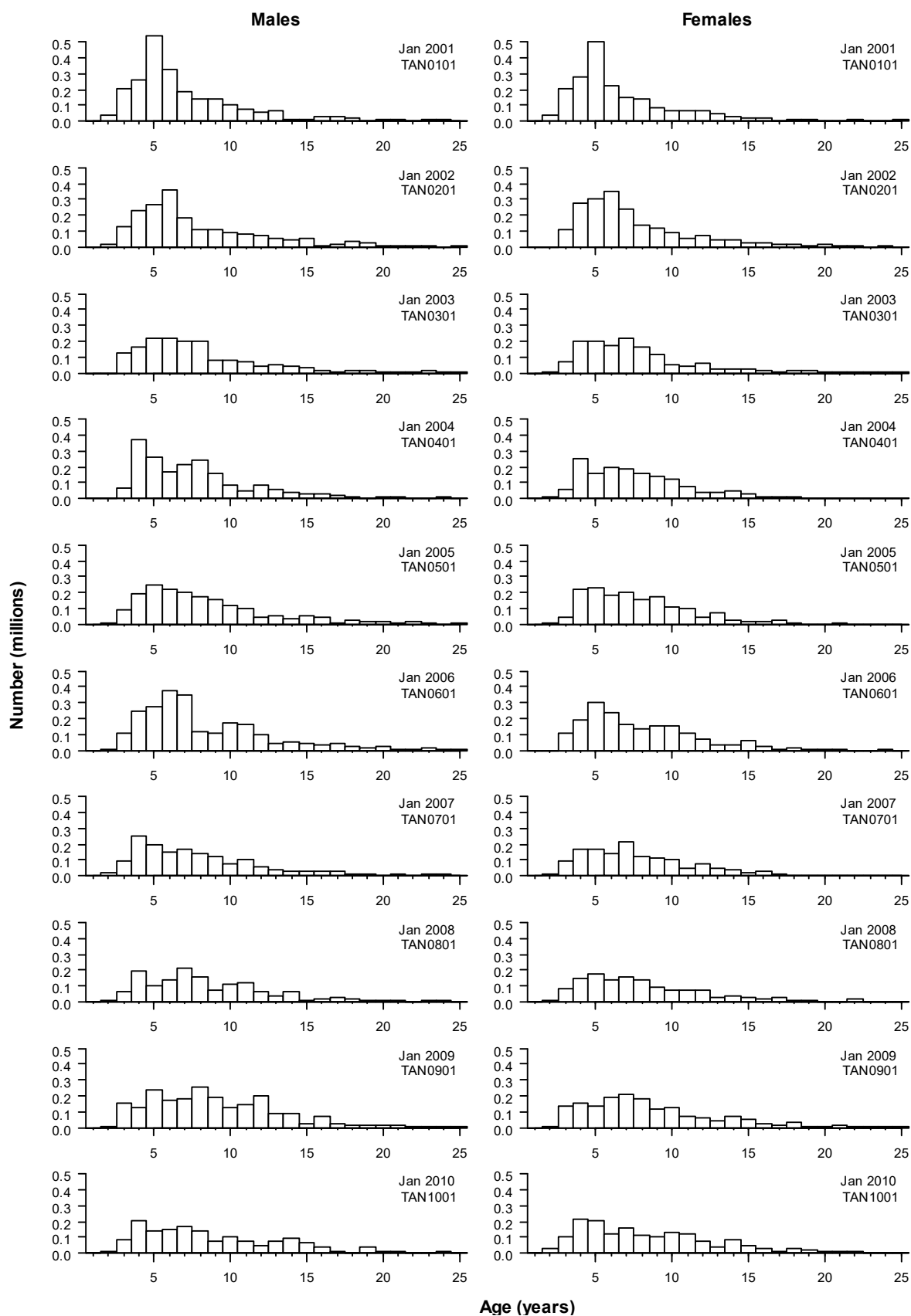


Figure B11 ctd.

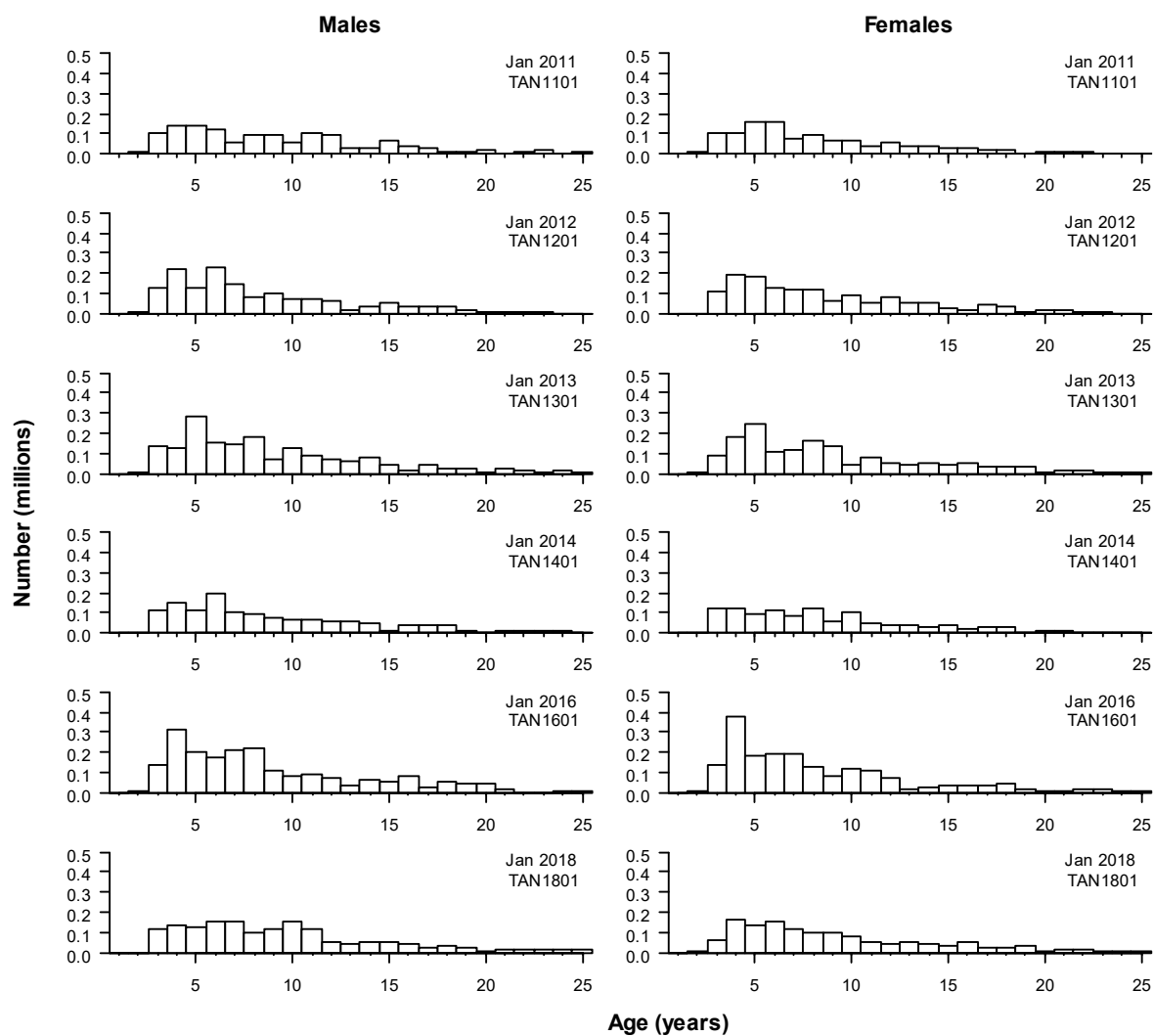


Figure B11 ctd.

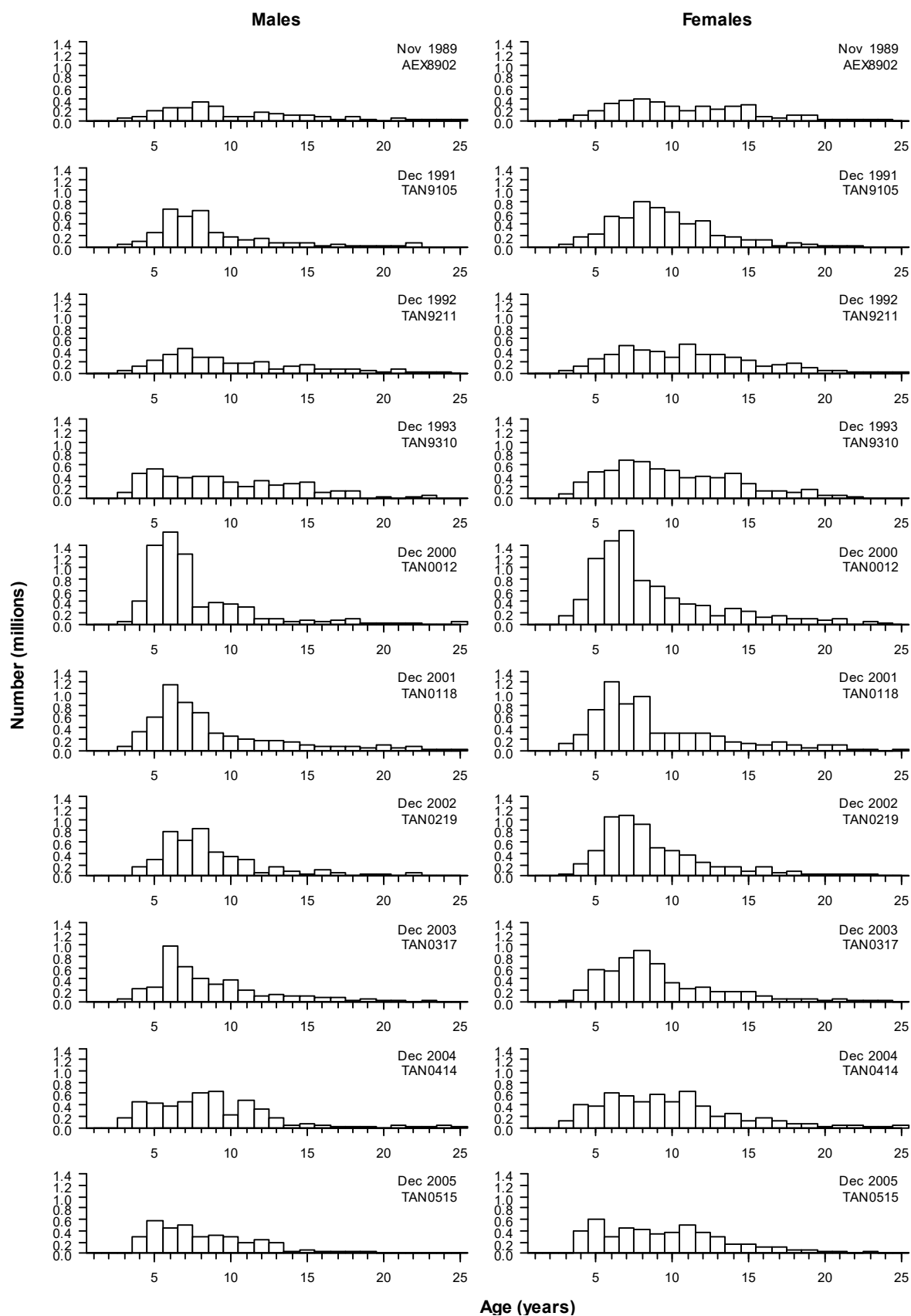


Figure B12: Age frequency distributions of ling (scaled numbers-at-age, ages 1 to 25) from summer trawl surveys of the Sub-Antarctic, 1989 to 2018.

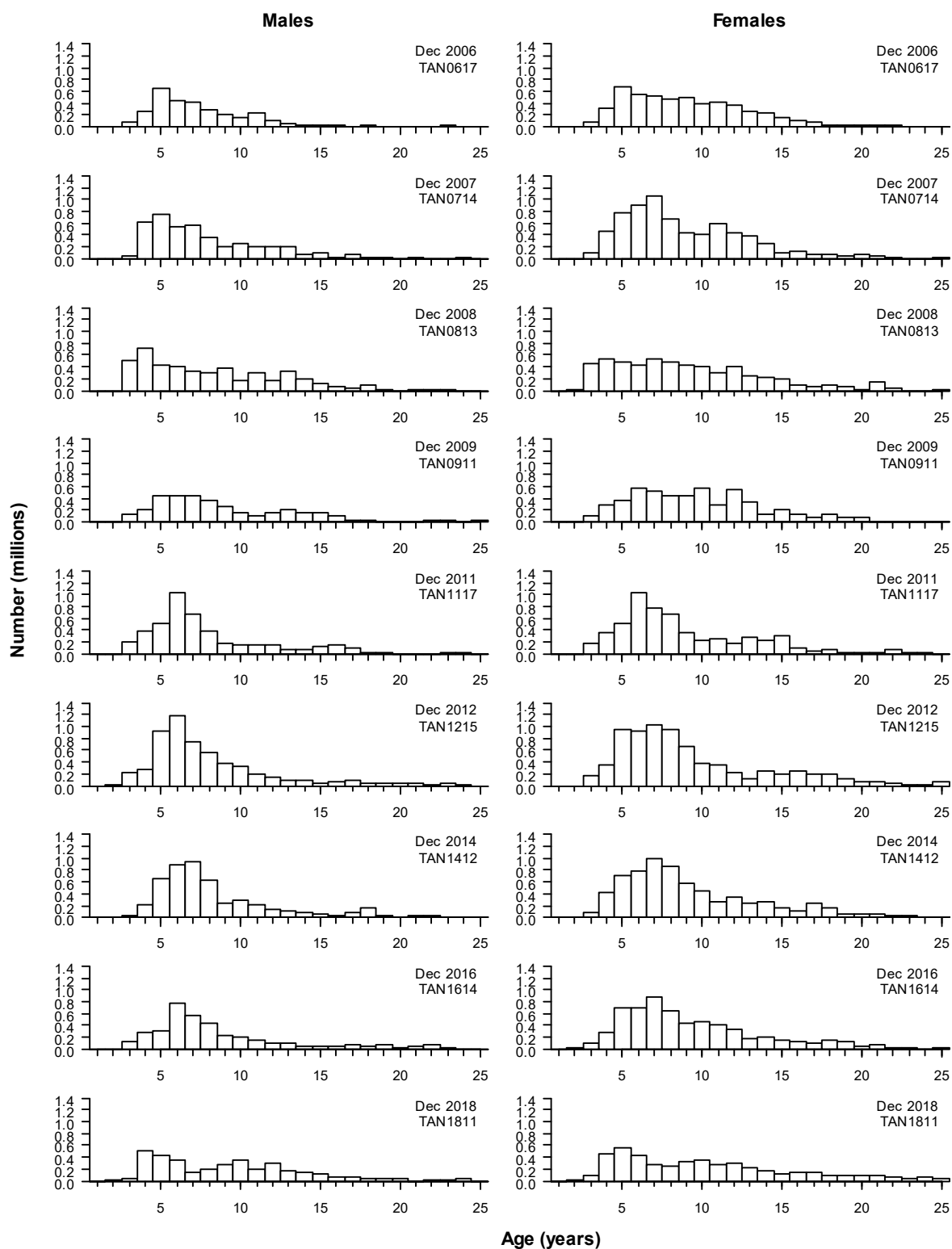


Figure B12 ctd.

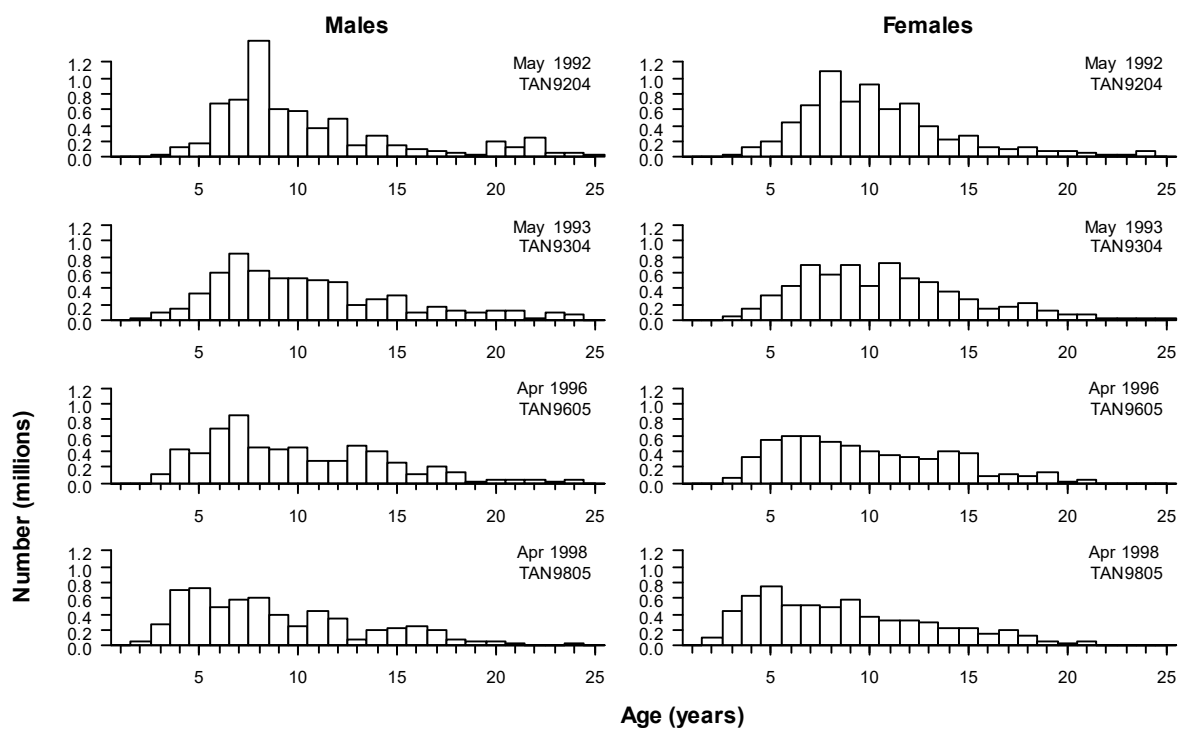


Figure B13: Age frequency distributions of ling (scaled numbers-at-age, ages 1 to 25) from autumn trawl surveys of the Sub-Antarctic, 1992 to 1998.

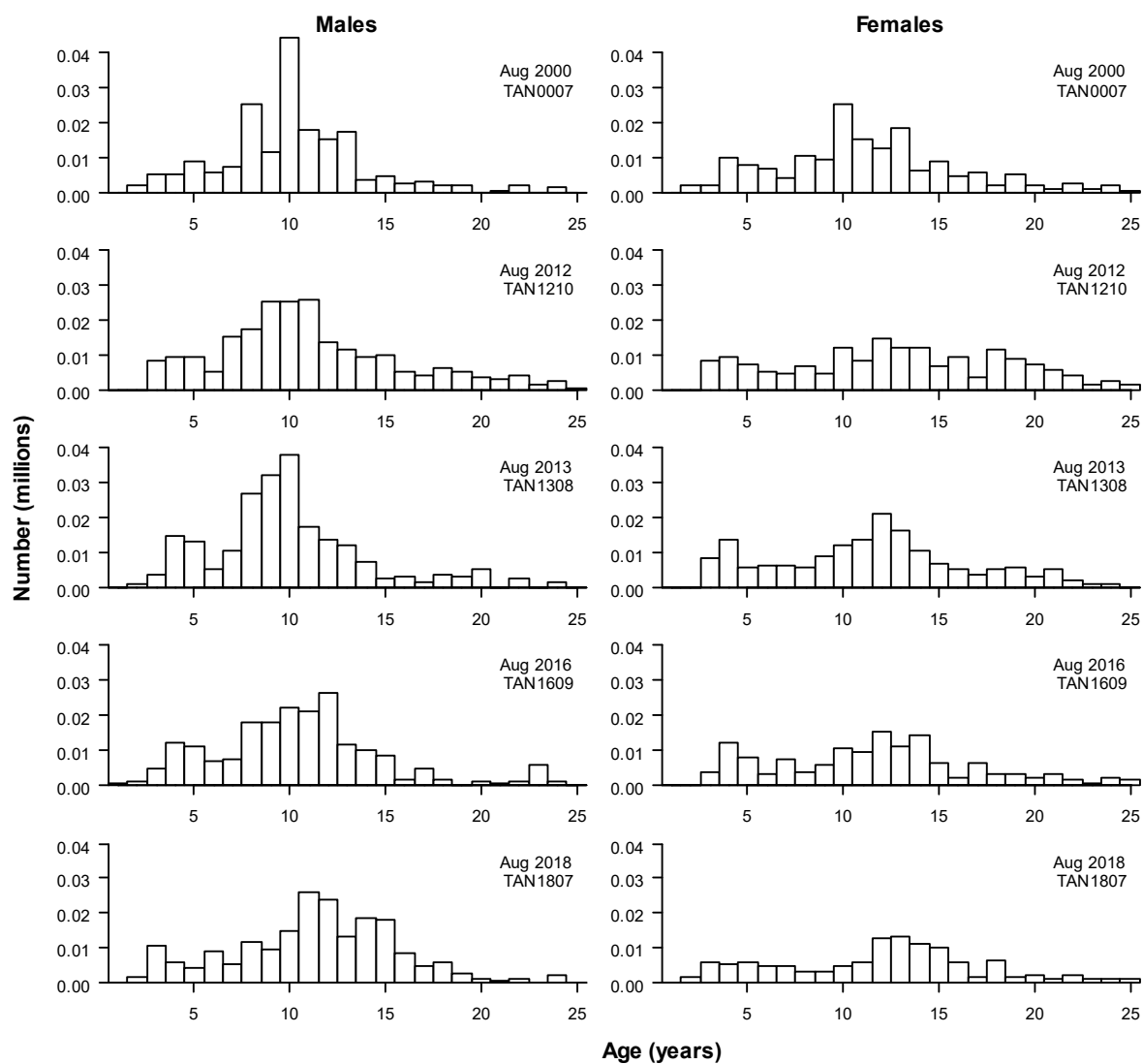


Figure B14: Age frequency distributions of ling (scaled numbers-at-age, ages 1 to 25) from winter trawl surveys ('core' strata only) of the WCSI, 2000 to 2018.

Appendix C: Observer sampling of hake from WCSI in 2017–18

The Deepwater Fisheries Assessment Working Group queried whether the observer sampling of hake in the WCSI fishery (HAK 7) in 2017–18 was representative of the fishery. Reported tow-by-tow landings of hake from the WCSI stock area were compared to the subset of those landings that were sampled for hake by observers. The analysis compared landings by month, statistical area, target species, and fishing method (Figure C1). All these categories were found to be comprehensively sampled in 2017–18 (i.e., 2018) as well as in all years since 2011. Most years before 2011 were also well sampled, although there was some under-sampling in June of some years.

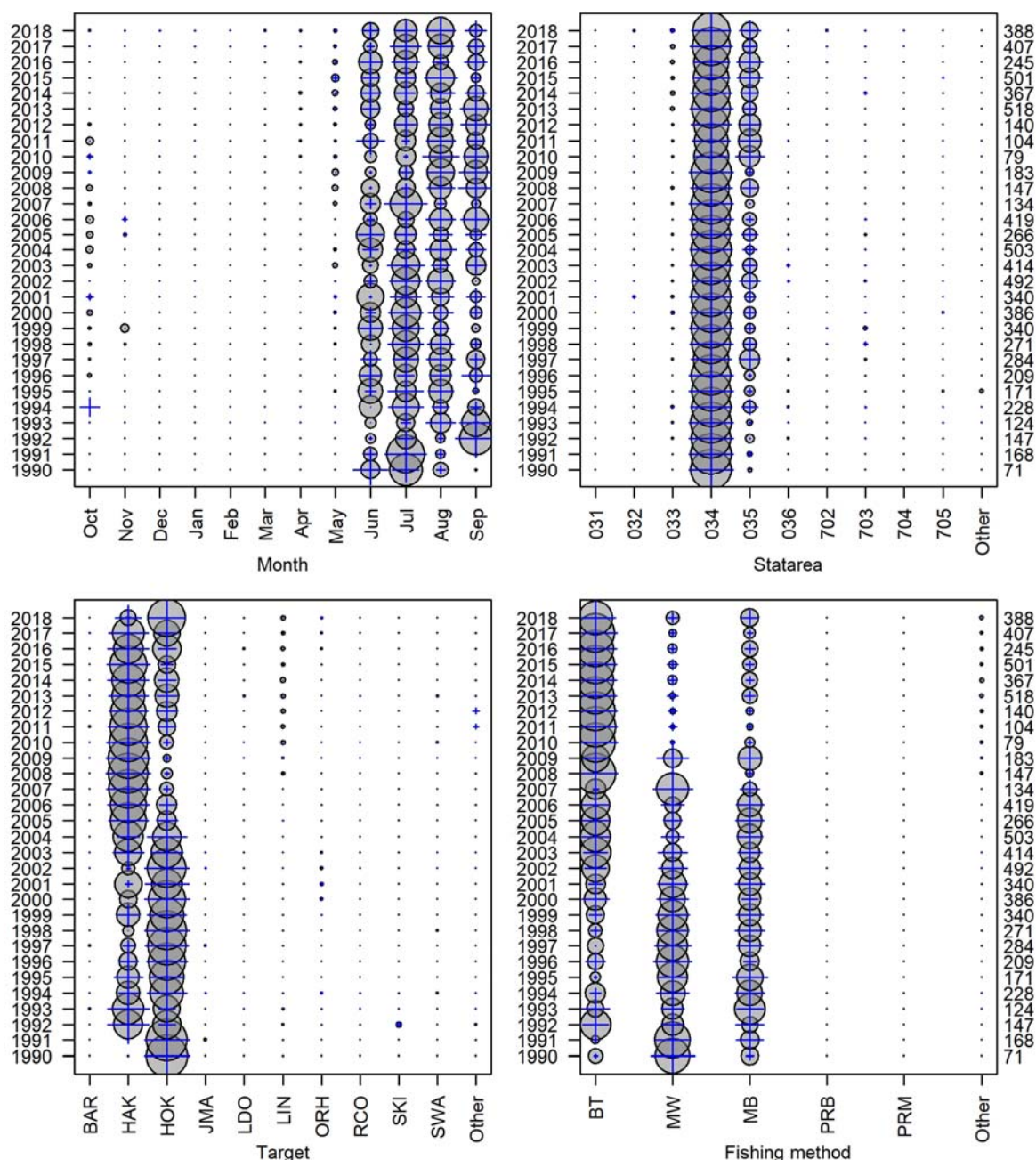


Figure C1: Comparison of estimated landed catch (grey filled circles) and observed catch (blue crosses), by fishing year (1989–90 to 2017–18), for HAK 7 by month, statistical area, target species, and fishing method. Circle area and cross width are proportional to estimated catch and observed catch, respectively, and sum to 1 across a year. Numbers on the right of the plots are the number of length-frequency samples taken each year.

The WCSI hake fishery catch-at-age series used data from June to September. The analysis shown in Figure C2 compared landings by depth, week, and area (latitude and longitude). All these categories were found to be comprehensively sampled in 2018. Tows that targeted hake and hoki were well sampled, but tows that targeted ling (which produced about 10% of the hake landings) were not sampled. It was concluded that observer sampling satisfactorily represented the WCSI hake trawl fishery in 2018.

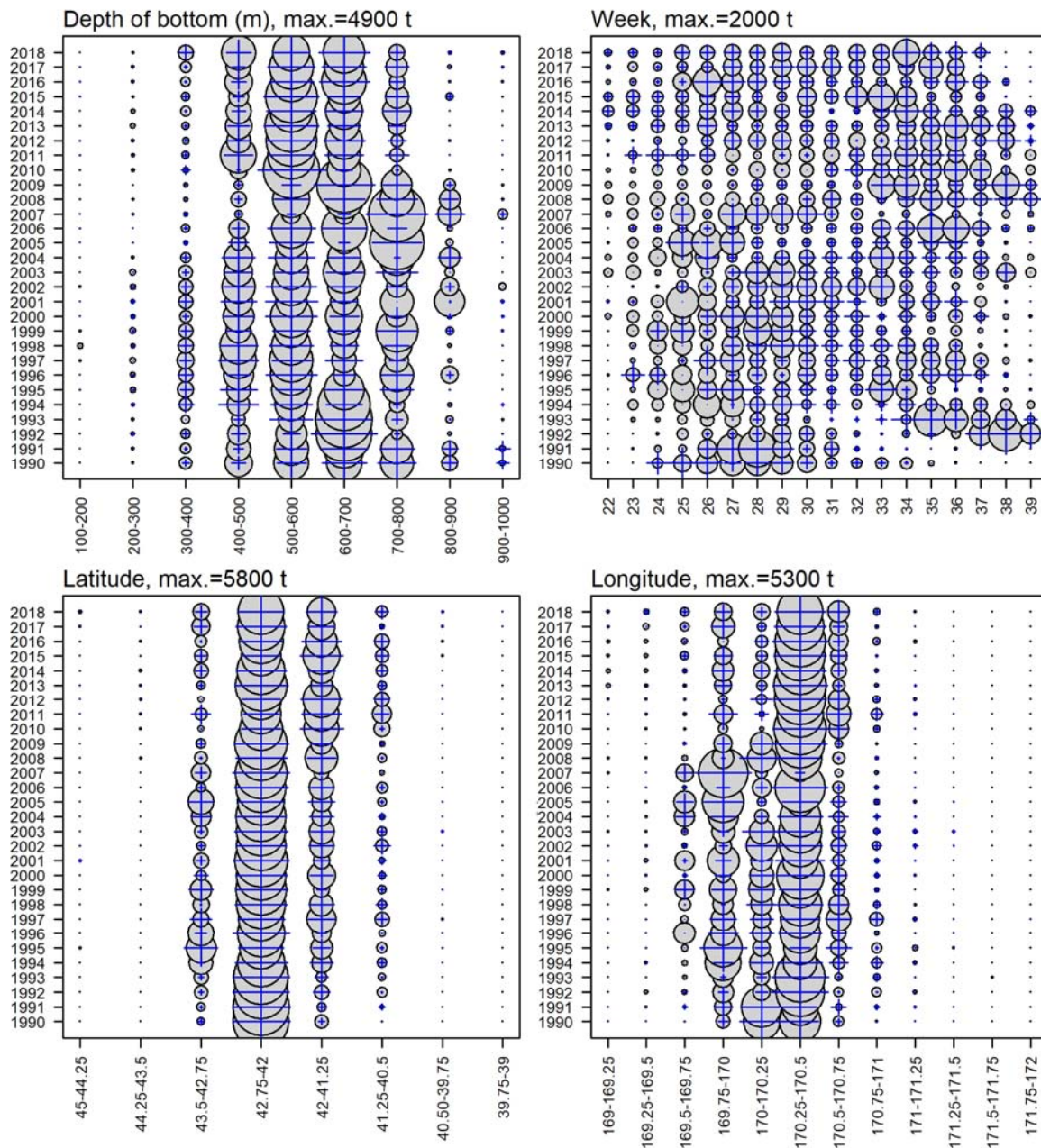


Figure C2: Comparison of estimated landed catch (grey filled circles) and observed catch (blue crosses) for the period June to September 1990–2018, for HAK 7 by bottom depth, week, latitude, and longitude. Circle area and cross width are proportional to estimated catch and observed catch, respectively, and sum to 1 across a year.